UDC: 502.131.1:711.433(439)
doi:10.5379/urbani-izziv-en-2023-34-02-03

Received: 21 June 2023
Accepted: 22 September 2023

Tamás SIKOS TOMAY
Dóra SZENDI

Analysing economic and environmental sustainability in Hungary: How cities with county rights perform in SDGs

Cities are the most important hubs of economic activity worldwide due to their concentration of population, businesses, trade, and stock markets. Nowadays, rapidly changing conditions resulting from factors such as globalization, industry 4.0, artificial intelligence, pandemics, and the Russian–Ukrainian war are raising new challenges for cities, which require innovative and smart solutions to maintain sustainability and competitiveness. This study analyses the performance of Hungarian cities with county rights in terms of their smartness level, with a special focus on the pillars of environmental and economic sustainability. Our hypothesis is that economically more developed cities (in terms of per capita income) are likely to be more sustainable due to the financial and professional resources available, but their ranking may not necessarily reflect the more populous group of cities due to, among other things, economies of scale and liveability. We analysed three elements of the seventeen UN Sustainable Development Goals (SDGs) and selected a set of indicators suggested by the Hungarian Central Statistical Office and the UN, adapted to the specific features of the Hungarian urban network, using min-max normalization and average calculation to construct the SDG pillars and a complex sustainability index. The cities were sorted into five cluster groups, which mainly differ in their development dynamics and liveability. The resulting clusters reflect the spatial characteristics of the Hungarian urban network, with the dynamic cities of the western and northwestern parts of the country showing outstanding sustainability performance.

Keywords: Hungarian cities, SDGs, sustainability, economic pillar, smart cities

1 Introduction

The United Nations Environment Programme (UNEP, 2018) estimates that the use of raw materials associated with the activity of cities will increase to ninety billion tonnes by 2050, up from forty billion tonnes in 2010. Mitigating global climate change and reducing its negative impacts on the environment has become one of the greatest challenges of life today (Yigitcanlar & Kamruzzaman, 2018). Policymakers promote sustainability as a key priority of urban development, as reflected in the UN's Sustainable Development Goal (SDG) 11, which emphasizes making cities inclusive, safe, resilient, and sustainable (UN, 2018).

Generally, there are three main pillars of sustainability, which also play a key role in the development of cities. These three pillars are the environmental, economic, and social dimensions of sustainability (Lehtonen, 2004). The environmental pillar is essentially concerned with environmental aspects (the natural environment: flora and fauna, and energy production). The social dimension represents equity, people's wellbeing, and the satisfaction of basic human needs, and the economic dimension can be understood as the economic competitiveness and diversity of urban areas (Toli & Murtagh, 2020).

As a result, a new concept has emerged in the literature – the *sustainable smart city* – and the terms *resilience*, *sustainability*, and *smartness* are applied simultaneously in its definition. Our study addresses how the twenty-five Hungarian cities with county rights are performing in some of the SDG index's priority dimensions. Our research hypothesis is that economically more developed cities (e.g., in terms of per capita income) are likely to be more sustainable due to the financial and professional resources available, but their ranking may not necessarily reflect the more populous group of cities, due to, among other things, economies of scale and liveability. Using this analysis, a complex sustainability ranking of the Hungarian cities can be drawn up based on economic and environmental aspects, which is comparable with the traditional urban network analyses carried out for the hierarchy of Hungarian cities.

2 Theoretical background: The concept of smart and sustainable cities

The term *smart city* became popular in the early 1990s and has changed several times since then, but even today there is no single agreed-on definition. Initially, most definitions focused on the technological aspect of smart urban development. One of the most frequently cited concepts in technocratic approaches is that of Harrison et al. (2010), emphasizing that smart and appropriate use of ICT (information and communication technologies) can lead to smart, institutionalized, and connected cities. Later, increasingly more researchers integrated soft elements such as knowledge, innovation, creativity, human capital, or sustainability into the definitions to create complex definitions (Szendi, 2021; Wataya & Shaw, 2022). According to the new definitions, a smart city consists of two main characteristics: technology and the creation of added value for stakeholders. It aims to ensure high quality of life and to increase competitiveness in a defined geographical area (Glasmeier & Christopherson, 2015). Therefore, the common feature of the concepts is that they aim to improve the living conditions of residents while emphasizing the role of sustainability, innovation, and knowledge. With the incorporation of soft elements, the concept of smart cities has become increasingly complex, and the measurability of their performance is a growing challenge for researchers. One of the most frequently used models is the six-component model developed by Giffinger et al. (2007; economy, people, governance, mobility, environment, and living conditions), which uses over eighty indicators to rank cities.

According to the European Parliament's (2014) studies (based on a sample of 599 cities), the environmental dimension is the most important pillar of European smart cities, accounting for 33% of the total list, and the economic dimension, for example, is the main priority axis in only 11% of cities (García Fernandez & Peek, 2020). Research indicates that the most dynamic segment of smart cities will be the smart governance and smart energy dimensions by 2025, which will further evolve until 2030 (Angelidou et al., 2022), meaning that the focus on the sustainability dimension is expected to grow further. The sustainable smart city includes all the basic elements of smart cities, complemented by indicators of the optimal management of limited resources (environment, waste and water management, green energy, etc.; Ahvenniemi et al., 2017). A sustainable smart city is a city that, with the support of ICT, meets the needs of its current inhabitants without compromising the ability of other people or future generations to meet their needs, thus not exceeding environmental limits (Höjer & Wangel, 2014).

This study measures the economic and sustainability performance of Hungarian cities, for which the UN Sustainable Development Indicators provide a good basis as a comprehensive set of indicators in sustainable development. Although there are several studies on the measurability of smart cities (e.g., Giffinger et al., 2007; Cohen, 2014), there are few comprehensive studies on Hungarian cities so far. SDG measurement in Hungary has only been carried out at the county level under the supervision of the Hungarian Central Statistical Office

(HCSO), with only Budapest as an urban example analysed by the Sustainable Development Solutions Network (SDSN) and the Brabant Centre for Sustainable Development (Telos). The Hungarian capital ranked thirty-seventh overall among the forty-five European cities analysed, with an overall score of 55.4 (moderate performance). In terms of SDGs, the city still faces significant challenges in five of the fifteen SDGs, seven others indicate crucial problems, and two (clean water and sanitation, and reduced inequalities) are only slightly behind the targets (one dimension is missing; Lafortune et al., 2019). We decided to exclude the capital city from the analysis because in many cases its outlier values would distort the results of the analysis (mainly through the standardization process) and would indicate unrealistic differences in the urban network.

Previously, European and US cities were also analysed using the SDG indices, and both analyses highlighted the problems of data availability and comparability. The first SDG index for US cities was produced in 2017. The index ranks the hundred most populous US cities along with metropolitan regions based on their performance on the SDGs. The results show that all US cities, even those at the top of the index (the San Jose–Sunnyvale–Santa Clara metropolitan region in California), need to make significant strides to achieve the SDGs (Sustainable Development Solutions Network, 2017). In Europe, the report compares the performance of the European Union (EU) and European Free Trade Association (EFTA) capitals and some other metropolitan areas on the seventeen SDGs. In this first prototype version, the results for forty-five European cities are presented using fifty-six indicators. Oslo is ranked first with a score of 74.8 before Stockholm and Helsinki. This means that Oslo has a 74.8% achievement rate of the SDGs according to the indicators used in the index. However, even for these best-performing cities, significant challenges remain to achieve all the goals (Lafortune et al., 2019). In 2022, a sustainability analysis was carried out for seventeen of Kazakhstan's largest cities. In their analysis, the authors developed a sustainable urban development index and clustered the cities. The study used a similar normalization method as the analysis presented here; however, its components included standard economic and social factors, not focusing specifically on SDGs (Nyussupova et al. 2022).

This article therefore calculates the SDG index of Hungarian cities with county rights by focusing on economic and sustainability aspects, and to characterize the city network in terms of SDG performance.

3 Methodology and data

In September 2000, the United Nations adopted the Millennium Development Goals, committing its members to a new global partnership focused on the problems of developing countries. Therefore, eight targets were set for the period up to 2015 (HCSO, 2022). Despite the achievements of the MDGs, by the mid-2010s there were significant disparities between the poorest and richest regions, and between urban and rural areas (UN, 2015). Therefore, taking the basic idea a step further, at the UN Sustainable Development Summit on 25–26 September 2015, world leaders adopted "Transforming Our World: the 2030 Agenda for Sustainable Development", which included seventeen global SDGs and 169 targets (European Environment Agency, 2020). The 2030 agenda, in addition to the previous focus areas, also considers developed countries' perspectives, while placing special emphasis on the environmental dimension. In the development of indicators, in 2020 the UN reached the goal of all indicators having a clear methodology (HCSO, 2022). Among the seventeen SDGs set by the UN, we have focused our analysis on three sustainability goals measuring the sustainability and smart economy of cities. They include two economic objectives – SDG 8 (decent work and economic growth) and SDG 9 (industry, innovation, and infrastructure) – and a social objective, SDG 11 (sustainable cities and communities).

The aim of the study was to show that, although national governments have adopted the SDG targets, it is also clear that regions and cities are playing a crucial role in achieving them (Lafortune et al., 2019). Based on this idea, we performed SDG index calculations by focusing on three SDGs. Among the SDGs, there are several that focus on economic sustainability in addition to environmental sustainability. In selecting SDGs 8, 9, and 11, our main research question was whether the most economically developed cities are sustainable in environmental, economic, and social terms. We selected the SDGs where this approach is emphasized, where data are available for a range of cities, and where the results provide relevant information for the Hungarian cities. In addition to these SDGs, we also analysed some indicators from SDG 12 (ensure sustainable consumption and production patterns) with data on waste management and financial support. In selecting the indicators, we chose data series supported by Hungarian and international literature. The data sources were the TEIR (National Regional Development and Spatial Planning Information System) database, the HCSO Dissemination Database, and the Hungarian Attractions Inventory. Twenty-seven variables were included in the baseline database after cleaning the database two times (in the first step, five variables were removed, and then one more) because of multicollinearity.

Table 1: List of indicators used for each SDG.

SDG	Indicator	Correlation with SDGs (+/–)
8. Decent work and economic growth	Net disposable income per capita (HUF)	+
	Long-term unemployment rate (more than 180 days; %)	–
	Old-age dependency ratio (65+ / 15–64 years)	–
	Proportion of self-employed persons in business (%)	–
	Employment rate of recent graduates (20–34 years; %)	+
9. Industry, innovation, and infrastructure	R&D expenditure as percentage of GDP (county level)	+
	Internet connections per 1,000 inhabitants	+
	Number of patents per 1 million inhabitants (county level)	+
	Length of national roads per 100 km^2 (county level)	+
	Per capita CO_2 emission (tons)	–
	Inward migration balance (permanent and temporary) per 1,000 inhabitants, 2020	+
	Commuters as share of locally employed persons, 2011	–
	Budapest access time by road (fastest, min)	–
11. Sustainable cities and communities	PM10 (particulate matter particle diameter below 10 microns), annual average (μg/m^3)	–
	NO_2 emissions per capita (kg/year)	–
	Average property price per square metre	–
	Satisfaction with household's financial situation (scale of 0 to 10)	+
	Satisfaction with quality of living environment (scale of 0 to 10)	+
	Aid (number of people receiving municipal aid as percentage of population)	–
	Number of local bus trips per inhabitant	+
	Number of cultural institutions per 100,000 inhabitants	+
	Number of attractions per 100,000 inhabitants	+
	Number of museums per 100,000 inhabitants	+
	Secondary utility gap (difference between proportion of dwellings connected to public drinking water network and proportion of dwellings connected to public sewerage)	–
	Waste generated per capita (kg)	–
	Separately collected waste in total waste collection (%)	+
	EDIOP support per capita for renewable energy development (HUF)	+

Note: The indicators used are about an 80% fit to the original version of SDG studies because of the available city database. Some variables that are not computed for the Hungarian city network were excluded (e.g., Community design applications, recharging stations, groundwater of good chemical status) and some were replaced with a suitable one.

Source: authors, based on data from HCSO, Eurostat, OKIR–LAIR, ingatlannet.hu, Google maps, palyazat.gov.hu.

When compiling the database used for the analysis, an important aspect was comparability and the possible addition of a data series to create a complex index. Accordingly, in an initial step, specific data were calculated, mostly using values per 1,000 or 10,000 persons, or using a percentage distribution. Because the data did not have the same units of measurement even after the specific values had been calculated, it was necessary to use standardization (Freudenberg, 2003) to calculate the components. By transforming or scaling the data (in our case, with min-max normalization), we achieved comparability of the indicators. The following formula was used for standardization:

$$x = \frac{x_i - x_{min}}{x_{max} - x_{min}} * 100$$

The main advantages of the method are that, while preserving the original context, it is possible to aggregate series of data in different units (e.g., kg, %, m^2, etc.), and it does not cause data loss or bias (Giffinger et al., 2007; Cohen, 2014). For those indicators for which a higher value had a more negative meaning (e.g., number of jobseekers, or various measures of air pollution), the reciprocal of the values was calculated using the following formula:

$$x_{corr} = \frac{x_i - x_{max}}{x_{min} - x_{max}} * 100$$

Complex components of the indicators were then formed using a simple arithmetic mean (because after standardization there is no outlier value in the database; Das & Imon, 2014) to produce the SDG 8, SDG 9, and SDG 11 indices and the resulting complex sustainability index. The twenty-seven indicators shown in Table 1 were used for the analysis.

After developing the final indicator structure, we reviewed the distribution using heatmaps and performed a cluster analysis based on literature recommendations (e.g., Bellantuono et al., 2022) to interpret the results.

4 Results

4.1 Heatmaps

The heatmap shows how the cities perform for each indicator or component (Dorofeev, 2022). It is a "two-dimensional visualization of data using colour to represent magnitude" (Cui & Zwick, 2016, p. 2). The values per column show the goodness or weakness of the area's position along a given variable. The values per row indicate the positive or negative values of the indicators for the cities (HCSO, 2015). For comparability among the datasets, standardized values were used, and each territorial unit was ranked on a scale from 0 to 100 in line with the literature (Arbatli & Johansen, 2017).

The SDG 8 (decent work and economic growth) heat map shows large heterogeneity in the performance of the cities studied. Esztergom, Győr, Tatabánya, and Veszprém showed the most stable positive performance in the more economic-focused indicators of SDG 8. The worst performers are Salgótarján and Szekszárd, as shown by several indicators. In Salgótarján, all components except self-employment are in the bottom third of the scale, whereas Szekszárd has positive performance in income and unemployment, but a significant lag in the other indicators. For all indicators, there is wide variation in the performance of the cities studied; for example, in per capita net income, the difference between the best-performing city of Székesfehérvár (HUF 1,723,192) and the worst-performing cities of Baja and Salgótarján is HUF 600,000 to 700,000.

In SDG 9 (industry, innovation and infrastructure), some cities have serious problems with several indicators. Győr stands out for its overall performance, with above-average scores for all dimensions. Győr is one of the most innovative and dynamic cities in the country, underpinned by its excellent educational background. Zalaegerszeg is the best cluster member in terms of five out of eight indicators, with a very low weight of "hard" innovation indicators, such as R&D and patents, which can only be significantly changed by the construction of Rheinmetall's new Lynx infantry fighting vehicle plant (in 2023), which will bring several new innovations to the city. Érd is outstanding in four out of eight indicators; its R&D and patenting performance is significantly improved by the application of Pest County's average, and because the city has no major industry it has clean air. Most of the below-average values, on the other hand, can be found in the Kaposvár and Debrecen areas.

SDG 11 (sustainable cities and communities) contains the most indicators, fourteen in total, and the cities' performance in this group is the most heterogeneous. Érd, Esztergom, and Veszprém show the most balanced performance, whereas Nagykanizsa and Nyíregyháza have the most negative indicators. Apart from these values, the dispersion of the cities' values is balanced, especially for NO_2. However, there is a significant difference in the average price per square metre of real estate. The difference between the highest price in Érd (more than HUF 720,000) and the lowest in Salgótarján (HUF 198,000) is almost four times. Prices mostly reflect the distribution of geographical peripheries. In the dimensions of satisfaction (based on the HCSO survey), the situation of the cities is similar in terms of their financial situation and living environment, with Győr and Sopron showing the most favourable values and Tatabánya, Nagykanizsa, and Nyíregyháza the least favourable, but the standard deviation of values among the cities is not significant.

4.2 Cluster analysis

The heat maps also highlighted the differences between the cities and the position of cities at the top and bottom of the list for each factor. It was assumed that cities with similar features and indicator values can be grouped together. To verify this, we used cluster analysis, which tries to form homogeneous groups from indicators of relatively heterogeneous objects (Anderberg, 1973). For the cluster analysis, we considered several possible solutions, including three, four, and five clusters. The three- and four-cluster versions over-aggregated the city types, making the results difficult to interpret. In the end, the five-cluster solution was chosen because of the interpretability of the results. The complex index values for the given cities, calculated from the indicators of SDGs 8, 9, and 11, are summarized in Figure 1. We have indicated the status of target achievement by the values of the components. For the five-cluster solution, we set thresholds of 20%, whereby cities

Cluster	City	8	9	11	Complex
1	Győr	73.56	60.94	61.83	65.44
	Veszprém	60.65	64.72	69.20	64.86
2	Esztergom	59.02	63.13	60.24	60.79
	Érd	65.12	68.32	45.57	59.67
	Sopron	61.03	51.71	65.11	59.28
	Szombathely	60.96	53.83	59.94	58.24
	Tatabánya	69.26	53.80	48.19	57.08
	Székesfehérvár	54.81	58.90	54.40	56.04
3	Szeged	52.12	54.96	46.38	51.16
	Hódmezővásárhely	57.47	41.59	51.43	50.16
	Kecskemét	54.82	42.54	48.63	48.66
	Eger	33.78	47.36	62.09	47.74
	Zalaegerszeg	51.03	42.94	48.09	47.35
	Nagykanizsa	51.55	35.82	48.24	45.21
4	Nyíregyháza	55.15	35.22	42.94	44.44
	Pécs	31.59	42.18	58.75	44.17
	Szolnok	43.09	41.89	46.06	43.68
	Debrecen	45.50	28.74	56.09	43.44
	Dunaújváros	52.34	36.91	39.27	42.84
	Miskolc	30.52	39.88	56.32	42.24
	Békéscsaba	44.64	29.36	48.00	40.67
	Baja	32.02	37.60	45.67	38.43
	Kaposvár	33.86	29.63	46.53	36.67
	Szekszárd	28.10	41.10	39.40	36.20
5	Salgótarján	26.11	38.08	40.18	34.79

Figure 1: Clusters of the complex sustainability index (illustration: authors).

with scores above 80% were given the highest ranking and cities below 20% of the average face serious challenges.

4.2.1 Cluster 1: The most dynamic and vibrant cities in the country

The first cluster included only two municipalities, Győr and Veszprém. Győr, formerly a city of trade fairs and merchants, is now the most dynamic and innovative county seat. This is reflected in the results of the indicators for SDG 8 (decent work and economic growth), SDG 9 (industry, innovation, and infrastructure), and SDG 11 (sustainable cities and communities), with the highest complex index value among the twenty-five cities studied (65.44). The Audi car plant and its related supplier network (Józsa et al., 2017; Fekete, 2018) significantly contribute to the dynamics and current development process of Győr. Thanks to excellent job opportunities, the city has a high net income per capita of HUF 1,662,287 and a low long-term unemployment rate of only 4.0%. Residents' satisfaction with their financial situation in the city is 5.9 (on a scale of 0 to 10), which is in the highest category. The city's secondary and higher education is high quality, and Széchenyi István University is a key player in the city's life, closely linked to the city's economy and a catalyst for the city's intellectual life. Győr's atmosphere is also enhanced by many historical buildings, which have a significant impact on residents' satisfaction with their living environment, which is 7.8 (on a scale of 0 to 10). In addition, the clean environment (20.4% of waste collected separately as a percentage of total waste generated) also enhances the image of the city. Veszprém is directly behind Győr in terms of net income per inhabitant (HUF 1,616,214), but the long-term unemployment rate is slightly higher (6.4%). After the collapse of communism, the city's economy suffered from the decline of heavy industry, and only the relocation of capital-intensive multinationals to the city has helped increase the city's dynamism and innovation capacity (Continental Automotive Hungary, Valeo Auto-electric Hungary, Balluff-Elektronika, Valeo Simens eAutomotive Hungary, Lasselsberger-Knauf Építőipari, Bramac Betoncserépgyártó és Építőanyag, etc.). The university still plays a major role in the city's scientific life (R&D expenditure as percentage of GDP, county level value of 3.44%). Veszprém is a truly liveable city thanks to its historic town, as shown by the satisfaction of its inhabitants with their living environment, which at 5.9 is behind that of Győr. The city of Veszprém received the third-highest amount of funding per capita among the towns in the EDIOP (Eco-

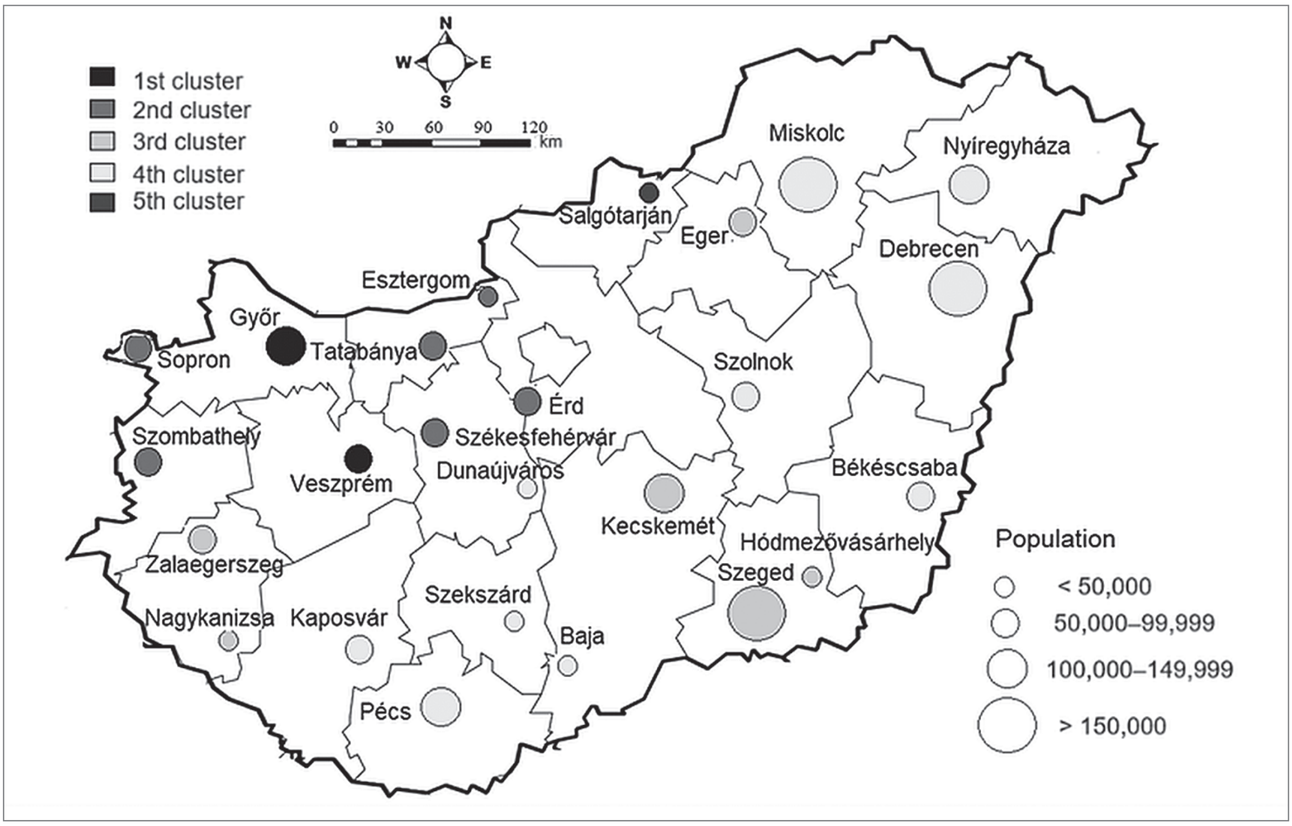

Figure 2: Spatial distribution of the clusters of the Complex Sustainability Index (illustration: authors).

nomic Development and Innovation Operational Programme of Hungary in the 2014–2020 EU support period) renewable energy applications, at HUF 2,590. Based on the indices obtained for the two cities, Győr is slightly stronger in jobs and innovation, but Veszprém is more powerful in liveability and sustainability, with a difference of just 0.58 points in the complex indices between the cities, which can be considered marginal. The spatial distribution of the clusters is illustrated in Figure 2.

4.2.2 Cluster 2: Emerging, dynamic, and liveable cities

The values of the complex index of the second, six-element cluster result in a seemingly heterogeneous group. However, when analysed in depth and individually, the characteristics of the cities in the cluster show a more homogeneous internal structure. Esztergom's main employer, Magyar Suzuki Corporation, and the group of satellite companies closely linked to it contribute to the outstanding scores of this city. These companies create job opportunities, resulting in a low unemployment rate and a favourable job prospect for recent graduates (88.2%). The number of patents registered in Esztergom is almost twice as high (16.58) as in the county seats (9.4). The city's liveability and living environment is rated by the residents as 7.7 (on a scale of 0 to 10). This high score can be explained by several factors: the historic character of the city, the picturesque surroundings of the Danube, and the clean air of the city. The city's position is reinforced by the fact that Esztergom is the northern intermodal hub of the metropolitan agglomeration thanks to the Danube bridge and the passenger terminal. In addition, the international transport corridor from Nitra (Slovakia) strengthens the city's position as an international hub (Gauder et al., 2011). The second city in the cluster based on the complex index is Érd, whose inclusion in the cluster is due to its high net income per capita (HUF 1,562,145), low long-term unemployment rate (4.4%), favourable employment rate of recent graduates (85.9%), and very high number of patents per million inhabitants (29.76). Érd's outstanding scores are also linked to its proximity to Budapest, its status as a dormitory city, and its social composition. The suburb is almost free of industrial enterprises, and because of this its air is very clean. However, road congestion (the M7 freeway and Expressway 7) and gravel dust pollution from unpaved roads increase particulate matter concentrations. For this reason, the city's residents have an average level of satisfaction with their living environment of 6.8 (on a scale of 0 to 10). The index for SDG 11 for Érd is only 45.57, which is partly because the city has not received a single cent of funding for energy development in the EDIOP programme among the cities studied. The next city in the cluster, Sopron, is known as a border town, monument town, and school town. Due to the city's favourable job creation potential, the long-term unemployment rate is extremely low (2.9%), and the employment rate of recent graduates is high (91.2%), the highest among the twenty-five cities studied. The city's liveability is reflected in its residents' satisfaction with the living environment (7.8 on a scale of 0 to 10), which is also supported by the city's clean air (low CO_2 and NO_2 emissions per capita). Szombathely is also rich in monuments, having received its city status from Roman Emperor Claudius. Since the 1990s it has undergone a major transformation. The city's industry used to be dominated by light industry (tens of thousands of people worked for the Savaria shoe factory and then at the Marc shoe factory, Latex, Styl Garment Factory, and similar plants), but the launch of the Opel motor factory marked the start of a new industry, the automotive industry. Today, the development of the city is linked to the car industry in Győr and Kecskemét, which is reflected in the higher-than-average per capita income (HUF 1,492,260). The arrival of modern technology has led to an increase in R&D expenditure and a significant increase in the number of patents in Szombathely (10.73 patents per million inhabitants). The city's liveability is reflected in the inward migration balance of 0.6, the high satisfaction of city residents with their living environment of 7.7, and the satisfaction with the financial situation of households of 5.8 (on a scale of 0 to 10). Due to its long history, the city is rich in monuments, cultural attractions, and museums (26.4 attractions and 14.5 museums per 100,000 inhabitants). Szombathely is a truly liveable border city with rich cultural assets, making it a popular destination for both domestic and foreign tourism. In Tatabánya, a former "socialist" town, coal mining was the dominant industry until 1987, when the last mine was closed. The transformation process was far from easy, and the city's active working-age population suffered significantly from the change, with unemployment rates higher than 25%, which was partly addressed by the introduction of manufacturing services (Gauder et al., 2011). Currently, the long-term unemployment rate is 8.2%. The age structure of the population is relatively young, with a 28.7% old-age dependency ratio. The number of patents per million inhabitants (16.83) is an indication of the city's renewed capacity for innovation. After the closure of the mines, the coal-fired power plant, and the cement plant, Tatabánya has become a liveable, clean environment, with a satisfaction index of 7.4. Tatabánya, like Érd, has a medium score (48.19) on the SDG 11 index, with a very low rate of separate waste collection of 0.9%, ranking it last among the cities studied. The last city in the cluster is Székesfehérvár, the former religious centre of the country, a royal city, and today a dynamically developing industrial city. The labour market offers a wide range of opportunities, which is why the city has a below-average long-term unemployment rate (7.5%) and a favourable employment rate for recent graduates (87.6%). It has the highest net income per capita of all the cities studied, at HUF 1,723,197. Székesfehérvár is one of the cities with a balanced performance on SDGs 8, 9 and 11, with a complex index around the previous three targets' average (56.04). The residents of the city are satisfied with the quality of their living environment (positive, 7.7), which is also helped by the cleanliness of the environment (20.6% of waste collected separately as a percentage of total waste generated). The city has received a significant amount of funding for renewable energy (HUF 690.9 per capita for renewable energy development in the EDIOP grant).

4.2.3 Cluster 3: Liveable cities on a slow growth path

The cluster cities' contribution to SDGs 8, 9, and 11 is average. Within the cluster, there are two groups of cities: the cities of the Great Plain with slow dynamics (Szeged with its free royal city past and Hódmezővárhely and Kecskemét with their rural town past) and the group of cities that are catching up, with lower innovation capacity, but still viable (the school and historic town of Eger and industrializing Zalaegerszeg and Nagykanizsa). Szeged is a famous school town (University of Szeged) and a centre of scientific life with internationally recognized research centres. The city has an outstanding record in science (its R&D expenditure as percentage of GDP is 2.34, ranking it second after Veszprém, and the number of patents per capita is 20.91). However, its contribution to SDGs 8, 9 and 11 is only average (net income per capita HUF 1,353,578, employment rate of recent graduates 85.1%, etc.). The parameters of the city's performance are worsened by the level of aid (31.2% of people receive municipal aid). The high level of municipal aid is partly due to the coronavirus pandemic, which has led to many people losing their jobs and finding themselves in a desperate situation. People living in Szeged are satisfied with their living environment and the comfort of the city (7.6 on a scale of 0 to 10), which has a lively cultural life (Egedy et al., 2018). Hódmezővásárhely, a rich former rural town with a long history, now has strong links to Szeged. In the 1950s it also had the function of a county seat, which was later transferred to Szeged. Hódmezővásárhely's relatively rapid population growth has led to a multiplication of services in the city. This sector is now the largest employer, accounting for over 60% of the total. Vásárhely also has a significant R&D expenditure of 2.34% of GDP and the number of patents per million inhabitants is 20.91 thanks to the attraction of Szeged. The people of Hódmezővásárhely are satisfied with their living environment, as shown by the high value of the index (7.5 on a scale of 0 to 10). The third major city in the cluster is Kecskemét, which has a rural past and became the administrative centre of Bács-Kiskun county in the 1950s. Today, it is an important automotive bastion of the country, home to Mercedes-Benz Manufacturing, which strives to develop environmentally friendly and energy-efficient production. The labour market structure of Kecskemét has been significantly improved by the operation of the Mercedes factory (Józsa et al., 2017), but the long-term unemployment rate is still 13.0%, while the number of patents per million inhabitants is almost twice the average of the other cities studied (16.82). Eger has a long history of trade and commerce, is very rich in monuments, and has the highest number of attractions per 100,000 inhabitants (118.7). The inhabitants of Eger are satisfied with their city's environment and its liveability (7.1 on a scale of 0 to 10). In contrast, the city is performing poorly in terms of development objectives for SDGs 8 (33.78) and 9 (47.36). This is due to the high long-term unemployment rate (16.5%), the highest old-age dependency ratio (37.2%), and the very low R&D expenditure as percentage of GDP: 0.54 (average 0.9). The last two cluster elements, Zalaegerszeg and Nagykanizsa, are on a slow growth path, especially regarding SDG 9 (Zalaegerszeg at 42.94 and Nagykanizsa at 35.82). The two cities have the same values for R&D expenditure as percentage of GDP (0.33%) and for the number of patents per million inhabitants (1.87). The cities in the cluster have average values for the SDGs.

4.2.4 Cluster 4: Cities with cyclical development and average conditions

The cities in the ten-item cluster have followed and are following very different development paths, which is clearly reflected in the evolution of their complex index values. The cluster also includes three cities with a regional role, immediately following Budapest in the city hierarchy: Debrecen, Miskolc, and Pécs (population over 100,000). The fluctuating performance of these cities is due to changes in their socioeconomic situation. Miskolc, formerly a stronghold of heavy industry, has seen a significant increase in unemployment (19.5% of the long-term rate) following the decline of the metallurgical industry. Dunaújváros, another typical industrial city, also had a high unemployment rate (18.4%), also due to the decline of the metallurgical industry. The population of these two cities has an ageing age structure (the old-age dependency ratio is 36.9% in Dunaújváros and 33.1% in Miskolc), with a worse rate for the elderly population only in Szekszárd, at 37.4%. Debrecen and Pécs stand out from the cluster, with an area of operation extending beyond the county boundaries and a catchment area of around 130,000 to 202,000 inhabitants. They are "rural cities" (in Hungarian terms) with corresponding institutions, as well as residential and business services (universities, clinics, scientific institutes, courts, etc.). Among the cities studied, Debrecen and Dunaújváros have the highest CO_2 emissions per capita (51.7 tonnes per capita in Debrecen and 35.1 tonnes per capita in Dunaújváros) due to the pharmaceutical factories in Debrecen and ISD Dunaferr in Dunaújváros. Dunaújváros has the lowest concentration of particulate matter among the cities studied, despite being a centre of transport-intensive industries due to its location and logistics (Gauder et al., 2011). In terms of liveability, the cities in the cluster are around average (7.3) or below average compared to the other cities studied. The most disadvantaged municipality in the cluster, Szekszárd, has a complex index of 36.2. Its transport situation contributes to this low value because low-capacity traffic connections affect it, which has led to a decline in its economic position, whereas the development of Szolnok, Nyíregyháza, and Békéscsaba, for example, has been supported by the railways.

4.2.5 Cluster 5: A declining and hardly liveable city

The modest ranking of Salgótarján among the cities studied is connected with its industrial past, which is also supported by a previous study on the dynamics of the Hungarian urban network conducted by Beluszky and Sikos Tomay (2020). Salgótarján was among the 346 cities they studied, ranking three hundredth. Based on the indicators examined in our analysis, it also scored only 26.11 on SDG 8, which is the weakest in terms of the indicators of "decent work and economic growth". The city has a high long-term unemployment rate, over 33.0%, and almost a third of the active jobseekers are unemployed. Salgótarján is not much better among the cities studied in terms of net per capita income (in last position at HUF 1,190,865). Formerly a highly ranked industrial centre, now it cannot find a strategy to recover from economic decline (Gauder et al., 2011). In terms of SDG 9, the county's innovation capacity is low, with the number of patents per million inhabitants in the city at 0.83, compared to the average of 9.4 for the cities studied. The low CO_2 emissions of the city are also linked to the decline of industry, a consequence of which is its high migration balance at −11.0%, which has also had a negative impact on property prices (198,994 HUF/m^2). Salgótarján's complex index (36.2) is the worst among all the cities examined, which is not surprising given the scores above. We can conclude that, as one of the former socialist flagships, but now abandoned by industry and lacking new elements of urbanization and functionality, it is lagging significantly behind the other cities with county rights.

5 Discussion

Today, the importance of sustainable and smart cities is increasing due to the impact of various social, economic, or environmental shocks (e.g., pandemics, military conflicts, and climate change), as shown by the growing literature on the subject. Our study assessed the economic and environmental sustainability of Hungarian cities with county rights, using the SDG methodology and set of indicators developed by the United Nations along three main dimensions.

Our attempt to measure sustainability in the context of county seats resulted in five clusters, which can be considered homogeneous and clearly explained. The methodology we developed for the analysis is suitable for the analysis of three SDGs (SDG 8: decent work and economic growth, SDG 9: industry, innovation, and infrastructure, and SDG 11: sustainable cities and communities). The resulting complex indices confirm that the most dynamic and vibrant cities in the country are Győr and Veszprém, followed by Esztergom and Érd. In other words, the dynamic cities of the western and northwestern parts of the country are also outstanding in terms of sustainability. Salgótarján closes the list, which is the most disadvantaged cluster member in most aspects.

In our opinion, the most important implications of this pilot study for the Hungarian city network are that the indicators included in the study allow the method to be applied to other model areas and the studies to be repeated at different times to analyse trends. The indicators used and the framework of the model can therefore be applied to other countries in sustainability calculations, but the analysis can also be extended to smaller urban or municipal levels. A specific feature of some indicators is that they are mostly available in all countries with similar content or can be substituted on a country-specific basis thanks to the UN recommendations and the SDG calculation methodology.

Of course, our method and complex sustainability index may have some limitations and shortcomings, which we must consider by calculating it for other territories or different time horizons. The greatest limitation is the data constraints because these kinds of indicators cannot be reproduced in any possible time; some data are available only for shorter terms. Regarding the data constraints, another issue might be that the content of indicators can change over time. In addition, the analysis contains only the performance of three SDGs, and so sustainable performance and the ranking of the cities could be modified by accounting for the other pillars of the UN methodology.

6 Conclusion

Our results thus partially support our initial hypothesis that economically more developed higher-income cities (mostly located in western and central Hungary) also stand out from a sustainability point of view, but this is not necessarily consistent with the ranking of the most populous cities. Out of the ten most populous cities in Hungary, only one, Győr, can be classified as the most sustainable (topping the list), but the other cities with a population of over 100,000 are mostly in the fourth cluster of cities with average conditions. Out of the top ten, only Székesfehérvár and Szombathely, with populations below 100,000, can be classified in the more sustainable second cluster. The generalizability of our hypothesis is somewhat distorted by the fact that the Hungarian capital Budapest was excluded from the analysis due to bias, although it has a long-term sustainability strategy (until 2030), which is currently being implemented. Thus, it is likely to top the list in terms of sustainability, population, and economic development.

The results reflect the results of the country-level comparisons of the UN to some extent because the countries of central and eastern Europe are far from achieving the SDGs (Lafortune et al., 2022). Hungary is twenty-third among the EU + EFTA member states, with a total of 69.9% goal achievement. However, it is promising that the tendencies show positive changes in the three goals analysed. The results also agree with the city-level analysis of Lafortune et al. (2019), in which the performance of central and eastern European cities ranges from Munich ranked eighth to Bucharest ranked forty-first (with Budapest at thirty-seventh). Except for cities in Germany, access and the quality of key public services and infrastructure are the greatest challenges.

Tamás Sikos Tomay, University of Miskolc, Faculty of Economics, Institute of Management, Miskolc, Hungary
E-mail: tamas.sikos.t@uni-miskolc.hu

Dóra Szendi, University of Miskolc, Faculty of Economics, Institute of World and Regional Economics, Miskolc, Hungary
E-mail: dora.szendi@uni-miskolc.hu

Acknowledgement

This study was supported by the Eötvös József Research Centre of the National University of Public Service.

References

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I. & Airaksinen, M. (2017) What are the differences between sustainable and smart cities? *Cities*, 2017(60), 234–245. doi:10.1016/j.cities.2016.09.009

Anderberg, M. R. (1973) *Cluster analysis for applications*. Burlington, MA, Academic Press. doi:10.1016/C2013-0-06161-0

Angelidou, M., Politis, C., Panori, A., Bakratsas, T. & Fellnhofer, K. (2022) Emerging smart city, transport and energy trends in urban settings: Results of a pan-European foresight exercise with 120 experts. *Technological Forecasting and Social Change*, 183(2022), 1–17. doi:10.1016/j.techfore.2022.121915

Arbatli, E. C. & Johansen, R. M. (2017) *A heatmap for monitoring systemic risk in Norway*. Research report. Oslo, Norges Bank.

Bellantuono, L., Monaco, A. & Amoroso, N. (2022) Sustainable development goals: Conceptualization, communication and achievement synergies in a complex network framework. *Applied Network Sciences*, 7, 14. doi:10.1007/s41109-022-00455-1

Beluszky, P. & Sikos Tomay, T. (2020) *Városi szerepkör, városi rang*. Budapest, Dialóg Campus.

Cohen, B. (2014) Estudio "Ranking de Ciudades Inteligentes en Chile". *País digital, 77*.

Cui, T. & Zwick, E. (2016) *Heatmaps for economic analysis*. Available at: http://www.ericzwick.com/heatmap/heatmaps.pdf (accessed 13 Jul. 2022).

Das, K. R. & Imon, A. H. M. R. (2014) Geometric median and its application in the identification of multiple outliers. *Journal of Applied Statistics*, 41(4), 817–831. doi:10.1080/02664763.2013.856385

Dorofeev, M. L. (2022) Interrelations between income inequality and sustainable economic growth: Contradictions of empirical research and new results. *Economies*, 10(44), 1–23. doi:10.3390/economies10020044

Egedy, T., Kovács, Z. & Szabó, B. (2018) Changing geography of the creative economy in Hungary at the beginning of the 21st century. *Hungarian Geographical Bulletin*, 67(3), 275–291. doi:10.15201/hungeobull.67.3.5

European Environment Agency (2020) *SDGs and the environment report: Background, purpose and methodology*. Available at: https://www.eea.europa.eu/themes/sustainability-transitions/sustainable-development-goals-and-the/chapters/background (accessed 25 Apr. 2022).

European Parliament (2014) *Mapping smart cities in the EU*. Available at: https://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/507480/IPOL-ITRE_ET(2014)507480_EN.pdf (accessed 13 Jul. 2022).

Fekete, D. (2018) Economic development and economic governance through the example of the city of Győr. *Deturope: Central European Journal of Tourism and Regional Development*, 10(1), 97–115. doi:10.32725/det.2018.006

Freudenberg, M. (2003) *Composite indicators of country performance: A critical assessment*. (= *OECD Science, Technology and Industry Working Papers*, 2003/16). Paris, OECD Publishing. doi:10.1787/405566708255

García Fernández, C. & Peek, D. (2020) Smart and sustainable? Positioning adaptation to climate change in the European smart city. *Smart Cities*, 3(2), 511–526. doi:10.3390/smartcities3020027

Gauder, P., Szabó, T., Márkus, I. & Toplak, T. (2011) *Budapest region draft structure plan, restructuring the metropolitan landscape*. Available at: https://www.academia.edu/16373892/Budapest_Region_Draft_Structure_Plan (accessed 19 Mar. 2022).

Giffinger, R., Ferner, Ch., Kramar, H., Kalasek, R., Pichler-Milanovic, N. & Meijers, E. (2007) *Smart cities: Ranking of European medium-sized cities*. Vienna, Vienna University of Technology; Ljubljana, University of Ljubljana; Delft, Delft University of Technology. Available at: http://www.smart-cities.eu/download/smart_cities_final_report.pdf (accessed 13 Jul. 2022).

Glasmeier, A. & Christopherson, A. (2015) Thinking about smart cities. *Cambridge Journal of Regions, Economy and Society*, 8(1), 3–12. doi:10.1093/cjres/rsu034

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., et al. (2010) Foundations for smarter cities. *IBM Journal of Research and Development*, 54(4), 350–365. doi:10.1147/JRD.2010.2048257

HCSO (2015) *Focus on counties – 1st half of 2015, regional comparison. Methodology*. Available at: https://www.ksh.hu/docs/hun/xftp/megy/152/index.html (accessed 13 Jul. 2022).

HCSO (2022) *Sustainable development goals*. Available at: https://www.ksh.hu/sdg/index.html (accessed 13 Jul. 2022).

Höjer, M. & Wangel, J. (2014) Smart sustainable cities: Definition and challenges. In: Hilty, L. M. & Aebischer, B. (eds.) *ICT innovations for sustainability* (= *Advances in intelligent systems and computing* 310), 333–349. Cham, Springer. doi:10.1007/978-3-319-09228-7_20

Józsa, V., Káposzta, J. & Nagy, H. (2017) The impact of corporate embeddedness of transnational companies on local economic development: Case studies from Hungary. *Regionalnaja Ekonomika: Jug Rossii / Regional Economy: The South of Russia*, 2(16), 14–21. doi:10.15688/re.volsu.2017.2.2

Lafortune, G., Fuller, G., Bermont Diaz, L., Kloke-Lesch, A., Koundouri, P. & Riccaboni, A. (2022) *Achieving the SDGs: Europe's compass in a multipolar world. Europe sustainable development report 2022*. Paris, SDSN and SDSN Europe.

Lafortune, G., Zoeteman, K., Fuller, G., Mulder, R., Dagevos, J. & Schmidt-Traub, G. (2019) *The 2019 SDG index and dashboards report for European cities (prototype version)*. Tilburg, Netherlands, Sustainable Development Solutions Network (SDSN) and the Brabant Centre for Sustainable Development (Telos). Available at: https://www.sdgindex.org/reports/sdg-index-and-dashboards-report-for-european-cities/ (accessed 27 Apr. 2022).

Lehtonen, M. (2004) The environmental-social interface of sustainable development: capabilities, social capital, institutions. *Ecological Economics*, 2004(49), 199–214. doi:10.1016/j.ecolecon.2004.03.019

Nyussupova, G., Kenespayeva, L., Tazhiyeva, D. & Kadylbekov, M. (2022) Sustainable urban development assessment: Large cities in Kazakhstan. *Urbani izziv*, 33(1), 70–81. doi:10.5379/urbani-izziv-en-2022-33-01-01

Sustainable Development Solutions Network (2017) *First-ever US cities SDG index ranks American cities based on sustainability performance*. Available at: https://www.sdgindex.org/news/first-ever-us-cities-sdg-index-ranks-american-cities-based-on-sustainability-performance/ (accessed 27 Apr. 2022).

Szendi, D. (2021) Practices of the penta-helix approach in the European leading smart cities. In: Urbančíková, N. (ed.) *Building smart communities for the future: SMART solutions for energy*, 85–92. Košice, Technical University of Košice. Available at: https://www.researchgate.net/publication/357913358_Practices_of_the_penta-helix_approach_in_the_European_leading_smart_cities (accessed 28 Apr. 2022).

Toli, A. M. & Murtagh, N. (2020) The concept of sustainability in smart city definitions. *Frontiers in Built Environment*, 6 (77). doi:10.3389/fbuil.2020.00077

UN (2015) *The millennium development goals report 2015*. New York, United Nations. Available at: https://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf (accessed 13 Jul. 2022).

UN (2018) *The sustainable development goals report*. New York, United Nations. Available at: https://www.un.org/sustainabledevelopment/progress-report/ (accessed 28 Apr. 2022).

UNEP (2018) *The weight of cities – resource requirements of future urbanization*. Paris, International Resource Panel Secretariat.

Wataya, E. & Shaw, R. (2022) Soft assets consideration in smart and resilient city development. *Smart Cities*, 2022(5), 108–130. doi:10.3390/smartcities5010007

Yigitcanlar, T. & Kamruzzaman, M. (2018) Does smart city policy lead to sustainability of cities? *Land Use Policy*, 2018(73), 49–58. doi:10.1016/j.landusepol.2018.01.034