

Linking smart city concepts to urban resilience

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SUMMARY

In this study, ten cities from the Visegrád countries are compared applying cross-sectional data (from the year 2015). After the standardization process of the involved 11 indicators, their adaptive capacity is measured by resilient index that we developed and a rank is created. This index is formed by three components (demographic, social-economic and spatial-environmental resilience components). Significant differences were revealed related to the adaptive capacity of the examined settlements. In spite of the fact that the capitals of the Visegrád countries are the most resilient cities from an economic perspective, their results are around or below the average regarding their demographic and spatial-environmental components. This indicates that the economic success of a city does not necessarily imply greater resilience: being an economically successful city is a necessary but not sufficient condition for being a resilient city.

Keywords: resilience; smart city; adaptation; Hungary; economic success

Journal of Economic Literature (JEL) codes: P25, R11, R58

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INTRODUCTION

Increasing globalization poses new challenges for cities. Today, cities make a significant contribution to global GDP, reaching over 80% in 2018 (Hajduk 2016, Kola-Bezka et al. 2016, World Bank 2018). The rate of urban populations is growing steadily. In 1950, there were only 80 cities in the world with a population of over one million, while by 2011, their number had increased to 480. World Bank (2016) data highlight that about 1.4 million people move into urban areas every day. As a result, more than three billion people live in cities today, which may grow to as high as five billion by 2050, and the total rate of the urban population may reach 70% (Muggah 2012). The importance of the cities is well reflected by four figures (2%, 50%, 75% and 80%) of the World Economic Forum: cities own 2% of the land while about 50% of the population live in cities, and cities are responsible for 75% of the world energy consumption and for the 80% of the carbon dioxide emission (WEF 2016).

Cities play an important role in the economic development of countries and regions. Cities provide economies of scale, agglomeration, they concentrate enterprises, capital and stock markets, they can attract a talented and skilled labour force to reach a higher level of knowledge and innovation and foster economic growth (Enyedi 1997; UN Habitat 2011).

The World Economic Forum (WEF 2014) emphasizes six megatrends that are related to the development of cities. These are increasing urbanization, rising inequalities, sustainability, technological change, industrial clusters and global value chains, and governance. In this environment, cities have complex challenges to adapt and reach competitiveness. Based on another analysis of the World Economic Forum (WEF 2016), a huge part of the technologies that are the major driving forces of global transformation show a significant connection to smart cities. The ten most important of them are Open Data, Smart Grid systems, location and position sensors, private e-ID, mobile health control, Internet of Things, forecasting with data analysis, mobile-device

based sensors, intelligent traffic and Big Data. The smart cities' main aim is to create new solutions mainly for city services by using these kinds of technologies.

Similar introductions and statistics on smart and resilient cities are available in numerous national and international publications, e.g. Lados (2011), Bizjan (2014), European Parliament (2014), Szczech (2014), Richter et al. (2015), and Hajduk (2016), with Szendrei (2014) illustrating the challenges caused by globalization, climate change and accelerated urbanization

The global pandemic has boosted these challenges further and drawn attention to the city level, where nationwide measures are actually implemented. As the Secretary General of the United Nations concludes, local action is the key and cities will have a critical role not only in prevention of the virus spreading, but in the global economic recovery, too (Guterres 2020). This brings to the surface the problem of inequalities among territories and different social groups and puts a spotlight on accessibility vs. mobility. Digitalization can serve as an action tool accelerating environmental awareness and supporting long-term recovery strategies (OECD, 2020).

The current study is divided into four well-defined parts. In the section *Theoretical Background*, urban resilience is interpreted, defining the related key concepts and introducing the various resilience indicators (with special regard to the results of the FM Global Resilience Index). Section 3 (*Methodology and data*) describes the data and cities included in the analysis, the methodology of standardization and computing the resilience index. In the section *Results*, not only the resilience index is described in detail but also its components, and values are compared with the results of the smart index obtained in one of our previous studies (Nagy et al. 2018). In the last section (*Summary*), conclusions are drawn and experiences are summarized.

THEORETICAL BACKGROUND

Cities can be considered very complex and complicated systems: they are the power centres of development and the engines of economic growth. Urban population, industry and services (due to their high attractiveness of capital) are very concentrated. As a result of this increasing concentration, the vulnerability and dependence of cities keep increasing. The well-being of the urban population can be ensured by the safe operation of the infrastructure systems, the communications networks, the big operational systems and the supply chains (World Bank 2016). At the same time, however, large-scale interdependence among the systems makes them vulnerable. The UNISDR (2015) predicts that the cost of recovery after the damages in the built environment (caused by human mankind or a natural disaster) will come to USD 314 billion on average yearly by 2030 and will be as high as USD 415 billion yearly after 2030. Therefore, the

focus should be on prevention rather than disaster recovery and reconstruction.

This study does not aim at synthesizing theories that focus on urban resilience and at developing new concepts. Numerous sources are available on the topic including Martin and Gardiner (2019), Pirisi (2019), Zhang and Li (2018), Wang et al. (2018), Buzási (2017), Meerow et al. (2016), and Bulkeley and Tuts (2013), who excellently summarize and clarify debates around the concepts. Hereinafter, the following definition of the World Bank (2016) is applied: "resilience is defined as the ability of a system, entity, community, or person to adapt to a variety of changing conditions and to withstand shocks while still maintaining its essential functions" (World Bank 2016: 12).

Cities should try to avoid shocks and reduce risks even if these shocks are often unpredictable. The aim is to keep the urban functions in their original state or to be restorable within a short time. Adaptability (or adaptive capacity) is the key to resilience (Bristow and Healy 2018). It shows how resilient a city is and how fast it can react to external changes (World Bank 2016). Therefore, adaptability is "a characteristic of a given system that ensures the long-term and sustainable operation of subsystems despite the changing external conditions, but also provides enough flexibility for partial or complete transformation" (Buzási 2017: 38). Adaptability enables cities to ensure their residents' well-being and contribute to long-term sustainability. The previously described concepts (adaptability and sustainability) go hand in hand; one cannot exist without the other. As Bănică and Muntele (2017) highlight, resilience is not only a normative concept but also a strategic concept.

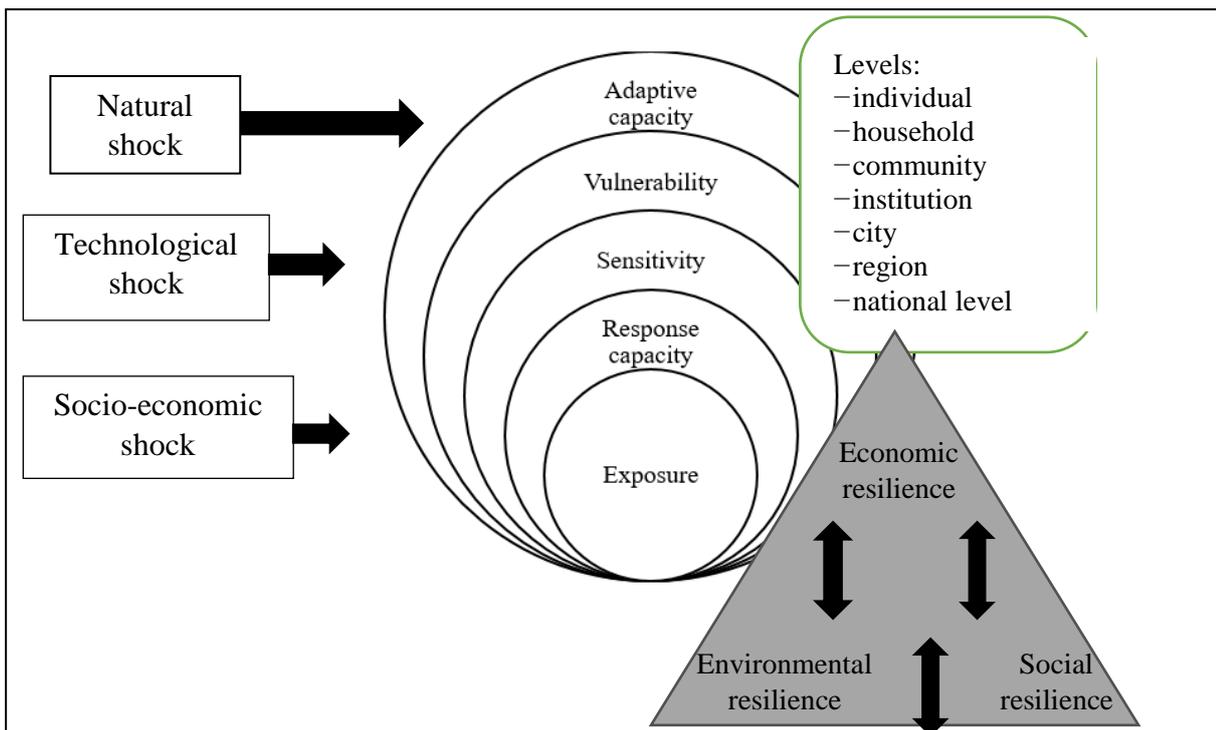
The basic approach of resilience, adaptation and stability is that cities are usually in some equilibrium state. Even if an external shock knocks them off balance, they aim at turning back to the equilibrium or reaching a new equilibrium state (i.e. finding stability). This corresponds to the definition of Pirisi (2019): "adaptive resilience refers to the ability which enables the system to change as a result of external effects, which implies that it adapts to changing external circumstances" (Pirisi 2019: 66). However, Bănică and Muntele (2017) have a completely different view, saying that urban development cannot be regarded as an uninterrupted and smooth process aimed at achieving equilibrium, but rather as progress among imbalances. This implies that stability is quite relative and it has to be accepted that a city is able to operate not only in a certain equilibrium state. The aim is to continuously "refine" each subsystem. It is as a result of flexible adaptation to changes that a steady state can be realized which can be considered stable (Buzási 2017).

It is important to examine the role of time. While in the short term, defence may be the main aim, the focus

in the long term is on adaptation. Urban resilience can also be interpreted as a key element of sustainable development (World Bank 2016). Resilience is, in fact, the means by which sustainability can be achieved (Buzási 2017; Pirisi 2019). A resilient city, as a concept, refers not only to economic development (although in most cases it is measured with per capita gross added value and therefore it is identified with economic growth), brown-field rehabilitation or conscious urban planning and urban sprawl. It includes the long-term improvement or maintenance of the quality of life and well-being of the population, a healthy and safe environment, equality and fairness (Bănică and Muntele 2017).

The global pandemic (Covid-19) brought the topic to the surface, highlighting the practical side of the concept. Chong (2020) lists 5 early conclusions that can be drawn after the coronavirus: 1) multi-hazard problem – importance of holistic approach, 2) proactive measures should be emphasized, 3) importance of big data approach, 4) identifying critical points, 5) efficient framework should be created.

Figure 1 describes the different examination levels, the potential conceptualizations of urban resilience and the typology of external shocks.



Source: own compilation based on Wang et al. (2018) and World Bank (2016)

Figure 1. Conceptual interpretation of urban resilience

The World Bank (2016) distinguishes three types of external shocks: natural, technological and socio-economic risks. The first group includes the negative impacts of climate change (like flash floods, floods, mudslides, intense storms, frequent fires, drought, and higher average temperatures). Technological risks include, but are not limited to, sudden changes in the built environment (such as the collapse of bridges and buildings, chemical disasters, cyber attacks, explosions, fire, gas or oil leaks, other industrial disasters, poisoning, traffic accidents, failure in major supply systems). The third group includes corruption, changes in the business cycle, demographic changes, economic crisis, high unemployment, strikes, terrorism, political and social conflicts, supply crises and war.

In most of the cases, studies on resilience focus on a selected shock and concentrate on its

analysis. Bulkeley and Tuts (2013) examine urban vulnerability, adaptation and resilience in the context of climate change. Kitsos and Bishop (2018) focus on the effects of the 2008-2009 crisis (economic resilience) and Beyer et al. (2016) analyse the resilience of individuals, households, communities and institutions in Nairobi, which struggles with significant social problems. Khan and Labonté (2017) consider the technology sector as a key to economic resilience (they describe Toronto in their case study). Bristow and Healy (2018) focus on the role of the development of innovation capacity and the innovation ecosystem in urban resilience. They conclude that the European regions that previously had had higher innovation capacity and performance were more resilient to the 2008-2009 crisis.

Options of measuring resilience, indicators of resilience

There are several options to measure resilience: it can be carried out at lower levels such as at the individual or household levels, although it is much more general at the city, regional or national level. Most of the studies (e.g. Bănică and Muntele 2017; Kitsos and Bishop 2018,) aim at the quantitative measurement of resilience with analyses dominated by labour market research and approaches. The main reason for this is that a good indicator of economic complexity is the sectoral distribution of the employed, which refers to the exposure and dependence of the given city. In addition, it is widely agreed that an advanced, flexible and innovative SME sector contributes to the resilience of a region to economic crises, and can reduce (or even prevent) negative impacts (Kitsos and Bishop 2018).

When measuring resilience and adaptive capacity, different researchers use different numbers of indicators. For instance, while Drobniak (2017) starts from one single indicator, namely GDP, when examining the economic resilience of the EU Member States and the Central European

regions, Wang et al. (2018) include 139 indicators in their analysis.

There are many very different resilience indicators available, including the City Resilience Index (2019), the Resilience Index Measurement and Analysis (RIMA) Model (FAO 2019), the Composite Resilience Index, the Savills Resilient Cities Index and the FM Global Resilience Index (FM Global 2019). The latter examines 130 countries in the world and ranks them based on 12 key factors that determine resilience. This is intended to provide investors and companies with information on the security of the business environment (FM Global 2019). It examines three components (economic, risk and supply chain components). The following indicators are related to the economic component: productivity, political risk, oil intensity and urbanization rate. The risk component takes into account natural disasters, the quality and type of the building stock (like fire protection rating or proportion of earthquake-proof buildings), and vulnerability to cyber attacks. The supply chain component includes the indicators of corruption and the fight against it, the quality of the infrastructure, and the assessment of corporate governance (accounting standards, rules about incompatibility, shareholder rights).

Table 1.

Position of the Visegrád Four countries based on FM Global Resilience Index (and its components) (2019)

	Hungary	Czech Republic	Poland	Slovakia
Resilience index	35	20	24	29
Economic component	25	15	19	9
Risk component	35	2	6	19
Supply chain component	43	29	33	49

Note: Light grey indicates belonging to the second quartile based on the given result, while dark grey indicates the first quartile.

Source: Own compilation based on FM Global (2019) data

Table 1 shows the position of the Visegrád Four countries in the resilience ranking including 130 countries. The Czech Republic has one of the best ratings for each component and Hungary has the worst performance, similarly to Slovakia, especially in risk and supply chain components.

Hereinafter we aim at calculating the Resilience Index for ten major cities of the Visegrád Four countries for 2015. It is carried out based on the study of Bănică and Muntele (2017), in which the authors identify the three main components of resilience based on the well-known pillar structure of sustainability. Using this definition, we distinguish demographic, social-economic and spatial-environmental components.

METHODOLOGY AND DATA

Cities were selected based on two factors. One of them is the availability of qualitative data and indicators,

given by the Urban Audit Perception Survey city list. The other is the EFOP-3.6.2. research project about the smart city characteristics of the Hungarian cities and about their relationship with urban resilience at the national and international level. Taking into account the available data, the cities included in the analysis are (Figure 2): Prague and Ostrava in the Czech Republic, two metropolitan areas according to ESPON (2007); Budapest (metropolis) and Miskolc (big city) in Hungary; Warsaw, Krakow and Gdansk (metropolitan areas) and Białystok (big city) in Poland; Bratislava (metropolis) and Košice (big city) in Slovakia.



Source: own compilation

Figure 2. The cities included in the study

Our aim was to use indicators and to develop an index that meets the following requirements:

- selecting data, which are available for all the cities,
- the analysis can be repeated at other times,
- enables national and international comparability.

Table 2 describes the components used, the related indicators and their sources. In the course of data collection, we aimed at collecting data at the city or at least at the metropolitan region level. The number of hospital beds per 100,000 people and the employment rate are only available at NUTS 2 level. The list of indicators is compiled based on Bănică and Muntele (2017). However, some minor modifications were carried out regarding the data. The indicators were reconsidered based on relevance and availability of data.

Table 2.

The set of indicators for the demographic, social-economic and spatial-environmental resilience components

Demographic resilience component				
<i>Indicator</i>	<i>Year</i>	<i>Territorial level</i>	<i>Effect on resilience (+/-)</i>	<i>Source</i>
Population change between 2005 and 2015 (%)	2005-2015	city	+	Eurostat
Proportion of 0-14 year olds to total population (%)	2015	city	+	Eurostat
Proportion of elderly population (> 65 years)	2015	city	-	Eurostat
Population density (person/ km ²)	2015		-	Eurostat
Social-economic resilience component				
<i>Indicator</i>	<i>Year</i>	<i>Territorial level</i>	<i>Effect on Resilience (+/-)</i>	<i>Source</i>
Number of hospital beds per 100,000 people	2015	NUTS-2 (region)	+	Eurostat
GDP per capita at current prices (EUR)	2015	metropolitan region	+	Eurostat
Number of students in higher education in the total population (person/1000 persons)	2015	city	+	Eurostat
Employment rate (%)	2015	NUTS-2 (region)	+	Statistics Poland, Hungarian Central Statistical Office, Czech Statistical Office, Statistical Office of the Slovak Republic
Spatial-environmental resilience component				
<i>Indicator</i>	<i>Year</i>	<i>Territorial level</i>	<i>Effect on Resilience (+/-)</i>	<i>Source</i>
Number of days when the ozone concentration exceeds 120 µg/m ³	2013	city	-	Eurostat
Built-up area per capita, (m ² /person)	2010	metropolitan region	-	European Commission (2019): Urban and territorial dashboard
Green infrastructure per capita, (m ² /person)	2010	metropolitan region	+	European Commission (2019): Urban and territorial dashboard

Source: own compilation based on Bănică and Muntele (2017)

The direction (as the effect on resilience) of the selected indicator is a key issue and it is admitted that some contradictions can be found here. However, the main purpose of this paper is to build a resilience index to measure the resilience performance of the involved settlements. The results are put into wider context, emphasizing the connections between smart city theory and resilience. There are indicators (e.g. proportion of 0-14 year olds to total population, %) whose direction may be positive and negative, too (depending on the perspective). If the environmental dimension is considered, infants and toddlers are more vulnerable to heat waves and to other negative effects of the global climate change (more details in Dian et al. 2019). However, a young society is a key component of long-term development, because they are more open to digitalization and smart tools, so this is assessed as positive in the calculations.

Another debatable area is the indicators of population density and built-up area per capita. They are strongly correlated. Other studies (e.g. Sebestyén Szép et al. 2020) and the latest events around the global pandemic highlight that urban areas with high population density are more vulnerable than rural areas (i.e. number of cases, death rate, etc.). The urban population is more vulnerable and exposed to the changes in the supply chains. Management of urban utility services is critical; any issue has a greater impact on local population. Both indicators are considered as having a negative effect on resilience.

Standardization of the values was necessary in order to ensure the comparability of the indicators with different units of measurement and scaling. A method to do so is z-transformation, which converts all indicator values to standardized values with an average of 0 and a standard deviation of 1. Its advantage is that it takes into account the heterogeneity of the units within the group and provides metric information. In addition, this transformation significantly increases the indicator's sensitivity to changes that occur. The method is widely used when data have different scaling/units of measurement and the aim is the comparability or the aggregation of individual components. This method is not new in the study of smart cities and urban resilience; Cohen (2014), Hajduk (2016) and FM Global (2019) also used it in their research. The method is based on a linear transformation of the data and can be performed using the formula below.

$$X = \frac{X_i - \bar{X}}{\text{standard deviation}} \quad (1)$$

where X_i is the value of the indicator in the i^{th} city and \bar{X} is the average of the indicator among the examined municipalities.

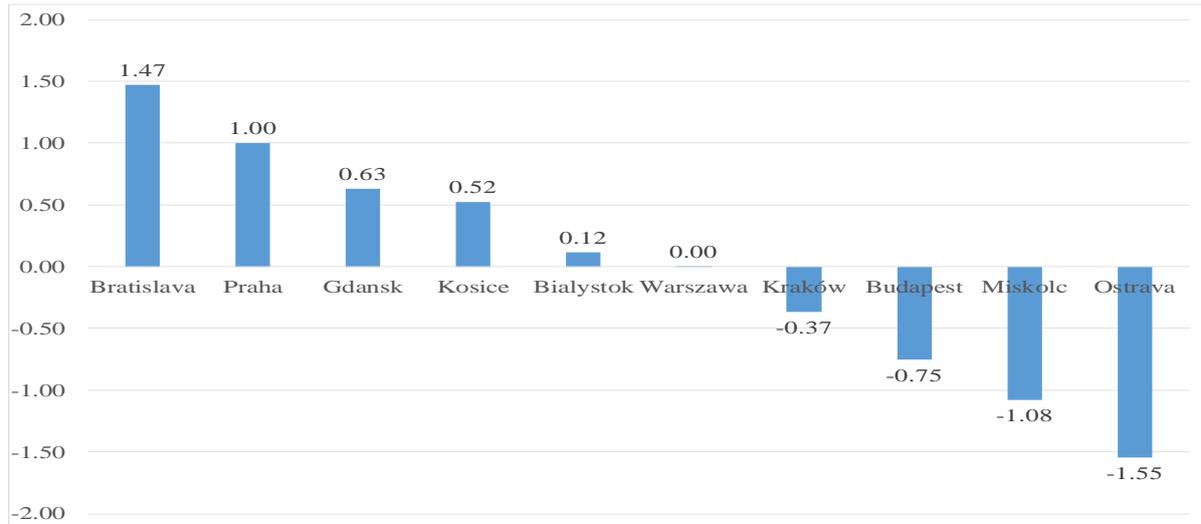
The main advantages of this method are:

- it allows aggregation of different sets of data (like kg, %, m²) while retaining the original relationships,
- it does not cause data loss or distortion (Giffinger & Pichler-Milanovic 2007, Cohen 2014).

In some cases, some changes were required in the course of the interpretation of indicators (components) and of the development of a complex indicator due to the different scaling of the indicators. If the metrics were not scaled properly (such as when lower values are associated with better positions of the cities as the proportion of the elderly population or the number of days exposed to higher ozone concentrations), the inverse of the selected indicators are used for further calculations. The value of each subsystem was calculated as the sum of the standardized values of the selected indicators. Then the so-called smart index, as a final result, could be calculated as the arithmetic mean of the values of the pillars, similarly to the methodology applied in other studies (Giffinger & Pichler-Milanovic 2007; Nagy et al. 2016).

RESULTS

Comparing the values of the resilience index (Figure 3) created based on the three components (demographic, social-economic and spatial-environmental resilience components), different conclusions can be drawn than in the case of the smart indexⁱ (see Nagy et al. 2018). Out of the capitals, only Prague could keep its leading position, Warsaw fell to sixth and Budapest fell to eighth place. Although Bratislava extremely underperforms on the basis of the smart index (it is one of the least "smart" settlements among the examined cities of the Visegrád countries), it still seems to be the most resilient city based on the resilience index. The same applies to Košice: while it is at the end of the list based on the smart index (ranked at 10th place), it is number four based on resilience. Ostrava performs differently: while it is the number four in the smart cities list, it is the least resilient (ranking 10 on the resilience index). In general, Polish cities are situated in the middle range according to the results of both indicators and the two Slovak cities are considered to be highly resistant. Miskolc performs poorly based on both indicators. Despite the smart city developments realized in recent years, it is ranked 8th on the smart city index list and 9th on the resilience index list.



Source: own compilation

Figure 3. Values of the resilience index in the examined Visegrád cities (2015)

In the following, we examine the performance of each city based on the components of the resilience index (Table 3).

In the case of Prague, Košice and Bialystok, the demographic pillar is the strongest one. In all three cities, the proportion of people aged 0-14 is over 14% (compared to the total population), population growth is significant, but population density is relatively low (compared to cities of similar category). This cannot be specifically explained by the high fertility rate, but rather by increasing urbanization and by the fact that these cities have become targets of internal migration. Bratislava lags behind these three cities in several respects and therefore is in fourth position. It is characterized by a higher population density and a decreasing population. At the same time, the rate of young people (aged 0-14) is high (14.3%), while the rate of those aged over 65 is lower than the regional average. Warsaw and Ostrava are ranked 5th and 6th with almost the same component values. The age composition of the population is nearly the same, but while Warsaw is a very densely populated and significantly attractive city, the population density in Ostrava is 53.9 persons/km² and characterized by outward migration. Miskolc and Gdansk are in the 7th and 8th position, respectively. The largest difference here, too, is in population growth and population density. At the end of the list there are two densely populated cities (Budapest and Krakow), where the rate of those aged over 65 is higher.

The capitals are that clearly the leaders in the social-economic component ranking, as they perform better than the average in the case of all four indicators (number of hospital beds per 100,000 people, GDP per capita, number of students in higher education and employment rate). On the one hand, Bratislava's exceptionally high employment rate may be due to the fact that its educational position is better than that of other cities in the country (it is clearly the centre of higher

education in Slovakia), and as a result, it has a large number of inhabitants with higher education attainment and with appropriate foreign language knowledge. Another factor is that large companies within the country prefer Bratislava as their main investment target. INC (2019) data reveal that in 2016, out of the 5,000 fastest growing privately owned companies in Europe, 215 were located in Slovakia, of which 77 were registered in Bratislava and 12 in Kosice.

According to a 2015 report of the European Commission, within European countries Prague, Cluj-Napoca, Munich and Bratislava are the cities where it is the easiest for new graduates to find a job (based on a population survey), while Budapest and Miskolc can be found in the second half of the list (European Commission 2015). While Krakow lags behind these cities in terms of GDP per capita, it is nevertheless considered a higher education-oriented regional center, with a very high number of students (and their proportion of the total population). Obviously, the second half of the list includes rural towns. Miskolc performs well in terms of the number of hospital beds and is close to the values of the capitals (it even exceeds the value of Warsaw) (one of the largest hospitals in Hungary, the County Central Hospital of Borsod-Abaúj-Zemplén and University Teaching Hospital, can be found here). It is, however, at the end of the list based on other indicators: per capita GDP (only EUR 8000/person in the region), the rate of the students in higher education to the total population is only 60 (per 1000) and the employment rate is below 50% (which is partly explained by the city's industrial past and its decline).

As was expected, the Polish cities and Miskolc and Kosice are at the top of the list in the case of the spatial-environmental component, which is due to the lower ozone concentrations (i.e. better air quality) and to the fact that the per capita built-up area is below the

average. Košice has a slightly different position with its high built-up data (548.9 m²/person), but with a significant green infrastructure. Budapest,

Bratislava, Ostrava and Prague proved to be the least environmentally resistant.

Table 3.
Values of the components of the resilience index and the smart index in the examined cities of the Visegrád countries (2015)

	Bratislava	Prague	Gdansk	Košice	Białystok	Warszawa	Kraków	Budapest	Miskolc	Ostrava
Demographic resilience component	0.14 (4)	2.24 (2)	-1.09 (8)	3.81 (1)	1.85 (3)	-0.64 (6)	-2.18 (9)	-2.49 (10)	-1.02 (7)	-0.62 (5)
Social-economic resilience component	5.66 (1)	2.58 (2)	-0.43 (6)	-1.71 (7)	-2.87 (10)	0.27 (5)	0.59 (4)	1.17 (3)	-2.82 (9)	-2.44 (8)
Spatial-environmental resilience component	-1.38 (8)	-1.82 (10)	3.41 (1)	-0.53 (6)	1.37 (2)	0.37 (5)	0.49 (4)	-0.94 (7)	0.61 (3)	-1.57 (9)
Resilience index	1.47 (1)	1.00 (2)	0.63 (3)	0.52 (4)	0.12 (5)	0.00 (6)	-0.37 (7)	-0.75 (8)	-1.08 (9)	-1.55 (10)
Human component	5.18 (1)	3.39 (2)	-0.05 (5)	-0.60 (6)	-3.11 (9)	2.44 (3)	1.02 (4)	-1.04 (7)	-4.31 (10)	-2.91 (8)
Economic component	3.80 (3)	4.86 (1)	-0.46 (7)	-6.11 (10)	-4.04 (8)	3.81 (2)	-0.18 (6)	2.21 (4)	-4.48 (9)	0.60 (5)
Environment component	-4.55 (10)	1.15 (4)	1.30 (3)	-0.95 (7)	4.81 (1)	-0.40 (5)	-1.95 (8)	-0.56 (6)	3.82 (2)	-2.69 (9)
Governance component	-1.24 (7)	-2.26 (8)	-0.74 (5)	1.90 (3)	1.69 (4)	-2.71 (10)	-2.47 (9)	4.00 (1)	2.84 (2)	-1.02 (6)
Mobility component	-2.89 (9)	4.40 (1)	0.45 (5)	-3.64 (10)	-1.46 (8)	2.10 (2)	1.67 (3)	-0.11 (6)	-1.37 (7)	0.86 (4)
Quality of life component	-6.29 (10)	2.66 (2)	-0.75 (6)	-1.19 (7)	1.52 (4)	-2.23 (9)	1.53 (3)	0.68 (5)	-1.42 (8)	5.51 (1)
Smart index	-1.00 (9)	2.37 (1)	-0.04 (5)	-1.77 (10)	-0.10 (7)	0.50 (3)	-0.06 (6)	0.86 (2)	-0.82 (8)	0.06 (4)

Note: the position in the ranking can be found in brackets.

Source: own compilation and own calculation based on Nagy et al. (2018)

CONCLUSION

It can be concluded that the economic success of a city does not necessarily imply greater resilience. Our results are summarized below:

- Being an economically successful city is a necessary but not sufficient condition for becoming a smart and resilient city.
- There are significant differences in the adaptation capacity of the examined cities.
- In economic terms, the four capitals of the Visegrád countries can be considered to be the most resilient, but in the case of the social and environmental resilience components, their results are rather around or below the average.
- There is no close and direct relationship between the values of the resilience index and the smart index.
- Flexible resilience can be enhanced by the proper application of the smart city concept. At the same time, however, other urban development

strategies may also be appropriate to improve resilience.

The global pandemic has put the issue of urban resilience into a new context. However, it raises more questions than answers. Our method and complex resilience and smart indexes suffer from certain limitations and shortcomings, which we have to consider by calculating it for other cities or different time horizons. The biggest limit is the data constraints, as these kinds of indicators cannot be reproduced in any possible time perfectly; some are available only for shorter terms or in some years. Regarding the data constraints, another issue is that these indicators are not available for every city in the same form, so the indicators' international comparability is imperfect. At the same time these examinations are crucially important, as local actions and resilient cities can contribute much to achieving sustainable development and sustainable development goals. In the long run Big Data can help to manage these issues. The new smart tools and solutions in the examined cities result in a lot of data. These data should be available and accessible for scientific research, which can open new dimensions.

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