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SUSTAINABLE CITIES

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ABSTRACT
This study analyses the publicly available Sustainable Cities Index (SCI) 2023 indicators produced by Corporate Knights Inc. The index, which is typically based on statistical data, examines the sustainability of seventy major cities in the world and characterizes it with scores. These are the subject of the research just described. The aim of the authors was to determine what factors determine the sustainable existence and operation of large cities based on SCI data. To this end, we examined the cities of the 2023 edition of the index in a pilot study. The research method was statistical studies and the analysis of the models based on them, supplemented by cluster analysis. Our results draw attention to the importance of political decisions and preparation for climate impacts.

KEYWORDS
Sustainability, infrastructure, green investment, urbanisation, globalisation

INTRODUCTION

One of the most frequently used concepts today is sustainability, i.e., securing the future without using up our resources in the present. The result of globalization and urbanization is a high concentration of population. This, as well as the ever-increasing consumption and its consequences, cause an ever-increasing environmental burden. Now is the time to act. In order to consciously and purposefully prepare for this, we must use both the experiences of the past and the conclusions that can be drawn from the statistics of the present. This research is a pilot study to determine what conclusions can be drawn from the data of the Sustainable Cities Index (SCI), which examines the sustainability of cities, and which can be used when planning the future. The purpose of this study is to examine the factors influencing the sustainability of cities by examining the data of the Corporate Knights Sustainable Cities Index 2023. The authors present the database in detail in the methodology chapter. The investigation covers three problem areas. The first is to determine to what extent the sub-indexes that make up the index influence the cities' final ranking. Related to this is the investigation of whether the weight figures used in Corporate Knights' method can be considered realistic. The third goal of the authors was to determine whether the examined cities can be classified into characteristic clusters based on the individual sub-indexes.

THEORETICAL BACKGROUND

The need for sustainable development

Sustainability is not a concept created in our modern world. Traditional societies, for example,

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only owned goods that they really needed for life, and these objects were also made from natural materials found in nature. Today, so-called modern societies are dominated by consumerism and the culture of disposability. Due to the increasingly obvious consequences, more and more people are now trying to live in an environmentally conscious way (energy-saving light bulbs, selectively collected waste, recycling, hybrid and electric cars).

However, every endeavour has an insurmountable and inescapable limit. By the very beginning of the 1970s, humanity reached the Earth's carrying capacity. The ecological footprint (Ecological Footprint - EFP) indicator created by Wackernagel & Rees (1996) clearly shows the ratio of the possibilities and the actual use, as well as the cut-off date when we reach the rate of renewable use for the entire year in a given year (Earth Overshoot day) (Figure 1).

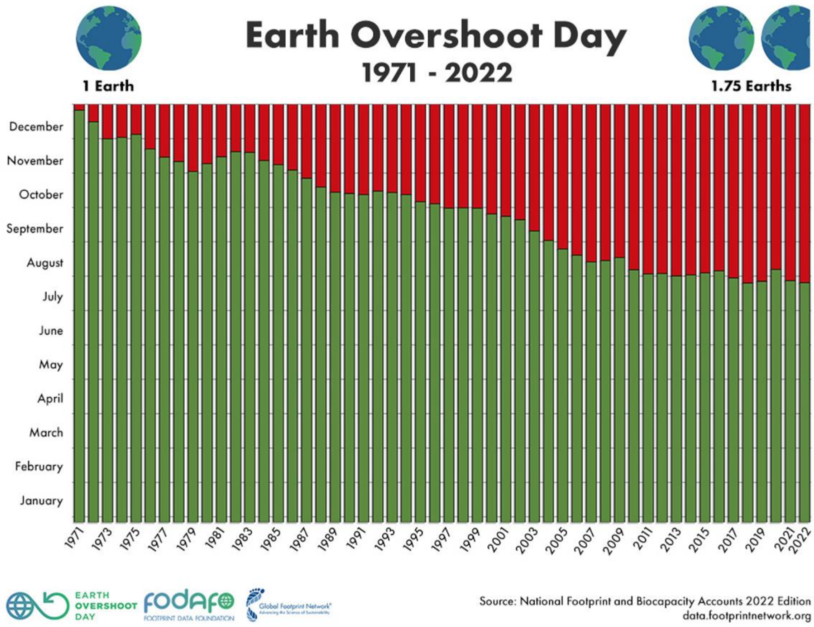

Figure 1. Ecological Footprint and Earth Overshot Day

The Earth's carrying capacity is limited, but we cannot accurately calculate how long it will last. In addition, we share our planet with other species - this significantly narrows the range of our estimates. The current direction is certainly unsustainable. All the more so, since welfare economies also use other people's resources to create their own prosperity, while millions of people live in poverty in the world.

Unfortunately, the first of the three most important factors necessary to maintain the current way of life, raw materials, energy and money, represents the bottleneck. The finite amount of materials at our disposal suggests to us that the only thing we can achieve by working more efficiently is that we have more time to find a solution. Infinite sustainability (or rather: a continuously growing economy) cannot be achieved with our current knowledge and possibilities. The history of any technical civilization seems to be finite. Some scientists, looking for a solution to the so-called Fermi paradox, arrived at a similar result with a different line of thought [2], [3]. The sketched picture is rather predestined and apocalyptic in nature. But man was never characterized by complacent surrender, because then we would not have developed to the present level. However, the learned facts inevitably confront me with the need to act.

Measuring sustainability

The importance of the problem of sustainability is clearly indicated by the fact that the UN has developed a 17-element framework of sustainability (Figure 2) for all of humanity [4].

Figure 2. UN sustainability targets (source: UN)

Similar ideas are expressed in the Hungarian strategy for sustainability [5]. It considers the preservation of available resources as one of its main tasks. The sustainability reports in Hungary have been published by the CSO every two years, under the title Indicators of sustainable development, since 2007. The methodology for selecting indicators is described in detail by Bartus (2013a),

One group of sustainability metrics uses aggregate indicators and usually bases social indices on economic indicators as well. The relationship between the economy and natural resources can be illustrated with the narrowest cross-section, the domestic material consumption (DMC), and the resource productivity derived from it (which is the GDP/DMC ratio). This indicator shows how well a given country manages its resources. The index can be used to determine the extent to which natural resources are used simultaneously with economic growth.

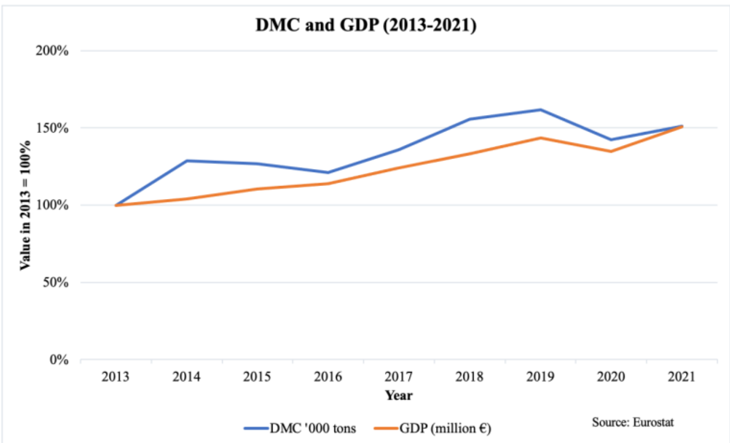

Figure 3. DMC and GDP measures of Hungary Magyarország (2013-2021) (authors' own calculation)

Table 1. Resource productivity in Hungary (2013-2021)

	2013	2014	2015	2016	2017	2018	2019	2020	2021
GDP (million €)	102,239.70	106,263.80	112,791.00	116,255.70	127,024.70	136,055.40	146,554.50	137,866.00	154,120.10
DMC '000 tons	98,396.87	126,721.83	124,617.93	119,229.39	133,749.78	153,180.05	159,074.69	139,894.03	148,674.07
Res. prod (€/tons)	1,039.05	838.56	905.09	975.06	949.72	888.21	921.29	985.50	1,036.63

(authors' own calculation based on Eurostat data)

Based on Figure 3 and Table 1, the following can be established:
Hungary's GDP increased one and a half times during the period under review. At the end of the period, the use of 1 ton of material contributed €1,037 to the gross domestic product, which is practically the same as the value of €1,039 in the beginning year. So the resource productivity did not change, i.e. the one and a half times GDP increase was based on the use of one and a half times as many materials. If we look at the intervening years, the situation is even more unfavorable, since in these years we were also unable to produce even €1,000 GDP using 1 ton of material.
The disadvantage of these indicators is that they usually express all components in money. Two methods have been developed to solve this problem. One does not aggregate the metrics, but evaluates the indexing dimensions separately. The other method looks for indicators that do not measure social factors in terms of money. The UN development indicator Human Development Index [7], for example, measures the triple scale of health-education-economic performance, and then aggregates them into a common indicator.

Opportunities for sustainable growth

In order to examine the possibilities of growth, it is necessary to see that we are talking about nested systems. Therefore, the conditions for growth must be examined from several angles.
Commonly mentioned lake criteria usually focus on the external system, i.e., the ecosystem and natural resources. Any kind of human activity can only be sustainable if its resource use does not exceed the rate of reproduction of the used resources, and its emissions do not exceed the Earth's waste processing capacity. Another group of criteria, namely well-being: equity, cultural and spiritual needs belong here, these are the social conditions of sustainability. It is difficult to find the same clear system criteria for social conditions as for the natural environment. Another condition is that we define an idealized, possibly unattainable state to be maintained, because we do not consider that society is a collection of individuals, people who are independent entities. The social environment is also only a framework for the main activities that are intended to be maintained (for example, the operation of the settlement). Therefore, it is always necessary to think through what conditions and regulators in the given subject area enable the analysed activity to achieve its own internal goals in such a way that, as a self-regulating system, it also continuously meets the external boundary conditions.
Sustainability is basically determined by two factors. One is the level of development, since the higher the level of development, the better the possibilities of sustainability can be used. The other factor is biocapacity, which simply means the carrying capacity of the ecosystem. the two factors are represented by the EFP–HDI diagram (Figure 4).

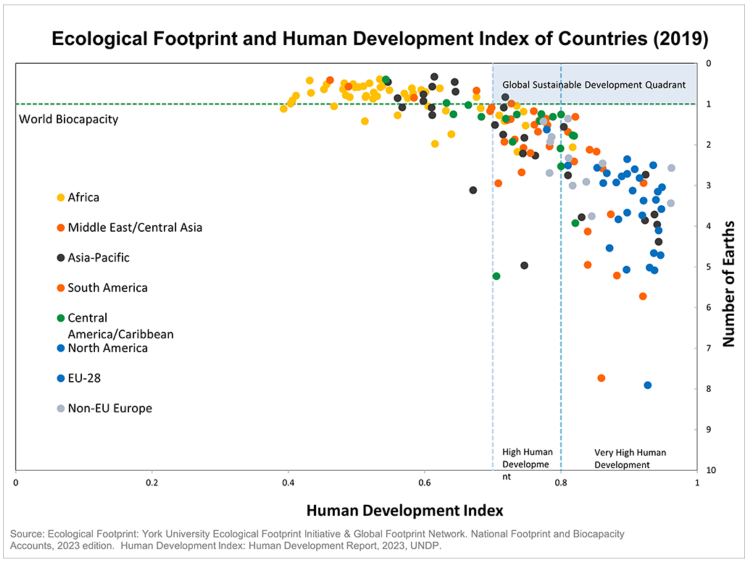

Figure 4. EFP–HDI diagram
(source: [8]

The most important information that can be read from the figure is that there are no sustainable countries according to both criteria. Because countries that do not exceed biocapacity are economically less developed, and therefore have financial obstacles to the application of modern sustainable techniques. On the other hand, those countries that have enough capital to introduce modern processes exceed the marginal conditions of biocapacity many times over.

Sustainable cities

The issue of sustainability is particularly important where masses of people live in a small area, i.e., in big cities. Cities occupy only 3 percent of the Earth's land area, but they are responsible for 60-80 percent of energy consumption and at least 70 percent of carbon dioxide emissions. In these, the significant water and energy consumption and the accumulated waste are a serious problem due to the significant environmental impact. It is no coincidence that for decades many books have dealt with the issue [9], [10] and also with the planning of such cities [11]. The sustainability of cities is also included in the already mentioned framework of the UN, the 11th goal deals with the issue. The topic is also part of the UN environmental protection program. This is no wonder, since big cities account for 80% of global GDP, while nearly 700 million people lived in poor and backward suburban areas already in 2017 - often in indecent conditions [12]. The program also names the three communities whose cooperation is necessary to create sustainable cities. These are: the government, the private sector and civil society.
Today, it is estimated that 55 percent of the world lives in urban areas, and the United Nations predicts that this number will rise to 70 percent by 2050 [13]. Nearly 2.5 billion more people may live in cities by 2050. This is likely to make it more difficult to create more sustainable communities [14]. A sustainable city, eco-city [15] or green city is a city that has been designed with social, economic, and environmental effects in mind. This triple direction is called the triple line in the literature [16]. A resilient habitat for the population without compromising the opportunities of future generations. The focus is on reducing energy, water and food consumption to a minimum, as well as a significant reduction of waste, heat and pollution emissions [17]. Ideally, a sustainable city is one that creates a sustainable way of life in terms of ecology, economy, politics and culture. At the same time, living in a city undoubtedly has

its beneficial side, which makes research on the topic of sustainable cities even more important. Being in a city can provide opportunities for social interaction and other conditions in which people can thrive. This type of urban areas would also promote the use of public transport, walking and cycling, which would benefit the health of citizens as well as the environment [18], [19]. Furthermore, cities provide the advantage of economies of scale for the use of renewable energy sources [20]. Methods to reduce energy-intensive air conditioning, such as passive daylight radiative cooling applications, planting trees and brightening surfaces, natural ventilation systems, increasing water content and covering at least 20% of the city with green spaces offset the abundance of asphalt and concrete. the so-called "heat island effect", which makes urban areas warmer than the surrounding rural areas by up to 6 degrees Celsius in the evening [21].

Sustainable cities create safe spaces for their residents. They reduce urban sprawl by allowing people to live closer to their workplace [22]. As jobs are usually located in the city, inner city or city centre, it is important to change the attitude of suburban residents towards inner city areas [23]. One way to do this is through the solutions developed by the Smart Growth Movement [24]. The most clearly defined form of modern urbanism is known as the New Urbanism Charter [25]. This is an environmentally conscious approach. Its goal is to successfully reduce environmental impacts by changing the built environment, as well as to create and preserve smart cities that support sustainable transportation. Residents of compact urban neighbourhoods drive fewer miles and have significantly lower environmental impacts by many measures than those living in sprawling suburbs. The concept of circular flow land use management [26] has also been introduced in Europe to promote sustainable land use patterns that aim for compact cities and the reduction of greenfield areas occupied by urban sprawl.

Although there is no international policy on sustainable cities and no established international standards, the United Cities and Local Governments (UCLG) is working to develop universal urban strategy guidelines. UCLG is an organization with a democratic and decentralized structure that works to promote a more sustainable society in Africa, Eurasia, Latin America, North America, the Middle East, West Asia and a metropolitan section. 60 members of the committee evaluate urban development strategies and discuss these experiences to make the best recommendations [27]. In addition, differences in regional and national contexts are considered. All member organizations strongly promote this concept in the media and on the Internet, as well as at conferences and workshops.

METHODOLOGY

Data used

Most of the world's international tourism is directed to big cities. These destinations are further away from the natural environment than rural areas. Therefore, the sustainability of tourism in cities is a particularly important issue. Among several indices, the authors use in this study the indicators of the publicly available Sustainable Cities Index (SCI) 2023 prepared by Corporate Knights Inc [28]. This index examines six main factors in its 12 sub-indexes, which are:

1) greenhouse gas emissions
2) dust pollution in the air
3) the proportion of open public spaces in the city
4) access to transport

5) water and waste management
6) sustainability policy

One of the comprehensive indicators of sustainability in the SCI is resistance to climate change and environmental impacts [29]. Based on this, a ranking of the countries can be established [30]. ND-GAIN assesses a country's vulnerability to climate change and global impacts by considering six life-sustaining sectors: food, water, health, ecosystem services, human habitat and infrastructure. ND-GAIN measures preparedness by considering a country's ability to invest in adaptation measures. The index helps in the proper classification of investments. This indicator is created by aggregating two data: one is the level of preparedness for the effects, the other is the level of vulnerability due to the effects. The methodology of the NDG aggregates with a formula developed for this purpose, but the SCI used in this study calculates with the quotient of readiness and vulnerability.
The creators of the SCI index typically compiled an index based on statistical data. Each of the twelve sub-indices is based on data that can be measured and expressed numerically. the score of the sub-indexes is then produced from these, which is a value between 0-1 for each sub-index. The SCI score (Total Score) is formed by summing up the partial index scores in the manner described in the SCI methodology, and by arranging this in order, the ranking of the cities (rank).

Methods applied

The authors used statistical methods to answer the questions. After describing and analyzing the descriptive statistics of the sample, a path model (Structural Equation Model - SEM) was created and the direct and indirect effects of the sub-indices on the SCI-score and other sub-indices were examined. After that, the clusters were created by clustering, using the K-means method, and then their characteristics were analyzed. The statistical data that form the basis of the sub-indices were used for the calculations. They were chosen because the rest of the z SCI scores and rankings are based on them. The authors made a single modification to the original data. In order to examine Q2, the weights of the original methodology [28] were not used when summing up the scores of the sub-indices. Therefore, the Total Score values were recalculated by simply summing the subscores. Calculations and tests were made using MS-Excel for Mac 17.76, Jamovi 2.3.21.0 and SmartPLS 4.0.9.5 programs.

RESULTS

Descriptive statistics

Descriptive statistics of the sample are included in Table 2. From this, it can be concluded that the database is almost complete, only the Scope1 GHG emission value of a single city is missing. The mean of most variables is greater than the median. So, the distribution of these variables is characterized by positive skewness. This means that most of the data have values higher than the average. In the case of an opposite sign, i.e., a negative skewness, the majority of the values measured for the variable fall in a range smaller than the average, we also find such variables in our data. Skewness is considered significant if its absolute value is above 2. Significant positive skewness characterizes only three variables:

- GHG emissions from consumption (Consumption-Based GHG Emissions)
- airborne dust concentration (Particulate Air Pollution)

- road density (Road Infrastructure Efficiency).

A significant negative skewness is characteristic of only one variable, namely access to piped water (Water Access). The proportion of this to the population varies between 69% and 100%, as can be read from the Min and Max values of the Water Access line in Table 2.

Conclusions related to such specifically skewed variables are discussed in the Discussion section.

Table 2. Descriptive statistics of the SCI sample

											Shapiro-Wilk	
	N	**Missing**	**Mean**	**Median**	**SD**	**IQR**	**Min**	**Max**	**Skewness**	**Kurtosis**	**W**	**p**
Overall Rank	70	0	35.50	35.50	20.35	34.50	1.00	70.00	0.00	-1.20	0.955	0.013
Scope 1 GHG Emissions	69	1	3.47	2.50	2.40	3.63	0.43	9.46	0.74	-0.50	0.907	< .001
Consumption-Based GHG Emissions	70	0	11.88	8.76	11.36	11.10	0.98	81.95	3.65	20.65	0.678	< .001
Particulate Air Pollution	70	0	18.90	13.70	14.92	14.98	5.50	78.10	2.01	4.63	0.771	< .001
Open Public Space	70	0	13.38	8.39	13.66	13.30	0.08	60.00	1.71	2.48	0.797	< .001
Road Infrastructure Efficiency	70	0	3.08	1.90	3.38	3.73	0.23	20.29	2.63	9.66	0.738	< .001
Sustainable Transport	70	0	50.31	49.00	22.58	38.20	6.20	96.00	-0.13	-1.04	0.963	0.035
Vehicle Dependence	70	0	0.88	0.84	0.50	0.68	0.07	2.38	0.60	0.28	0.969	0.084
Water Access	70	0	97.52	100.00	5.25	2.43	69.00	100.00	-3.64	15.25	0.521	< .001
Water Consumption	70	0	219.28	181.50	105.32	134.32	60.00	488.49	0.93	0.16	0.914	< .001
Solid Waste Generated	70	0	0.41	0.40	0.14	0.14	0.16	0.94	1.22	2.96	0.922	< .001
Climate Change Resilience	70	0	1.57	1.73	0.63	1.25	0.50	2.98	-0.23	-1.16	0.915	< .001
Sustainable Policies	70	0	2.96	3.00	1.55	2.00	0.00	5.00	-0.22	-1.18	0.904	< .001

The SEM model

Figure 5 shows the completed road model. The numbers in these blue circles indicate the explanation of the given element. The arrows show the strength of the direct effects of the elements on each other. The strength of the interactions between the elements is shown in Table 3.

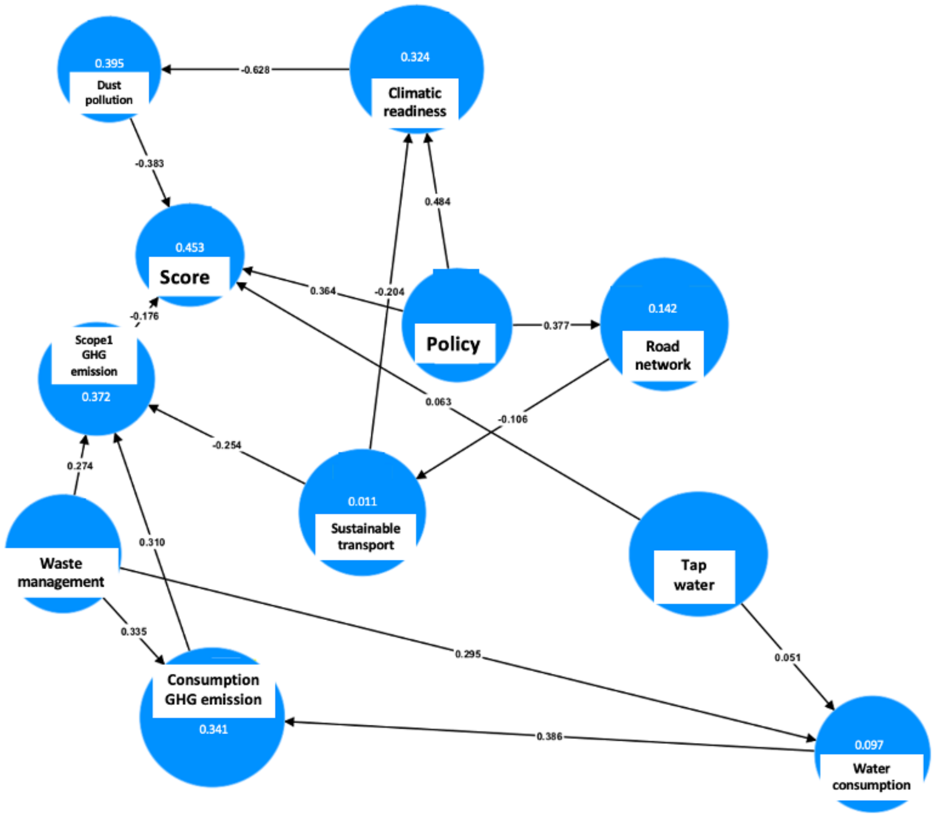

Figure 5. A road model based on the data
(source: authors' own elaboration)

Table 3. Effects between the elements of the path model

	Sustainable transport	Consumption GHG emissions	Waste management	Climatic preparedness	Policy	Score	Scope1 GHG emissions	Hostel powder	Tap water	Water consumption	Road network
Sustainable transport				(-0.204) + 0 -0.204		0 - 0.004 -0.004	(-0.254) + 0 -0.254	0 + 0.128 0.128			
Consumption GHG emissions						0 - 0.054 -0.054	0.31 + 0 0.31				
Waste management		0.335 + 0.114 0.449				0 - 0.073 -0.073	0.274 + 0.139 0.413			0.295 + 0 0.295	
Climatic preparedness						0 + 0.241 0.241		(-0.628) + 0 -0.628			
Policy	0 + (-0.040) -0.040			0.484 + 0.008 0.492		0.364 + 0.117 0.481	0 + 0.010 0.010	0 - 0.309 -0.309			0.377 + 0 0.377
Score											
Scope1 GHG emissions						0 - 0.176 -0.176					
Hostel powder						0 - 0.383 -0.383					
Tap water		0 + 0.020 0.020				0.063 - 0.001 0.062	0 + 0.006 0.006			0.051 + 0 0.051	
Water consumption		0.386 + 0 0.386				0 - 0.021 -0.021	0 + 0.120 0.120				
Road network	(-0.106) + 0 -0.106			0 + 0.022 0.022			0 + 0.027 0.027	0 - 0.014 -0.014			

Note: the top row shows direct + indirect effects, below them the total effect (sum of direct + indirect effects).

The model's fit statistics are adequate (Table 4):

Table 4. The fit statistics of the road model

Fit index	Model value	Reference value	Note
SRMR	0.098	Adequate below 0.1	Hu & Bentler (1999); Whittaker & Schumacker (2022)
NFI	0.903	Adequate below 0.9	
Khi-square / df	0.282	Adequate under 5	

Note: instead of Chi-square, its quotient divided by degrees of freedom (chi-square/df) is usually used as an indicator [31], [32].

Results related to clusters
Table 5 and Figure 6 summarize the results of cluster formation.

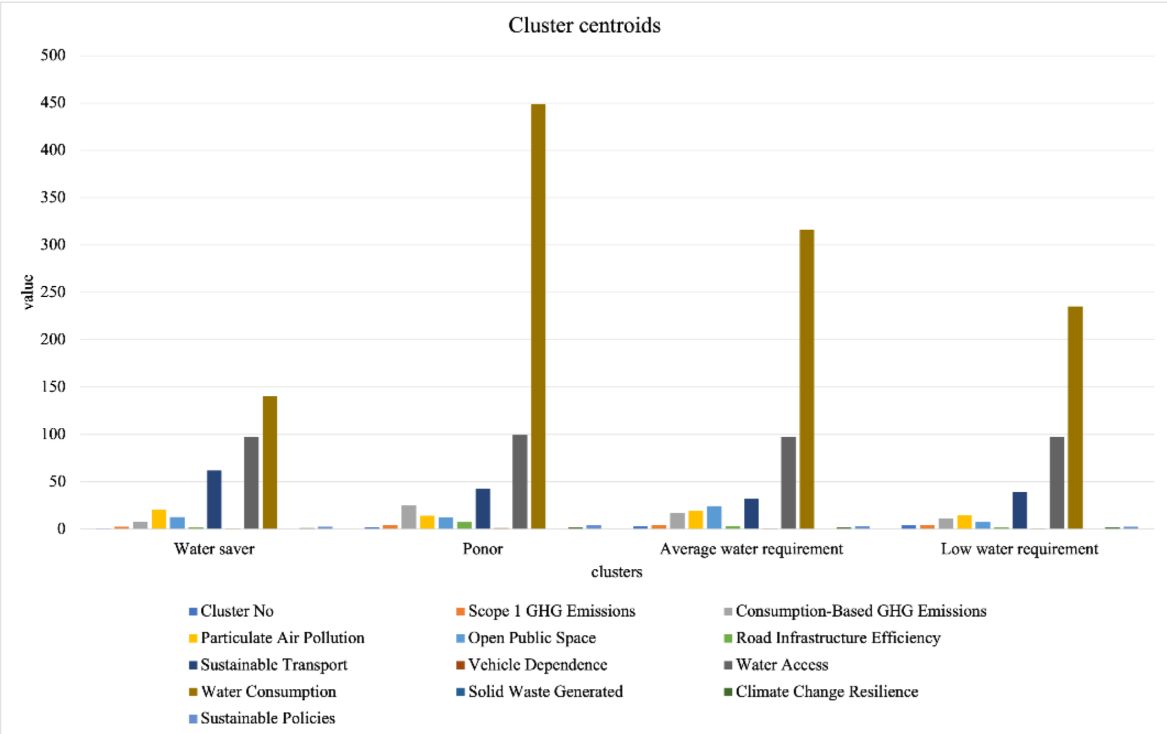

Figure 6. The resulting cluster centers and clusters
(source: authors' own elaboration)

Table 5. The K-centres of the clusters

Cluster No	Scope 1 GHG…	Consumption Based GHG…	Particulate Air Pollution	Open Public Space	Road Infra-structure	Sustainable Transport	Vehicle Dependence	Water Access	Water Consumpt ion	Solid Waste Generated	Climate Change Resilience	Sustai-nable Policies
1	2.575	8.065	21.079	12.933	2.434	61.949	0.675	97.079	140.579	0.395	1.446	2.694
2	4.232	25.027	14.4	12.716	7.453	42.953	1.321	99.571	448.611	0.539	1.83	4.143
3	4.551	11.471	14.731	7.435	2.444	39.393	1.072	97.72	235.382	0.389	1.644	2.6
4	4.455	17.555	19.394	24.518	3.443	32	1.04	97.818	316.358	0.396	1.812	3.727

DISCUSSION

Information provided by descriptive statistics

The skewness analysis led to the following conclusions. Big cities are characterized by above-average air pollution (GHG, dust) associated with high consumption and a denser than average road network. In the majority of large cities, all residents have access to piped water (in the Water Access row, the median value is 100%). However, 30 of the 70 metropolises examined do not have piped water. This primarily includes large cities in Africa, Latin America and China, where significant there is a suburban poor residential area around the city core. The worst situation in this respect is Dhaka in Bangladesh, where the access rate is only 69%. In Rio de Janeiro, this figure is 78%. It should be noted that there are also cities in Europe where access is not complete piped water supply (Istanbul, 99%).

SEM model

The primary explained variable of the model is sustainability, which can generally be characterized by the Score variable. 45.3% of this is explained by the examined variables. The result indicates that sustainability is a complex phenomenon, and our model captures only a part of it. Among the variables we examined, sustainability is directly affected (ranked according to the strength of direct effects): politics (0.364) and the availability of piped water (0.063), the better performance of which improves sustainability. Air dust concentration (-0.383) and (Scope1) GHG emissions from transport and heating (-0.176) also have a direct effect - their increase, however, worsens the chances of sustainability. The impact of the other examined factors on sustainability is only indirect. Taking into account the total impact strength, politics (0.481) is also the most important, climate preparedness (0.241) came in second place, while the chances are mainly due to the increase in particulate matter concentration (-0.383) and the increasing waste due to increasing consumption (-0.073) and the GHG emissions (-0.054) which also rise for this reason make it worse. Transport, on the other hand, only has an indirect effect on sustainability: by reducing climate readiness, it contributes to an increase in particulate matter concentration, while Scope1 improves sustainability by reducing GHG concentration.

Clusters

Despite the almost identical accessibility, the biggest difference between the clusters is in significantly different water consumption, which is why they got their names. The biggest water consumers (water sinks) also consume the most in other areas. This is shown by the fact that consumption-related GHG emissions are also the largest in this cluster. Sinks include 10% of the cities in the index. On the other hand, the water-saving cluster is also more sustainable than the others in other areas, for example, well-organized public transport is typical in such cities, and the GHG emissions related to transport and heating are only half of what can be measured in other cities. Although the road network infrastructure in these cities cannot be said to be developed, the number of households' own vehicles is only half that of average cities. This also indicates that the scope 1 type of GHG emissions is dominated by heating equipment rather than motor vehicles. The same is indicated by the fact that the cities of the water-saving cluster have the highest proportion of particles (airborne dust) entering the air. It is an encouraging fact from the point of view of sustainability that 52% of the cities included in SCI belong to this cluster. A positive characteristic of cities with an average water demand is that such cities have the largest expanses of public open spaces (parks, public squares, walkways, green surfaces).

The road network of such cities can also be said to be average, i.e., their road density is lower than that of the watersheds, but higher than that observed in the other two clusters. 16% of the investigated cities belong to this cluster. The characteristic of the moderate cluster is that it does not have any special distinguishing features.

CONCLUSIONS

This study analysed the Sustainable City Index report published in 2023 by Corporate Knights. This index primarily ranks sustainability based on environmental and economic-social indicators. The results highlight the importance of the role of politics in sustainability. For example, infrastructure development, waste management, or GHG emissions depend on political decision-makers. Large cities, due to their size and population, place a great burden on their environment. Global urbanization and the development of megalopolises only increase this phenomenon. Another remarkable result is the importance of water. Earth's water resources are finite and rapidly depleting. Water is one of the materials that has the narrowest cross-section of sustainability factors.

It is appropriate to say a few more words about the limits and limitations of the research, as well as its future possibilities. The SCI methodology is based on statistical data, which facilitates the examination of data using statistical methods. However, the sustainability of tourism and tourism is influenced by many other factors. For example, attractions and nightlife. [33]. Public safety is also an important issue. The key to the sustainability of tourism is that the arriving guest feels like a guest and not a stranger. Feel safe and don't have to fear being a victim of crime or a target of xenophobic expressions. This area is measured by [34].

We accepted our results in the light of the fact that we examined the data of only one year and the data of a total of seventy cities are included in the index. A multi-year study covering several cities can provide much more nuanced and reliable results. Although it is not easy to involve other cities in the research, the data on which the SCI is based is available from publicly available statistics. In this way, the point value for the 12 index-forming factors can also be calculated for cities not included in the index. By summarizing these using the SCI methodology, the SCI score of the given city can be obtained. We are currently continuing our research in this direction. Ensuring sustainability is an increasingly urgent task due to our Earth's finite resources and growing population. We wanted to participate in this with our research, drawing attention to the factors with which our future can be founded.

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