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Smart city performance of the EU15 capitals, a comparative study

The urban population is growing steadily today, and smart cities are playing an increasingly important role across all continents. More international organizations and institutions are supporting the development of smart cities, and an increasing number of recommendations are being made for measuring their effectiveness. This study examines the capitals of the EU15 region in terms of their smart performance and ranks them accordingly. The assessment is conducted using a comprehensive smart city index, in line with the recommendations and pillars outlined in the international literature. The index evaluates the cities' performance across six components and identifies differences among them. The results suggest that there are disparities in urban indicators even within the region; like the European average, northern-southern and western-eastern differences can be observed. The Northern and Western cities perform consistently well across multiple components, while Southern cities lag due to economic and governance challenges.
Keywords: smart city, EU15 capitals, measurement, performance.
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Introduction

Urbanization is a critical challenge of nowadays. Urban population is increasing continuously in the world (in 2024, 58% of total population was living in cities by the Worldbank data) and expected to grow further. According to a 2025 UN report, more than 12,000 cities worldwide have populations of at least 50,000 (including 33 megacities with more than 10 million inhabitants) and the total number of urban citizens will be growing to the two third of the global population until 2050 (UN, 2025). In 2025, Tokyo was the most populated city with more than 37 million inhabitants, however until 2035 it is expected to change, as Delhi can overlap it with more than 43 million. This rapid urbanization has set several challenges for the cities (increased pollution, overcrowding, heat islands or traffic jams) which require novel solutions from the cities. Smart cities can be among the possible answers which use high-developed technological solutions with active citizen-participation models to tackle these problems. Since their emergence, more people have been trying to rank these smart cities researching which ones are the most successful and resilient for the external shocks (like the short and long term effects of COVID19 pandemics analysed by Szendi & Sárosi-Blága, 2022). Among research institutes, the IMD publishes an annual report on city rankings, and the Cities in Motion Index is another from such comparisons. In Europe, regarding the assessments, cities in the northern and western part of the continent perform exceptionally well; in my study, I focused on the capital cities of the classical EU-15 (who have joined the EU until 1995, except UK). My goal was to establish a smart city ranking for these cities and to determine whether there are differences among them within this geographical region, and to what extent the traditional EU15 is homogeneous in terms of smart cities. The novelty of this analysis lies in the fact that, by continuing to apply the methodology used in the previous studies (Szendi, 2019; Szendi et al. 2020), we can conduct a cross-sectional comparison of the EU15 capital cities, thereby gaining insight into the development of smart city initiatives. Furthermore, the analysis of these capitals may yield novel findings by revealing the internal development dynamics within a region that can be considered economically homogeneous in terms of the capitals' smart performance, and highlight which capitals were the most successful during the years that included the COVID-19 pandemic.

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Theoretical background

Smart city is a concept of the 21st century emphasizing the need for ICT adoption and the life quality improvement of the cities. Several researchers and institutions have analysed them and tried to find a complex approach, however, regarding smart cities or their performance measurement there is no uniformly accepted definition or concept. The smart city concept has gone through several changes over the years (Anari & Jakobi, 2025). The first definitions were created in the 1990s and initially focused on incorporating digital technologies into urban infrastructure to enhance efficiency and functionality (Wendt-Lucas et al., 2025). After that many hard and soft elements were built into the model (like citizen participation, sustainability, environment, resilience) and the definition became more multidimensional. Based on Macke et al. (2018) a smart city is an area which integrates ICT and human capital to improve the quality of life of inhabitants and foster economic growth. A quite complex definition was carried out by Vázquez et al. (2018) who stated that a smart city "highlights the potential of cities to improve citizen welfare, emphasizing the need for local governments and public–private partnerships to redesign services in a collaborative, sustainable, and innovative manner in order to optimize opportunities for socioeconomic development and enhance the quality of life". So, this latter encompasses many different aspects of smart city development.

In my definition, a smart city is an area that applies innovative strategies and solutions to improve the quality of life of their inhabitants, while making effective use of their creativity and knowledge base (Szendi, 2019). Besides quality of life (which is not only a single component of many models, but also the long-term objective of SC development), I have stressed the active participation of the citizens.

From the first comparing analysis of smart cities, the measurement has developed, and more components and indicators were added to it. One of the most comprehensive analyses was made by Giffinger et al. (2007) for the European medium-sized cities with six smart components (economy, people, governance, mobility, environment, life quality) creating a strong basis of SC evaluation. In their rank based on 74 indicators, Luxemburg was the smartest one before Aarhus and Turku, so the Scandinavian cities and Western Europe were quite well performing areas. In their overall performance the so-called hard dimensions of Economy and People were the highest evaluated ones. The next figure summarizes the main components and dimensions of different smart city models.

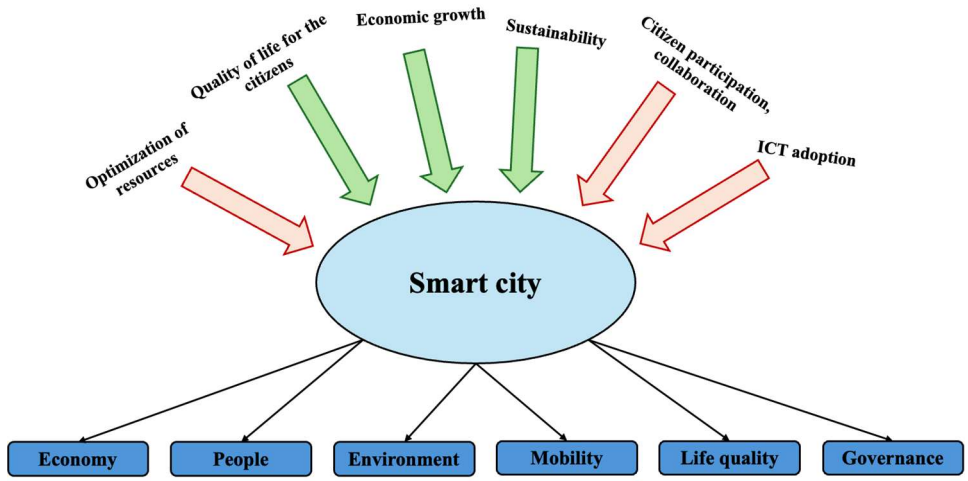

Figure 1. Dimensions and components of smart cities
Source: own compilation
Note: orange arrows are the way of smart city methods, while the green arrows are indicating the main objectives of smart cities

From the above we can summarize the most definitions common points regarding methods and objectives. Most definitions are emphasizing the improvement in the quality of life besides economic growth and sustainability. It can be achieved by the optimisation of resources through ICT adoption and the effective collaboration of public and private authorities.
Nowadays, the analysis of smart cities in the EU relies on multidimensional indices, citizen perception data, and multicriteria evaluation frameworks. The performance measurement and ranking of smart cities mainly relies on the six-component model of Giffinger et al. (2007) which integrates besides technological indicators also the citizen participation, some governmental issues and soft elements of being smart. In the concept of Marjanovic et al. (2026) it includes infrastructure and technology with human and social capital.
A multi criteria approach is represented in the study of Shmelev and Shmeleva (2024) who have checked 1300 cities and regions in Europe based on a set of 17 smart and sustainable performance indicators using the ISO quality standard for the indicators. The results show that Stockholm, Paris and London are among the best cities, while the European cities differ most in environmental and governance dimensions. Another article (made by Huovila et al., 2019) has only classified the factors determining smart city development and built an applicable framework for smart city assessment. All the indicators can be grouped based on the authors in input, output, process, outcome or impact types along the different dimensions of smartness. Both hard and soft types of indicators are classified which is unique trend in such analyses. One of the most diverse clusters is governance and citizen engagement (together with education and ICT components) which has all the types of indices. This can be a good starting point for future analyses.
Besides multidimensional approaches, more models and methods are carried out based on citizen participation or questionnaire surveys, which try to measure the performance of smart cities by only soft dimensions. Marjanovic et al. (2026) have started from the six-dimension approach mentioned above, however, have used only the data coming from the Urban Audit Perception Survey. A sum of 29 indicators was assessed and ranked for 40 European cities in 2023. The results have revealed that the Northern and Western European cities, such as Zürich, Copenhagen, and Vienna, lead the ranking with the highest index values, while the Southern European cities, including Madrid, Lisbon, and Athens, have shown moderate performance. The development of the Eastern and Balkan cities like Cluj-Napoca, Prague, and Ljubljana is rapid, however the one-year analysis does not allow long term evaluation of the data. Among Eastern European cities, Cluj-Napoca performs outstanding (Marjanovic et al., 2026). The same basis was applied by Stankovic et al. (2026) for urban efficiency measured by six components (mobility, liveability, environment, economy, governance and people). The results have raised attention on the fact that only 4 out of the 80 analysed cities have achieved urban efficiency. However, there are significant differences across countries, and the cities in Southern Europe tend to exhibit lower levels of urban efficiency compared to their counterparts in other regions.
Georgiadis et al. (2021) have also checked the smart city performance including the citizens' perceptions based on six pillars for the Greek cities with a questionnaire survey of 545 inhabitants. After the introducing question about smart city definition, the respondents were asked about some components how they correlate with smart cities (modern management, ICT, sustainable development, energy efficiency, citizen involvement, urban mobility). Most of the participants emphasized the efficient use of energy and sustainable development as the most important factors for smart city concept, while also a strong issue is technological development.
The IMD is evaluating the smart cities since 2019 along technological and structural factors, where in 2026 Zurich was the smartest among 148 cities. Based on the IMD, the next classification can be created among the best performing (top5) European capitals assessed by the total number of cities.

Table 1. Position of the top performing EU15 capitals based on the IMD smart city index (2019, 2023, 2026)

Rank	IMD 2019	Rank	IMD 2023	Rank	IMD 2026
5	Copenhagen	4	Copenhagen	5	Copenhagen
8	Helsinki	8	Helsinki	11	Helsinki
11	Amsterdam	10	Stockholm	14	Stockholm
17	Vienna	15	Amsterdam	17	Amsterdam
21	Madrid	28	Vienna	28	Vienna

Source: own compilation based on IMD data

Based on the IMD ranking, the best performing EU15 capitals are in the Northern part of the EU, Copenhagen and Helsinki, and after 2023 also Stockholm are among the top 10 or 15 cities, while Vienna and Amsterdam have also stable positions.

Starting from the indicators of IMD, Ivaldi et al. (2026) have analysed the smart city notion based on the following dimensions using the IMD index values: digital readiness, infrastructure and mobility, environmental quality, community and economic resiliency, proximity and liveability, and circular economy and resource management. They computed a type of maturity level of cities and made four clusters among them. In their assessment the given clusters had specific character with a good performance of one or two dimensions, but not generally overperforming cities in all dimensions. This also raised attention to the need of complex performance approach of cities. In this model, the best performing cities were from Europe Helsinki, Copenhagen and Oslo (Scandinavian capitals), while the average performance cluster included most of the Western European smart cities, while the worst cluster e.g. Athens and Rome. Also this analysis has reflected the classical economic development clusters in smart city development inside Europe.

Loucanova et al. (2026) have started from the quintuple helix approach (elaborated by Carayannis and Rakhmatullin, where to the classical triple helix it was further added the civil society and the natural environment as fourth and fifth element), including natural capital, social capital (evaluated by the civil society), economy, governance and education for smart city measurement. From the results (having both quantitative and qualitative data), they have created three clusters of cities among the EU capitals with different character. The first was explained by high index scores, besides the Scandinavian capitals also the Baltic capitals and Vienna are members of the cluster. The medium performing cluster contains Western European capitals, while the lowest index scores were associated with the Southern and Eastern capitals, so the geographic division of Europe is quite clear by this model.

Smart-city research in Europe shows that cities perform very differently depending on the indicators used: multidimensional assessments highlight strong results for Stockholm, Paris, and London, while citizen-perception surveys rank Zürich, Copenhagen, and Vienna highest. Across studies, environmental quality, governance, and citizen engagement emerge as the most uneven dimensions, and clustering approaches consistently reveal a clear geographic divide, with Scandinavian and Western European capitals outperforming Southern and Eastern ones.

Methodology

In my study, I rank Western European capitals in terms of smart cities for 2022 and compare the results with our previous findings (Szendi et al., 2020). Several studies have been conducted on European capitals that have assessed smart city performance based on multiple pillars; as a synthesis of these and primarily building on the model by Giffinger et al. (2007), I analysed the indicators of Western European capitals based on six components. In this study, “Western Europe” refers to the 15 EU member states that joined the European Community by the end of 1995 (except for London, which left the European Union following Brexit and is therefore not included in the analysis). Thus, a total of 14 capital cities were included in the analysis. The figure below illustrates the countries analysed and the methodology of the study. The main data sources were

the Eurostat database, the Urban Audit and Urban Audit Perception Survey databases, and the Metro region database. A sum of 26 indicators was applied among the 6 components of the analysis.

Economy	Mobility
GDP per capita (euro)	Public transport in the city, for example bus, tram or metro: very satisfied
GVA per capita (euro)	Share of journeys to work by public transport (rail, metro, bus, tram) -%
Patent nr per 10000 capita	Number of registered cars per 1000 population
Unemployment rate	**Environment**
People	Ozone O3 concentration days average compared to EU target (120)
Employment rate (%)	Particulate matter PM10 concentration average compared to EU target (50)
Share of students in higher education in the total population (per 1000 persons)	Municipal waste generated (domestic and commercial), total - 1000 t
Young-age dependency ratio (population aged 0-19 to population 20-64 years)	Green spaces such as public parcs or gardens: very satisfied
In this city it is easy to find a good job: strongly agree	**Living**
Governance	Cultural facilities such as concert halls, theatres, museums and libraries in the city: very satisfied
When you contact administrative services of this city, they help you efficiently: strongly agree	Public spaces in this city such as markets, squares, pedestrian areas: very satisfied
Generally speaking, most people in this city can be trusted: strongly agree	The financial situation of your household: very satisfied
The public administration of the city can be trusted: strongly agree	Most important in my city: health services
Individuals using the internet for interacting with public authorities	In this city, it is easy to find good housing at a reasonable price: strongly agree
	Total nights spent in tourist accommodation establishments per resident population
	Overcrowding rate by degree of urbanisation - total population

Figure 2. Applied indicators and geographical scope of the analysis
Source: own compilation

The methodology organizes indicators into six thematic categories: Economy, People, Governance, Mobility, Environment, and Living conditions, like the model of Giffinger et al. (2007). Each category includes specific measurable variables. Many variables are perception-based on the Eurostat's Urban Audit Perception Survey (e.g., "very satisfied," "strongly agree"), so the applied methodology relies not only on objective statistics but also on survey data reflecting residents' experiences. There are both hard indicators (e.g., patents, unemployment rate) and subjective perceptions in the measurement of urban smartness.
To compare data measured on different scales and in different units, it was necessary to transform the values. One method for this is the so-called z-transformation, which converts each indicator value into a standardized value with a mean of zero and a standard deviation of one. The value of an indicator can be computed with the following equation.

$$X = \frac{X_i - \bar{X}}{standard\ deviation}$$

where X means the standardized value; X_i is the indicator's value in city i; $\bar{X}$ is the average of the indicator among the examined capitals; the $standard\ deviation$ is the standard deviation of the indicator among the examined EU15 capitals.

In certain cases, it was necessary to adjust the data during the interpretation of components and the creation of the composite index, where the scaling of the given indicators differed. In these cases, I calculated using the inverse value of the indicator (the included indicators: unemployment rate, ozone concentration, particulate matter concentration, municipal waste, and overcrowding rate). The value of a given component (sub-category or pillar) is the sum of the standardized values of the selected indicators, while the smart index can be calculated as the arithmetic mean of the pillars' values (as it is also by Giffinger et al. 2007).
Of course, the composite index approach also has limitations, as there are no generally accepted recommendations regarding either the components used or the scope of data to be considered, and

the literature does not treat them uniformly. There may also be differences regarding whether weighting is applied during the construction of the indices, and if so, what shifts in emphasis occur among the individual components; furthermore, the ability to make repeatable spatial comparisons of the data over time and across the geographic units under study is not guaranteed for long time series. Consequently, the analysis is naturally limited in both space and time; however, since all available data originate from the Eurostat database, it can be considered methodologically consistent, meaning that the methodological regulations of individual countries do not influence the distribution of the index.

Results

After collecting the data and summarizing the index scores, I have created the rank of the EU15 capitals based on their smartness level. The table presents a comparison of European capitals based on the aggregated smart city index for two years (2015 and 2022), allowing for both ranking changes and performance trends to be observed. From the results we can see that among the top three we can see quite stable position; however, the leadership has changed. In 2015, Luxembourg ranked 1st (15.89), followed by Copenhagen (14.90) and Stockholm (14.75). By 2022, Copenhagen moved into 1st place (16.54), while Luxembourg dropped slightly to 2nd (15.40), and Stockholm remained stable in the 3rd place (13.31).

Table 2. Ranking of the Western European capitals based on the smart city index (2015, 2022)

rank	capital	Index sum 2015	rank	capital	Index sum 2022
1	Luxembourg	15.89	**1**	Kobenhavn	16.54
2	Kobenhavn	14.90	**2**	Luxembourg	15.40
3	Stockholm	14.75	**3**	Stockholm	13.31
4	Helsinki	8.86	**4**	Dublin	12.28
5	Dublin	6.38	**5**	Amsterdam	8.81
6	Amsterdam	5.15	**6**	Helsinki	8.01
7	Wien	3.84	**7**	Wien	1.76
8	Paris	0.82	**8**	Paris	-3.89
9	Bruxelles	-3.36	**9**	Bruxelles	-4.42
10	Madrid	-7.35	**10**	Berlin	-7.18
11	Berlin	-8.87	**11**	Madrid	-8.06
12	Lisboa	-11.00	**12**	Lisboa	-12.60
13	Athina	-18.27	**13**	Athina	-18.31
14	Roma	-21.74	**14**	Roma	-21.66

Source: own compilation

There are some capitals who have showed significant improvement, like Dublin or Amsterdam, while Helsinki has made a slight drop in rank, but maintained a high score. So, the north-western European capitals have shown the best performance among the smart indices. Vienna's position remained stable in 7th place, but its score dropped sharply, which is like the value change of Paris. The worst performing capitals are in Southern Europe, with Madrid, Lisbon, Athens, and Rome. The table shows a quite stable but increasingly polarized urban hierarchy.
The results and changes are represented on the below figure, which reflects the values of the smart index. As we have seen above by the ranking, there are three strong performing smart capitals, Copenhagen, Luxembourg, and Stockholm stand out as the highest positive values in both years.

Compared the two years in Copenhagen there was a slight increase in the index value, while Luxembourg and Stockholm have shown a small decline.
In Dublin and Amsterdam, it was a significant improvement in the smart index, however their values were not balanced in the given sub-indices. Athens and Rome have the lowest figures in both years, with persistent low smart city performance. Both for the top-ranked regions and for those at the bottom of the list, there is a strong correlation with other analyses in the literature based on composite indices (e.g. Lapinskaité et al. 2022; Tundys & Wisniewski, 2024; Loucanova et al. 2026). In most cases, the results show a dominance of Northern Europe (Helsinki, Stockholm, and Copenhagen), while at the bottom of the list—even when using multidimensional indices—two capitals from the Mediterranean region, Athens and Rome, typically appear.

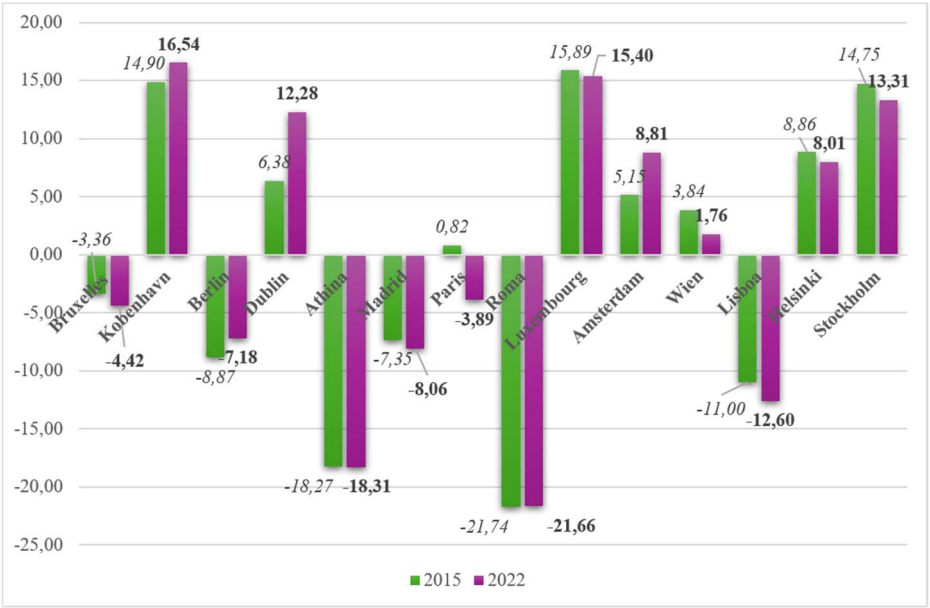

Figure 3. Smart index values of the Western European (EU15) capitals (2015, 2022)
Source: own compilation

So, the chart reveals persistent regional disparities: Northern and some Western European EU15 cities tend to maintain strong positive values, while Southern cities remain negative. While some cities improved between 2015 and 2022 (e.g., Dublin, Amsterdam), others experienced stagnation or decline. Overall, the differences between cities remain pronounced, with no clear convergence over time. Compared to our previous analysis results (Szendi et al., 2020), Copenhagen and Stockholm were among the smartest capitals in 2015 for the whole European continent, and for the EU a clear northern-southern divide was recognizable. The results are quasi-similar, so the EU15 almost reflect the trends of the EU.
Besides the complex index, it is also worth to check the performance of the given components in the cities. That is why I have created the below radar charts to have a comparative approach for the factors influencing the smartness of the city. The first compares the EU15 capitals across the six smart city components for 2015. The values range from –8 to +8, allowing a comparable view of strengths and weaknesses. Economy and Governance show the widest variation across cities. Some cities (e.g., Luxembourg, Copenhagen) score very high, while others (e.g., Athens, Rome) are strongly negative. Mobility and Living are more moderate, with most cities clustered around small positive values. Environment varies but tends to be moderately positive in Northern cities and weaker in Southern ones.

Copenhagen and Luxembourg stand out with consistently high scores, especially in Governance and Economy (values around +6 to +8). These cities appear well-balanced across most components. Stockholm and Helsinki also perform strongly, particularly in Environment, Governance, and Living, indicating a sustainability-oriented smart city model. Amsterdam shows high values in Economy and Governance, though Mobility is relatively weaker. Dublin stands out in Environment, while Berlin is more balanced but slightly weaker in Governance. Vienna and Paris show mixed profiles with moderate scores in most components. Athens and Rome display the lowest overall scores, particularly in Economy and Governance. Lisbon and Madrid also show weaknesses, especially in Governance and Economy, though their Mobility and Living scores are less negative.

In 2015, Governance is a key differentiator pillar, as there are some high-performing Northern cities, but Southern cities lag significantly. Environment tends to be stronger in cities like Stockholm, Helsinki, and Dublin, indicating environmental policy effectiveness. Mobility is relatively even across cities, suggesting that transport systems are less polarizing but not a strong competitive advantage. Living is generally positive across many cities, indicating relatively good quality of life even where economic or governance factors are weaker.

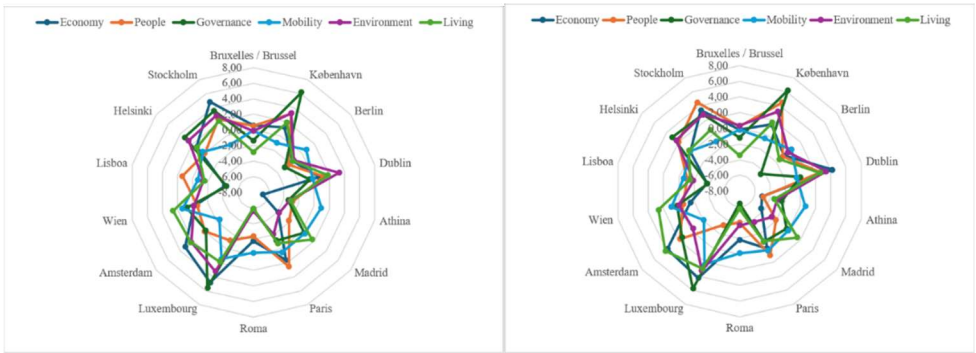

Figure 4. Smart index components of the Western European (EU15) capitals (2015 left, 2022 right)
Source: own compilation

The right figure represents the smart index component values in 2022, which also highlights top-performing areas, as Copenhagen and Luxembourg show consistently high scores across most components, especially in Governance, Economy, and Living. Stockholm and Helsinki are in contrast strong in Environment and Living, indicating sustainability-oriented development. Amsterdam, Berlin, Dublin, Vienna are generally positive across multiple components but lacking a dominance in all areas. In Athens and Rome, similarly to 2015, there are consistently negative values in Economy and Governance, while Lisbon and Madrid perform mixed but generally below-average. Also, in 2022, Governance and Economy are decisive factors, while Environmental performance is a strength of Northern cities, reinforcing the sustainability gap within Europe.

From the two radar maps, a clear North - South divide emerges, where the Northern and Western cities perform consistently well across multiple components, and Southern cities lag due to economic and governance challenges.

So, the figures demonstrate that smart city performance depends on a balanced combination of components rather than strength in a single area. Leading cities (e.g., Copenhagen, Luxembourg, Stockholm) exhibit consistency across governance, economy, and quality of life, while weaker cities are characterized by systemic deficiencies, particularly in governance and economic capacity.

Summary

In my recent analysis I have checked the smart city performance of the EU15 member states' capitals (except London) smart city performance for 2022 and have compared it with previous analysis results from 2015. The selection objective was to analyse the Western European capitals from the aspect of smart cities and track the tendencies of the indicator. Copenhagen, Luxembourg, and Stockholm consistently rank as the strongest smart-city performers, though Copenhagen overtook Luxembourg between 2015 and 2022. Northern and Western capitals show stable high scores, while Southern cities such as Athens, Rome, Lisbon, and Madrid remain persistently weak. Some cities, including Dublin and Amsterdam, improved significantly over time, although their sub-index values remain uneven. Vienna and Paris kept mid-level positions but experienced notable score declines. The overall hierarchy of European capitals appears increasingly polarized rather than converging. Radar charts for 2015 show wide gaps in Economy and Governance, with Northern cities performing strongly and Southern cities scoring negatively. Environment is a clear strength for cities like Stockholm, Helsinki, and Dublin, while Mobility and Living remain more balanced across capitals. The 2022 radar chart confirms continued dominance of Copenhagen and Luxembourg across most components. Southern capitals still struggle with systemic weaknesses in Economy and Governance, reinforcing the North–South divide. Overall, leading cities succeed through balanced strength across governance, economy, environment, and quality of life, while weaker cities show structural deficiencies across multiple dimensions.

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