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Developing an evaluation framework for smart countries with a focus on sustainability as a basis for comparative analysis

The concept of smart cities based on the principles of sustainable development and the approaches to their comparative assessment have been extensively studied. However, with both analysis and, above all, implementation concerned predominantly with matters of economy, there is not much research that combines a macro-level view with a focus on social and environmental issues. The article addresses this gap, proposing to develop a sustainability index for macro-level comparison of countries and regions. Based on a comprehensive review of printed and online sources, a set of indicators was selected and applied to 14 countries from different regions of the world. The compiled data were then normalized to generate a comparative ranking. An analysis of the results reveals regional differences in the emphasis placed on sustainability in general as well as its environmental and social aspects in particular. It also shows that if the government takes concrete regulatory measures for insreasing sustainability, with time quality of life improves, and the economy benefits. By identifying potential problem areas, systematic and ongoing assessment of sustainability indicators would make it possible to address them, thus supporting the efforts to meet climate strategy targets. For this reason, efforts should be made to elaborate the index further and include more countries, so that better recommendations may be made on its basis.

Keywords: climate change, smart country, sustainable development, quality of life

JEL classification: D01, O18, R41, Q01

Introduction

In December 2018, the European Union and 196 other countries met at the 24th United Nations Climate Change Conference and agreed on the Katowice Climate Package implementing the Paris Agreement towards a sustainable global climate policy [UN, 2018]. In October 2018, in preparation for the conference, the Intergovernmental Panel on Climate Change published a special report (IPCC 2018) [IPCC, 2018]. Its key finding was that it is still possible to limit the temperature increase to 1.5°C above pre-industrial levels, but further reductions in greenhouse gas emissions and human-caused CO_2 emissions would be necessary. The climate strategy set key targets for the use of renewable energy, cuts in GHG emissions, and improved energy efficiency.

The EU has paid great attention to climate change in recent years. With the latest major update in November 2018, the European Commission presentedthe European Green Deal, its ambitious long-term strategy with for a climate-neutral Europe by 2050 [EC, 2019; 2020]. More precisely, the key objective is to achieve a GHG reduction of 50–55% by 2030 and climate neutrality in terms of GHG net emissions by 2050 (instead of the original aim of a 60% reduction).

Science has already sufficiently described the adverse effects of global warming with regard to human health and mortality (one example being the negative impact of air pollution on mental health) and its historical ramifications for the present and future of humanity as a whole [Dai, 2013; Hansen et al., 2006; US GCRP, 2018; Vitousek, 1994; Mathioudakis et al., 2020; Solanas et al., 2014; Turan, Beşirli, 2008].

At the same time, a year-by-year trend of movement from rural areas to cities can be recognized. OECD countries show a steady increase of urbanization, whose level rose from 62.5% in 1960 to 80.6% in 2018, and it is expected to reach 86% by 2050 [WB, 2018]. There is a particular threat to the more vulnerable populations in developing countries, because increasing urbanization with its negative effects is particularly evident in the emerging markets [Patz et al., 2005; Berry, 2008; Sadorsky, 2014].

Ultimately climate change and urbanization present some of the most significant challenges facing humanity in the coming decades, which shows the necessity for a closer look at these topics. A smart country should set the course for the urban regions of tomorrow to make a significant contribution to counteracting global climate change. Initial approaches to a smart country have already been examined in the literature from various perspectives.

There are a number of ways to evluate the performance of cities or urban regions. In addition to productivity and infrastructure improvements, they increasingly focus on social aspects such as quality of life, equity, inclusion, and environmental sustainability [Ruso et al., 2019]. The measures differ for particular regions, depending on their individual characteristics and needs [Antwi-Afari et al., 2021; Sourav et al., 2020]. Adamik and Sikora-Fernandez [2021] emphasize the importance of Industry 4.0 and technological innovation for performance results on three levels: (1) smartness, (2) competitiveness, and (3) sustainability.

However, to set a country on a path of sustainable development, a prerequisite is an efficient political and economic environment. A holistic approach to performance assessment must therefore be adopted, which prioritizes the "health" of the economy, acknowledges all stakeholders, systematically solves the challenges it faces, and thus strives to align social behaviors and habits with the ethos of sustainability.

The main aim of this article is to develop a sustainability evaluation framework and on its basis analyze and compare selected countries. Whereas typically such efforts focus primarily on financial considerations, this one offers a more comprehensive view, placing stronger emphasis on social and environmental aspect. This is all too rare not just in research, but above all in practice, making it a contribution of special value for macro-level decision-making.

1. Selected countries – overview

The research focuses on Europe (the EU), two regions of Asia (the Gulf and the Far East), and the United States. It includes countries that reached the stage of economic maturity (Austria, Germany, the US, South Korea), newly industrialized countries (China, India, Malaysia), and developing countries (United Arab Emirates, Qatar, Saudi-Arabia). Although the sample is not generally representative, it is heterogenous in terms of sizes, economic power, cultures, and political systems. The 14 countries analyzed in the article are presented in Table 1.

Table 1. Selected countries – population and CO_2 emissions

Country (region)	Population (total / world share in %)	CO_2 emissions (total in Mt / world share in % / per capita in tonnes)
Austria (EU)	9,006,398 / 0.12	68.50 / 0.19 / 7.61
China (Far East)	1,439,323,776 / 18.47	10,174,68 / 27.92 / 7.07
France (EU)	65,273,511 / 0.84	323.75 / 0.89 / 4.96
Germany (EU)	83,783,942 / 1.07	701.96 / 1.93 / 8.38
India (Far East)	1,380,004,385 / 17.70	2,616 / 7.18 / 1.90
Malaysia (Far East)	32,365,999 / 0.42	250.09 / 0.69 / 7.73
Poland (EU)	37,846,611 / 0.49	322.63 / 0.89 / 8.52
Qatar (Gulf)	2,881,053 / 0.04	109.34 / 0.30 / 39.95
Saudi Arabia (Gulf)	34,813,871 / 0.45	582.15 / 1.60 / 16.72
Singapore (Far East)	5,850,342 / 0.08	38.94 / 0.11 / 6.66
South Korea (Far East)	51,269,185 / 0.66	611.26 / 1.68 / 11.92
Spain (EU)	46,754,778 / 0.60	252.68 / 0.69 / 5.40
UAE (Gulf)	9,890,402 / 0.13	190.68 / 0.52 / 19.28
US (North America)	331,002,651 / 4.50	5,524.70 / 14.50 / 16.97

Source: Population: [Worldometer]; CO_2 emissions: Own elaboration based on: [GCA].

Together, these countries have a population of more than 3.5 billion, and thus represent almost 46% of the global population. They also own ca. 65% of the world's wealth (USD 234.5 trillion) and are responsible for nearly 60% of global CO_2 emissions (China and the US alone account for 42.5%).

2. Sustainability indicators

When conceptualizing a smart country, there are many criteria, challenges, and risks to be taken into consideration, all of which should first be listed and analyzed [Kitchin, 2016]. As proposed by Shen et al. [2010], sustainability of development of a smart country can be then evaluated in the following dimensions: 1) environmental, 2) economic, 3) social, and 4) governance, which are divided into further 37 categories and contain as many as 115 indicators. This comprehensive International Urban Sustainability Indicator List is based on sets of indicators used by different international and regional organizations [UN, 2007; UN-Habitat, 2004; WB, 2009; EF, 1998; EC, 2000]. This article is based on a set of indicators belonging to four dimensions: 1) general, 2) environmental, 3) social, and 4) economic.

As part of the Agenda 2030, the UN and its 193 member states agreed on 17 sustainable development goals related to environmental sustainability, peace, justice, good governance and partnership, and social inclusion [Gigliotti et al., 2018; UN, 2018a; 2019b]. This means that decisions about the future of any country should take into account not only economic parameters, but also, and primarily, social and sustainability issues – and at every stage involve all stakeholders [SDSN, 2015]. With that in mind, the human development index was included in the general dimension, as was the democracy index [EIU], since any real involvement of residents in the decision-making processes rests on the political system they live in. Its inclusion also serves to promote the interests of residents, fulfil their basic needs, and eliminate corruption. The last general indicator, gross national income per capita, shows the total income generated by all residents of a country.

The environmental dimension groups indicators of particular importance from the point of view of sustainability. The first three focus on areas crucial for the conservation of the Earth: share of renewables in energy sources, volume of CO_2 emissions, and environmental protection. A shift from fossil fuels to "green" energy is one of the main steps on the path to climate neutrality [Johnsson et al., 2019; Salvia et al., 2021]. The last two indicators concern various impacts on mortality rates [Balakrishnan et al., 2019; WHO, 2016].

The social dimension contains a single indicator describing the proportion of the elderly in the population. This ratio is an indication of economic development, but at the same time the higher it is, the greater the burden (fiscal and otherwise) on the rest of the society, and the more difficult it will be to achieve sustainability.

The first indicator in the last, economic dimension, measures the volume of a country's investments in fixed assets (infrastructure, machinery, valuables, etc.) and goods held by firms. The second indicator measures the volume of investments in research and development, which are a crucial factor of innovation and efficiency.

The complete set used in the comparative analysis consists of the following 12 sustainability indicators[1]:

O: General
- O1: Human development index
- O2: Democracy index
- O3: Gross national income per capita

ES: Environmental
- ES1: Environmental parameters
  - ES1.1: Renewable energy consumption
  - ES1.2: Carbon dioxide emissions
  - ES1.3: Natural resource depletion
- ES2: Environmental threats
  - ES2.1: Mortality rate – air pollution
  - ES2.2: Mortality rate – sanitation

SS: Social
- SS1: Old-age dependency ratio

E: Economic
- E1: Gross capital formation
- E2: Research and development expenditure

3. Evaluation methodology

The values of sustainability indicators for the 14 selected countries were carefully analyzed. In order to achieve comparable results, various rules and assumptions were applied, which led to some limitations in the evaluation, but had only slightly negative effect on the significance of the results. The most recent available data were always used, and for some indicators – an average from several years. The values were correlated in each case with either the highest (e.g. democracy index, renewable energy consumption) or the lowest value (e.g. HDI, natural resource depletion). Cluster analysis was performed under different threshold

[1] Detailed description of the indicators can be found in Appendix A.

distances in order to define an optimal cutting level for grouping the countries into three clusters: (very) well, moderately, or (very) poorly developed[2].

4. Sustainability indicators – data

The next sections present the results from the sustainability factors are shown. The evaluation of the general dimension shows that Germany has the highest score when measured on the HDI of the countries considered, followed by Singapore. India, ranked 124th in the world, is by far in last place. Regarding the democracy index, again Germany is at the top, followed by Austria and Spain. Concerning the countries compared, the governments of the UAE, China, and Saudi Arabia are considered the most authoritarian. Looking at GNI per capita, the picture is somewhat different, with Qatar in first place, followed by Singapore and the UAE. However, it should be emphasized that the first two, in particular, represent very small countries with quite a few inhabitants. Even though India and China have been growing strongly in economic terms for years, the prosperity does not reach the broad masses, and the GNI per capita is relatively low.

Table 2. Sustainability indicators – general dimension

Country	O1: Human development index (from 0 worst to 1 best)	O2: Democracy index (from 0 worst to 10 best)	O3: Gross national income per capita (USD)
Austria	0.922	8.29	46,231
China	0.761	2.26	16,127
France	0.901	8.12	40,511
Germany	0.947	9.58	46,946
India	0.645	6.90	6,829
Malaysia	0.810	7.16	27,227
Poland	0.880	7.35	27,626
Qatar	0.848	3.19	110,489
Saudi Arabia	0.854	1.93	49,338
Singapore	0.938	6.02	83,793
South Korea	0.916	8.00	36,757
Spain	0.904	8.29	35,041
UAE	0.890	2.76	66,912
US	0.926	7.96	56,140

Source: Own elaboration based on IMF, OECD, WB, and UN figures.

2 Threshold values can be found in Appendix B.

The next, environmental dimension (cf. Table 3), focuses on the environment-related factors on which this analysis places a particular emphasis. For example, the relationship between energy consumption from fossil fuels and renewable energies is examined. Unfortunately, the picture is still very negative; only Austria and India have a renewable energy consumption of more than 30%.

The type of energy generation impacts CO_2 emissions, which are considered separately concerning economic output. Singapore is particularly strong here, followed by France and Spain. Only France can show a value of less than 50% for energy generation based on fossil fuels. However, for France, it is mainly not due to a high share of renewable energies, but to the high share of nuclear energy, which does not emit any CO_2, but is now viewed critically from an environmental and social point of view due to the nuclear waste and the increased risk [Prăvălie, Bandoc, 2018]. China and South Korea are economically very strong, but the high CO_2 emissions indicate that the processes to achieve this economic performance are not very sustainable.

Policymakers in many countries still do not consider that processes detrimental to the environment resulting from a lack of regulation, e.g. for the emission of CO_2 and other pollutants, also directly affect the economy to a great extent. While these effects are not immediately perceptible, they will be as they progress.

Table 3. Sustainability indicators – environmental dimension – parameters

Country	ES1.1: Renewable energy consumption (% of total final energy consumption)	ES1.2: Carbon dioxide emissions (kg per GDP unit in 2010 USD)	ES1.3: Natural resource depletion (% of GNI)
Austria	34.4	0.17	0.1
China	12.4	0.47	0.9
France	13.5	0.12	0.0
Germany	14.2	0.21	0.0
India	36.0	0.26	1.0
Malaysia	5.2	0.28	3.1
Poland	11.9	0.31	0.4
Qatar	0.0	0.27	7.4
Saudi Arabia	0.0	0.33	7.9
Singapore	0.7	0.10	0.0
South Korea	2.7	0.33	0.0
Spain	16.3	0.16	0.0
UAE	0.1	0.31	4.0
US	8.7	0.29	0.2

Source: Own elaboration based on IMF, OECD, WB, and UN figures.

The last factor of the Environmental parameters compares the country regarding the monetary valuation of energy, mineral, and forest depletion. Compared with the other countries evaluated, the UAE, Qatar, and Saudi Arabia, in particular, have a very high and thus negative value.

The second part of the environmental sustainability factors reflects the environmental threats. It shows that the mortality rate attributable to household and ambient air pollution is still relatively high. Policies in the EU and increasingly in other countries are introducing more and more regulations to reduce air pollution [EC, 2021; Krämer, 2020]. In recent years, the economies of China and India have grown rapidly, but their high mortality rates are an indicator that this has been at the expense of human health. In addition, in India in particular, a high percentage of the population does not have access to clean water, and thus a high mortality rate is caused by unsafe water, sanitation, and hygiene services.

Table 4. Sustainability indicators – environmental dimension – threats

Country	ES2.1: Mortality rate – air pollution (per 100,000 population)	ES2.2: Mortality rate – sanitation (per 100,000 population)
Austria	15	0.1
China	113	0.6
France	10	0.3
Germany	16	0.6
India	187	18.6
Malaysia	47	0.4
Poland	38	0.1
Qatar	47	0.1
Saudi Arabia	84	0.1
Singapore	26	0.1
South Korea	20	1.8
Spain	10	0.2
UAE	55	0.1
US	13	0.2

Source: Own elaboration based on IMF, OECD, WB, and UN figures.

In the assessment dimension "SS: Social sustainability", it is evident that the population, especially in Europe, is becoming increasingly older on average. As a result, there is a lack of young and well-educated citizens. However, these play a crucial role in driving innovations and developing the economy adequately, especially in the long term, to meet climate challenges. It is noticeable that Saudi Arabia, the UAE, Singapore, and India have an exceptionally high proportion of working-age people.

Table 5. Sustainability indicators – social dimension

Country	SS1: Old-age dependency ratio (% of people aged 65 and more per 100 people aged 15–64)
Austria	38.5
China	25.0
France	40.4
Germany	44.0
India	12.5
Malaysia	38.2
Poland	14.7
Qatar	37.0
Saudi Arabia	5.7
Singapore	8.3
South Korea	34.5
Spain	39.8
UAE	6.4
US	32.5

Source: Own elaboration based on IMF, OECD, WB, and UN figures.

In the last, economic dimension, the indicators are considered that have a concrete connection to social and environmental sustainability. For example, within the gross capital formation, different factors to improve the infrastructure such as construction of roads, railways, schools, hospitals, and private residential dwellings and business offices are considered. In addition, inventories are included, which compensate for fluctuations in production or sales and thus make the economy more robust. It is evident that Middle Eastern and Asian countries such as Saudi Arabia, China, India, and Malaysia perform better than European countries. One indicator for this may be the strong dependence of Western countries on the Asian market based on just-in-time delivery of goods and raw materials.

Investment in research and development is essential for creating innovative products and processes for sustainable economic change [WEF, 2019].

Malaysia, Austria, and Germany have a quite good rate in terms of GDP. On the other hand, India and Saudi Arabia Certain countries are trying to compensate for this by investing in innovative products and commissioning foreign companies.

Table 6. Sustainability indicators – economic dimension

Country	E1: Gross capital formation (% of GDP)	E2: Research and development expenditure (% of GDP)
Austria	25.3	3.1
China	44.3	2.1
France	23.5	2.2
Germany	21.3	2.9
India	31.0	0.6
Malaysia	30.2	4.2
Poland	23.6	1.3
Qatar	20.7	1.0
Saudi Arabia	44.6	0.5
Singapore	25.9	0.8
South Korea	26.6	2.2
Spain	21.9	1.2
UAE	22.4	1.0
US	20.6	2.7

Source: Own elaboration based on IMF, OECD, WB, and UN figures.

5. Sustainability index – comparative analysis

Since the values of raw data obtained in the previous step were measured on different scales, they had to be normalized using the following formula:

$$z\ value = \frac{(raw\ scale - mean\ (raw\ scale)}{sd\ (raw\ scale)} \quad [1]$$

The score value was calculated based on the z-transformed factor scores as a simple average over all factors, taking the pre-defined directions, plus for stimuli and minus for penalties, into account. The total normalized average scores were then used to rank the countries and obtain the sustainability index. Thus, Austria, with a score of 0.532, is in first place, ahead of Singapore with a score of 0.310, followed closely by Germany with a score of 0.308.

In addition, the results are allocated into three categories based on the raw values according to the defined thresholds and color coded: green = (very) well developed, yellow = moderately developed, red = (very) poorly developed, yields the result, shown in Table 7.

Table 7. Sustainability index – comparative analysis

Country	O1	O2	O3	ES 1.1	ES 1.2	ES 1.3	ES 2.1	ES 2.2	SS1	E1	E2	NAS	Rank.
	+	+	+	+	–	–	–	–	–	+	+		
Austria	0.67	0.78	-0.01	1.98	0.89	0.61	0.67	0.32	-0.94	-0.25	1.14	0.532	1
China	-1.29	-1.55	-1.12	0.11	-2.15	0.32	-1.29	0.22	0.22	2.14	0.23	-0.379	13
France	0.41	0.71	-0.22	0.20	1.40	0.64	0.77	0.28	-1.28	-0.48	0.32	0.252	4
Germany	0.97	1.27	0.02	0.26	0.49	0.64	0.65	0.22	-1.34	-0.75	0.96	0.308	3
India	-2.70	0.24	-1.47	2.12	-0.02	0.28	-2.77	-3.46	0.76	0.47	-1.12	-0.698	14
Malaysia	-0.70	0.34	-0.71	-0.51	-0.22	-0.47	0.03	0.26	0.73	0.37	2.13	0.114	7
Poland	0.15	0.42	-0.70	0.06	-0.53	0.50	0.21	0.32	-0.72	-0.46	-0.49	-0.112	9
Qatar	-0.23	-1.19	2.37	-0.95	-0.12	-2.02	0.03	0.32	1.44	-0.83	-0.76	-0.177	10
Saudi Arabia	-0.16	-1.67	0.11	-0.95	-0.73	-2.20	-0.71	0.32	1.17	2.18	-1.22	-0.352	12
Singapore	0.86	-0.10	1.38	-0.89	1.60	0.64	0.45	0.32	0.25	-0.17	-0.94	0.310	2
South Korea	0.59	0.67	-0.36	-0.72	-0.73	0.64	0.57	-0.03	-0.18	-0.09	0.32	0.063	8
Spain	0.45	0.78	-0.42	0.44	0.99	0.64	0.77	0.30	-1.02	-0.68	-0.58	0.152	6
UAE	0.28	-1.35	0.76	-0.94	-0.53	-0.80	-0.13	0.32	1.46	-0.61	-0.76	-0.210	11
US	0.71	0.65	0.36	-0.21	-0.33	0.57	0.71	0.30	-0.56	-0.84	0.78	0.196	5

Source: Own elaboration.

The distribution of results depends on the evaluation criteria. Since all countries are quite highly developed, all HDI and GNI per capita values are relatively high. However, there are clear outliers when it comes to the democracy index – Qatar, the UAE, Saudi Arabia, and China are considered authoritarian. Environmental parameters are quite negative, especially in industrialized countries. The consequences this has for human health and life are most dire in India and China. This underscores the need for urbanized areas to position themselves better based on environmentally friendly initiatives implemented jointly by politicians, private companies, educational institutions, scientific institutes, and the residents.

On another note, most of the countries do well in terms of economic sustainability, which means a high number of well-educated specialists, large research investments, and relative prosperity. However, low gross capital formation relative to GDP suggests that Germany, the US, Spain, and Qatar may be suffering from infrastructure deficits. But, since GDP varies and is a relative value, additional parameters are necessary for a more detailed analysis.

6. Reliability analysis

The quality of data used to calculate the index was tested using confirmatory factor analysis (dimensional test) supplemented by the reliability coefficient Cronbach's alpha. Multidimensional scaling had to be applied since not all factors show high loadings (> 0.6) in the score dimension – e.g. O3 and ES1.1 show particularly low factor loadings (Table 8).

Table 8. Goodness-of-fit test

Factor	Factor loading	Encoding alpha	Alpha item excluded
O1	–0.796	invers	0.775
O2	–0.801	invers	0.774
O3	–0.142	invers	0.839
ES1.1	–0.091	invers	0.842
ES1.2	0.647	–	0.788
ES1.3	0.623	–	0.796
ES2.1	0.874	–	0.764
ES2.2	0.460	–	0.814
SS1	–0.813	invers	0.773
E2	0.716	–	0.781
E4	–0.487	invers	0.808
alpha total	0.813	–	–

Source: Own elaboration.

However, since the score is by definition intended to represent entirely different dimensions, and since it was previously included in the macroeconomics for domain-specific reasons, these do not necessarily have to be in a robust correlative relationship and are therefore not removed from the score. The reliability coefficient nevertheless reaches a good, if somewhat lower value of 0.813 (removing factor O3 would boost it to 0.839, and ES1.1 – to 0.842)

To check the robustness of the normalized average scores, a simulation was performed by removing one country from the sample and calculating z-scores and normalized average scores for the remaining countries based on the reduced sample, and repeating this step 14 times, ech time removing a different country. As a result only minor deviations from the simulated mean can be observed, and a ranking based on the simulated values is identical to the original one, which confirms the robustness of the normalized average scores. The distribution of the simulated values is shown in Table 9.

Table 9. Robustness score values

Country	Normalized average scores		Simulated normalized average scores					
	Value	Rank.	Mean	Rank.	Med.	SD	Min.	Max.
Austria	0.532	1	0.534	1	0.530	0.028	0.504	0.607
China	–0.379	13	–0.385	13	–0.365	0.074	–0.623	–0.330
France	0.252	4	0.253	4	0.253	0.021	0.224	0.295
Germany	0.308	3	0.305	3	0.307	0.024	0.277	0.352
India	–0.698	14	–0.673	14	–0.669	0.031	–0.733	–0.600
Malaysia	0.114	7	0.106	7	0.112	0.042	–0.009	0.154
Poland	–0.112	9	–0.110	9	–0.102	0.025	–0.159	–0.068
Qatar	–0.177	10	–0.180	10	–0.172	0.040	–0.285	–0.137
Saudi Arabia	–0.352	12	–0.350	12	–0.344	0.032	–0.436	–0.323
Singapore	0.310	2	0.312	2	0.316	0.020	0.277	0.341
South Korea	0.063	8	0.045	8	0.073	0.082	–0.218	0.094
Spain	0.152	6	0.154	6	0.157	0.023	0.123	0.199
UAE	–0.210	11	–0.209	11	–0.203	0.034	–0.283	–0.181
US	0.196	5	0.198	5	0.200	0.025	0.148	0.233

Source: Own elaboration.

Conclusions

Urbanization, bringing with it problems such as traffic congestion, air pollution, and the resulting physical and psychological stressors, causes an increasing need for sustainable urban development. However, previous research considered the different aspects of building a sustainable country in relative isolation. This article offers a more comprehensive approach. Based on an extensive literature review, a set of sustainability indicators was compiled, which could be used as an argument for urban development programs to prioritize ecological and social factors over economic ones.

Moreover, based on those indicators, a sustainability index was developed, allowing to evaluate and rank countries in terms of sustainability in four different dimensions. It was applied to 14 countries and showed that countries such as China, India, Saudi Arabia, and the UAE, economically strong but also marked by pronounced inequalities, are straggling behind the EU in terms of environmental and social sustainability. Hence, the importance of a socially-oriented economic policy. The EU, in turn, is dealing with problems related to CO_2-emitting raw materials, infrastructure, and aging society.

Overall, three EU countries – Austria, France, and Germany – are at the top of the ranking in all four dimensions, accompanied by the a city-state of Singapore in the second place. South Korea tends to rank in the middle due to low social and environmental sustainability.

Neither was the analyzed sample of countries representative, nor the chosen set of indicators necessarily best suited to evaluate those countries, and it is possible that using different indicators would yield a different ranking. The sample was relatively small, overrepresented Europe and Asia, and comprised predominantly economically strong countries. Including developing countries with more extreme factor values would likely affect the mean and the standard deviation. However, as the robustness analysis revealed no relevant biases, it can be assumed that even if only European and Asian countries were selected for analysis, they would maintain their relative positions in the ranking.

This article should be treated as an element of a broader discussion and an alternative to the propositions of other researchers [Kitchin, 2016; Shen et al., 2010]. The evaluation framework it presents can be used by others for the purpose of examining other countries and include different indicators, e.g. to put more emphasis on social and environmental sustainability. In this regard, considering their mutual dependency, city-level solutions should be adapted to a country-wide macroeconomic level. This way policies promoting sustainability can positively affect the values of established environmental, social, and economic indicators. When implementing a holistic solution, it is important to measure its impact, to make sure that in practice it really is a sustainable, iterative and continuous process of improvement.

A significant contribution to managing climate change can only be made if long-term thinking is applied and the environmental and social factors (quality of life) are given priority. Environmentally harmful processes are still prevalent, especially in industry and in urban areas, due to the dominance of individual motorized transport. Moreover, as a result of increasing urbanization, cities shoulder more and more responsibility for climate change. Therefore, concrete measures based on international agreements must be broken down to country level and ultimately to the level of cities and municipal councils. This also means that policymakers must focus on long-term sustainability rather than on short-term profit maximization even if it means making disruptive decisions [EC, 2020].

This paper shows that a systematized evaluation framework for urban development sustainability is an effective way to address climate change substantially. The next step should therefore be to elaborate it further and use it in practice as a tool for an ongoing progress assessment, so that it can help ensure prosperity for present and future generations and sustainability in all dimensions of social life.

Countries around the world should adopt a more holistic view of sustainability, assessing economic health based on natural and human capital rather than financial measures such as GDP and GNI, which do not take into account long-term negative impacts on the environment, people, and other living organisms [Lange et al., 2018].

A stronger focus on sustainability indicators can facilitate the implementation of development strategies that can take us one step closer to global climate neutrality. Many countries are already making progress on the road to sustainability, demonstrating that it stores great potential, and with practices of shared learning and experience exchange – maybe even a promise of greater efficiency. Ultimately, the processes of today will have to be put to the test and reorganized with a view to sustainability, if we are to achieve the climate neutrality turnaround in the coming decades.

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Appendix A. Description of the sustainability indicators

Indicator	Description
O1: Human development index	A composite index measuring average achievement in three basic dimensions of human development: long and healthy life, knowledge, and decent standard of living.
O2: Democracy index	Countries scored on a 0–10 scale, with higher scores indicating higher level of democracy (x > 8 = full democracy; 8 ≤ x 6 = flawed democracy; 6 ≤ x > 4 = hybrid regime; x ≤ 4 = authoritarian).
O3: Gross national income per capita	Aggregate income of an economy generated by production and ownership of factors of production, less the incomes paid for the use of factors of production owned by the rest of the world, converted to international dollars using PPP rates, divided by midyear population.
ES1.1: Renewable energy consumption	Share of renewable energy (incl. hydroelectric, geothermal, solar, tidal, and generated by wind, biomass, and biofuels) in total final energy consumption.
ES1.2: Carbon dioxide emissions	Anthropogenic CO_2 emissions due to burning fossil fuels, gas flaring, and cement production, incl. forest biomass emissions caused by deforestation.
ES1.3: Natural resource depletion	Monetary valuation of energy and mineral and forest depletion.
ES2.1: Mortality rate – air pollution	Deaths resulting from exposure to ambient (outdoor) air pollution (generated by transport and industrial and household activity) and household (indoor) air pollution (from using solid fuel for cooking).
ES2.2: Mortality rate – sanitation	Deaths resulting from unsafe water, sanitation and hygiene services, focusing on inadequate wash services.
SS1: Old-age dependency ratio	Ratio of people aged 65 and more (i.e., generally economically inactive) to 100 people aged 15–64.
E1: Gross capital formation	Total volume of investments in fixed assets of the economy (land improvements, machinery, equipment, valuables, construction of infrastructure, etc.) plus net changes in inventories (work in progress and finished goods held by firms).
E2: Research and development expenditure	Public and private current and capital expenditures on creative work (basic research, applied research, experimental development, etc.) undertaken systematically to increase knowledge (incl. knowledge of humanity, culture, and society) and the scope of its application.

Source: Own elaboration based on: [UN, 2019a; 2019c, pp. 342, 346, 347; EIU; Lange et al., 2018].

Appendix B. Thresholds for sustainability indicators

Indicator	Data for	Formula	(Very) well developed	Moderately developed	(Very) poorly developed
O1: Human development index	2019	0–1 scale	x ≥ 0.8	0.8 > x ≥ 0.7	x < 0.7
O2: Democracy index	2020	0–10 scale	x ≥ 8	8 > x ≥ 6	x < 6
O3: Gross national income per capita	2019	USD	x ≥ 30,000	30,000 > x ≥ 10,000	x < 10,000
ES1.1: Renewable energy consumption	2015	% of total final energy consumption	x ≥ 40	40 > x ≥ 15	x > 15
ES1.2: Carbon dioxide emissions	2016	kg per GDP unit in 2010 USD	x ≤ 0.15	0.15 > x ≤ 0.25	x > 0.25
ES1.3: Natural resourcedepletion	2018 (av. 2012–2017)	% of GNI	x ≤ 0.5	0.5 > x ≤ 5	x > 5
ES2.1: Mortality rate – air pollution	2016	cases per 100,000 population	x ≤ 20	20 > x ≤ 60	x > 60
ES2.2: Mortality rate – sanitation	2016	cases per 100,000 population	x ≤ 0.5	0.5 > x ≤ 4	x > 4
SS1: Old-age dependency ratio	2018	% of people aged 65 and more per 100 people aged 15–64	x ≤ 10	10 ≥ x ≤ 25	x > 25
E1: Gross capital formation	2015–2018	% of GDP	x ≥ 30	30 > x > 22	x ≤ 22
E2: Research and development expenditure	2018	% of GDP	x ≥ 2.5	2.5 > x ≥ 1.5	x < 1.5

Source: Own elaboration.