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Can smart city planning enhance the sustainable transition of the E.U. capitals? A project and strategy-based smart, sustainable performance analysis in the programming period 2014-2020

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Abstract
Cities across the globe perceive their opportunities for digital transition pathways. This paper presents a project and strategy-based assessment of smart city ambitions in the light of sustainable urban development pathways in the European Union capitals considering the programming period 2014-2020. The purpose of the research is to understand better the smart city trends in Europe and identify any correlation between smart city and sustainability ambitions through the European capitals. The basis of the research was the official project result platforms of European funds with priorities related to smart cities. The collected best practices of transnational smart city projects provide statistics from the previous programming period and draw attention to the developing trends of smart city functions and the activity level of European capitals in the digital transition. Results show that between 2014 and 2020 nearly half of the capitals owned a specific smart city strategic document. Evaluating the smart urban performance of the capitals, it can be stated that most smart solutions were implemented related to mobility and environment in the previous period. Furthermore, it was also considered whether smart city projects could facilitate the shift toward sustainability. Based on the assessment of their planning strategies, a complex image of the European capitals has been revealed in their smart city development concepts; their strategic-level planning can be understood better, which is essential for policymaking in the era of digitalisation, identifying synergies with sustainable urban development ambitions, and monitoring the reached targets at the city level.

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1. Introduction

Information and communications technology (hereinafter: I.C.T.) affects our daily lives, and city leaders like mayors and local decision-makers cannot avoid the phenomenon of digitalisation: more and more urban development projects and strategies on different levels set the objective of becoming smart cities (Borsboom-van Beurden et al., 2017). According to U.N. predictions on urbanisation, 68% of the global population will live in cities by 2050 (U.N., 2019), which envisages the escalation of the problems and aspects that have to be taken into account by urban development, particularly environmental challenges (Bai et al., 2017). Due to the technological development and digital transition, there will be new opportunities for planning, managing and developing cities (Repetti, Bolay, 2010). Smart or intelligent cities can manage urban functions and services efficiently and with the involvement of local citizens by applying I.C.T. tools and digitalisation (Campisi et al., 2021). Shift towards smart cities can eventually facilitate the realisation of urban sustainability by applying smart technologies and citizen involvement solutions in order to design liveable cities while also taking into account the sustainability principles (Richard, David, 2018), (Sofeska, 2017), (Todeschi et al., 2020).

This research was initiated to receive information about the level of smart cities in Europe, and their connection to sustainability efforts. Several studies have already been published in the field of smart city evaluation including in topics

of city evaluation design approaches through case studies in the United Kingdom (Caird and Hallett, 2018), analysis of the smart city transformation of Barcelona (Bakici, Almirall, Wareham, 2013) or analysis of the state of smart cities in Central and Eastern Europe (Kola-Bezka et al., 2016). Authors decided to have wide European results, therefore, one city per Member State, i.e. European capitals came into focus.

This study focuses on the main sectors of urban services and the implemented smart solutions by applying the "Smart City Wheel" categories (Cohen, 2012), i.e., smart economy, smart people, smart government, smart mobility, smart environment and smart living. Although there are many different categorisations of smart city solutions (Dirks, Keeling, 2009), (Dr. van Dijk, Teuben, 2015), (Falconer and Shane, 2012), the "Smart City Wheel" approach was selected as a middle-ground option which is not too detailed, but has already been used by several documents and projects, preferably at the European Union level (Brussels-Capital Region, 2021), (Millard et al., 2014), (Vienna UT, 2007). By examining the smart city application areas based on sustainability principles, connections between the Smart City Wheel dimensions and the United Nations' Sustainable Development Goals adopted in 2015 have been identified (U.N., 2015).

Desk research was conducted to define the level of smart cities through implemented projects as indicators, and to identify the connection between smart ambitions and sustainability in the case of the capitals of the European Union. The methodology of the research was to examine the smart city projects of the capitals granted by the innovation and transnational programmes of the European Union. The authors applied the keyword method to the project topics and descriptions because there is no universally accepted definition of the smart city. The collected project history of the capitals not only provide statistics about the smart city projects granted by different E.U. funds and programmes between 2014 and 2020 but also draw attention to the development trends of smart city functions and the progress level of the European capitals in digital transition (Chernyaev et al., 2023).

Furthermore, it was also considered if smart city progress can facilitate the shift towards sustainable urban development. Based on the assessment of the smart city strategies of the E.U. capitals, a complex image of the European capitals has been revealed in their smart city development concepts: besides good practices, strategic urban planning can also be understood, which is essential for policymaking in the area of digitalisation, identifying connections with sustainable urban development ambitions and opportunities, and their monitoring at city level (Zoldy et al., 2022).

The dual approach of the research, i.e., smart cities and sustainability, is in line with the strategic priorities of the European Union. In the reference period, the critical elements of the European development policy were innovation and sustainable development, essential for promoting a resource-efficient, greener and more competitive economy (European Commission, 2010a). Implementation of innovation can be facilitated significantly by smart and sustainable urban development investments, projects and solutions.

The present paper focuses on the project-based assessment of the smart city ambitions of the European Union capitals. Smart cities exploit I.C.T. to ensure more efficient urban services and better quality of life (Carrión-Martínez et al., 2020). The theoretical background of the 'smart city' definition has been evolving since the 2000s towards providing a better description of the complex connections among Information and Communication Technology, infrastructure, networks, economic growth, and quality of life in the city (Russo et al., 2014). According to the dedicated website of the European Commission, "*a smart city is a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business*" (*European Commission, n.d.*).

Several European Union documents, policies and strategies have contributed to developing the smart city concept in the reference period. Authors hereby list the major milestones in the evolution of the smart city concept in the European Union not only to emphasize the relevance of the concept in the policies and priorities of the EU, but also to show how sustainability is more and more connected to the smart city idea.

One of the first essential documents was Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth, approved in 2010, which defined the objectives of the European Union related to economic growth until 2020. One of the three priorities in the strategy was 'smart growth', i.e. "*developing an economy based on knowledge and innovation*" (European Commission, 2010b).

Since the Europe 2020 strategy launch, several E.U. strategy documents have started to follow its guidelines and objectives. The following documents supported the smart city concept and initiatives (European Commission, 2011a); the Energy Roadmap 2050 introduced in 2011 (European Commission, 2011b), and Directive (E.U.) 2018/844 amending Directive 2010/31/E.U. on the energy performance of buildings and Directive 2012/27/E.U. on energy efficiency.

The 'Pact of Amsterdam: Urban Agenda for the E.U.', accepted in 2016, created a multilevel cooperation method between member states, cities, the European Commission and other stakeholders (Informal Meeting of E.U. Ministers Responsible for Urban Matters, 2016). The Pact of Amsterdam fostered better regulation, better funding and better knowledge. Reference for encouraging smart city development can be identified in its priority themes (10.11 Digital transition) and also in its cross-cutting issues (12.5 Innovative approaches, including Smart Cities).

In the programming period 2014-2020, implementation of the Sustainable Urban Development strategies (hereinafter: SUD) became compulsory to establish a strategic dimension for the integrated cooperation approaches between different policies, levels, stakeholders and public administration territories. According to the Amsterdam Pact, harmonisation of the innovation policies of SUD and the European Union is highly recommended, especially regarding smart specialisation strategies, which define a smart approach to economic development to reach higher competitiveness with research and innovation (Hassink and Gong, 2019), (Joint Research Centre, (2020)

Initiatives and partnerships in the European Union support the development and spread of the smart city concept. One of the most significant ones regarding its mission and scope of activities is the European Innovation Partnership on Smart Cities and Communities (EIP-SCC) created by the European Commission in 2011. EIP-SCC encourages strategic cooperation between the main stakeholders: cities, industry, small and medium-sized enterprises, the bank sector and researchers (Maschio, 2016). The goal is to improve urban life with integrated and sustainable solutions in different areas, such as energy or transport. Any entity planning to develop or implement integrated smart city solutions can join the online Marketplace of the EIP-SCC to find partners or exchange information and experiences (Kaiser and Pejstrup, 2021). EIP-SCC also urges smart city solutions to meet the 20-20-20 climate goals of the European Union (European Commission, 2014), such as decreasing the emission of greenhouse gases, increasing energy efficiency or improving air quality. EIP-SCC aims to accelerate the transition towards smart cities by encouraging co-financed demonstration projects and coordinating ongoing initiatives (Maschio, 2016).

The next major element in developing the smart city concept will be the regulation of artificial intelligence (hereinafter: A.I.) at the European Union level. As smart cities rely on information and communication technologies and vast amounts of data (Tadić et al., 2022), A.I. and machine learning can play a crucial role in processing and analysing data and supporting decision-making in urban systems and services such as intelligent transport systems (Nikolett et al., 2023), smart grids or advanced health care mechanisms (Ullah et al., 2020). In April 2021, the European Commission submitted a proposal for Regulation to harmonise rules on artificial intelligence (Artificial Intelligence Act) (European Commission, 2021). The proposal aims to support the uptake of A.I. while also addressing the expected risks and promoting a legal framework for a trustworthy A.I.

The different smart city functions and solutions can also be studied and evaluated based on their impact on sustainability. The concept of sustainable urban development appeared first in 1992 in the Agenda 21 programme of the United Nations (U.N.,1992). Taking into account the needs and challenges of future generations was promoted on national, regional, and local levels. Localisation of United Nations Sustainable Development Goals (hereinafter: S.D.G.s) is vital, and smart cities can support local initiatives and urban sustainability transitions. (Clement et al., 2023)

Although the different smart city definitions focus on exploiting the I.C.T., more and more approaches also set sustainable objectives for smart solutions (Szalmáné Csete and Buzási, 2020). Sustainable cities and smart cities are not interchangeable concepts. Nevertheless, as the previously listed European Union strategic documents suggest, nowadays, smart solutions are expected to contribute to sustainable development by pursuing smarter energy usage, reducing pollutant emissions, or promoting more rational resource management (Girardi and Temporelli, 2017).

The possible impact of the 'Smart City Wheel' categories on sustainability can be examined based on their comparison to the S.D.G.s (U.N., 2015). At first glance, the list of S.D.G.s shows that smart cities can contribute to Goal 11, "Make cities and human settlements inclusive, safe, resilient and sustainable" is an S.D.G. which smart cities can contribute to. The specific targets of Goal 11 are expectations that can also be imposed on the smart cities: ensure access for all to adequate, safe and affordable housing and essential services; provide access to safe, affordable, accessible and sustainable transport systems; enhance inclusive and sustainable urbanisation; protect and safeguard the world's cultural and natural heritage; significantly reduce the number of deaths and substantially decrease the direct economic losses caused by disasters; reduce the environmental impact of cities; and provide universal access to safe, inclusive and accessible, green and public spaces (U.N., 2015).

By exploring each Smart City Wheel category (Cohen, 2012) in different smart city publications (Deloitte, 2015) (I.B.M., 2009), (Millard et al., 2014), we can find more consistencies with further S.D.G.s. Objectives of Smart Economy can be the promotion of sustainable economic development, innovation, sustainable industrialisation, and sustainable consumption and production patterns. Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities fit into the ambitions of the Smart People category. Smart Government can be linked to the 16th S.D.G., especially its targets on developing effective, accountable and transparent institutions and ensuring responsive, inclusive, participatory and representative decision-making. Smart Transport solutions usually set goals to use more clean energy and reduce climate change's effects. By creating a Smart Environment, cities can provide access to safe drinking water and reliable, affordable and modern energy services, contribute to coping with climate change, and preserve life below water and on land. Smart Living objectives align with the goals to ensure healthy lives, promote well-being, and ensure sustainable consumption.

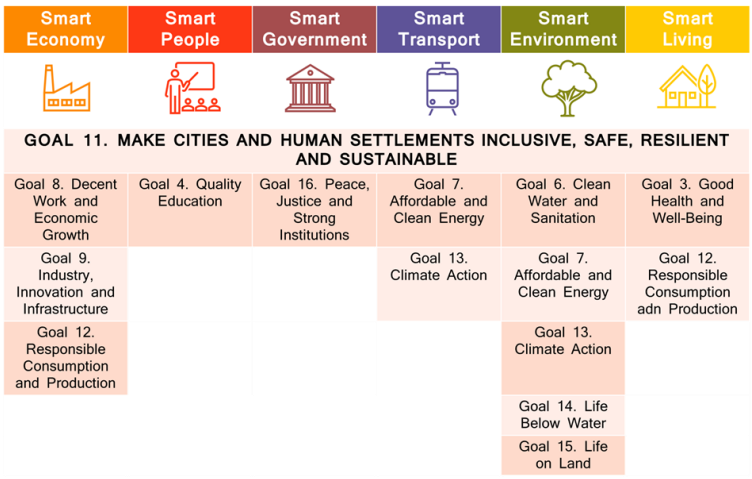

Fig. 1. Comparison of Smart City Wheel and U.N.'s S.D.G.s.

2. Literature review - Smart city ambitions in the strategic documents of the European Union capitals

The European Union promotes smart cities through its priorities, policies and programmes. A 2018 study analysed the smart city concept in the EU policies and the role of tools as clusters or living labs, and found, among others, that although the main driver for smart city development was I.C.T., a shift could be seen in the recent years towards the importance of municipalities as an organisational element. (Alaverdyan et al., 2018)

A 2017 study analysed 16 sets of city assessment frameworks, a total of 958 indicators both regarding smart city and sustainability, and large gaps had been identified. In order to improve sustainability in smart cities, the term "smart sustainable cities" should be used, and re-definition of the concept was recommended. (Ahvenniemi et al., 2017)

As a first step of the present research, a territorial analysis of the European Union was conducted by comparing their strategic documents aiming at becoming smart cities. Many papers have focused on smart city strategies in the recent years. For example, a 2016 study examined four European smart city strategies (Angelidou, 2016), another study analysed large Polish cities including content analysis of official documents and websites, and the significance of smart city strategies within local development policies (Masik et al., 2021). According to our knowledge, no strategic document review on all European capitals.

A targeted online, keyword-based desk research was conducted in English and the national language. In case of no results for "smart city strategy" + city name", the official webpages of the municipalities were visited for a targeted search by exploring their website sections for strategic documents or urban development areas. Besides language barriers, another challenge in filtering the results was that the terminology of "strategy" does not only refer to a document itself but also to the overall concept of the city on its ambitions, objectives, initiatives and plans. The fundamental research question was if cities have any strategic planning documents specifically promoting smart cities and solutions and if yes, what time frame they were designed for.

The desk research allowed us to categorise the E.U. capitals based on the availability of their smart city strategies. The first category includes all the capitals which have prepared a specific strategic document for their smart city objective. These strategies set different timeframes, although they usually determined middle-term goals.

The City of Paris elaborated their strategy in 2015 in a way that it can continue its efforts after 2020, their main milestone for energy transition („Looking Ahead to 2020 and Beyond") (Mairie de Paris. 2015). Berlin also prepared their Smart City Strategy in 2015, in the framework of the Urban Development Concept Berlin 2030 (Senate Department for Urban Development and the Environment, 2015).

Both Prague and Stockholm approved their smart city strategies in 2017. While the former set priorities targeting 2030 (Prague City Council, 2017), the latter defined a target vision and principles until 2040 (Stockholms Stad, 2017).

Athens chose a different method: the Greek capital decided in 2017 to create one-year-long action plans, which can focus more on implementing projects and initiatives than long-term strategies (Wray, 2018). In preparing this paper, besides the first document covering 2018/2019 (City of Athens. 2018), no further developed action plan was available online.

The capital of Cyprus prepared a ten-year strategy for 2018-2028 (Municipality of Nicosia. 2018). Bratislava created its strategy in 2018 to better exploit the opportunities of digital innovations (Council of Bratislava, 2018).

The cities of Zagreb, Vilnius and Budapest decided to elaborate their mid-term smart strategies in 2019 until the milestone of 2030 (Budapest Főváros Önkormányzata, 2019), (Grad Zagreb, 2019), (Vilniaus miesto savivaldybės, 2019)

Vienna prepared the smart city strategy with the longest timeframe. The Smart City Wien Framework Strategy elaborated based on a 2014 strategy, was adopted in 2019 (Vienna Municipal Administration, 2019). The most recent document is from Italy: the Municipality of Rome adopted its Smart City Plan in March 2021 with over 80 planned projects in 11 intervention areas (Roma Capitale, 2021).

In the second group of capitals, the development of the smart city strategy is under preparation. The leaders of Bucharest signed the contract in 2018 to elaborate their strategy for 2018-2025 (Romania Insider, 2018). No recent information was found about the status of the document.

The other capitals in the third category do not own a specific smart city strategy document. However, their goals and ambitions are available in other resources. These cities have different levels of progress in their smart city ambitions. Some cities can be considered pioneers in the field than others (e.g. Amsterdam or Helsinki), and there are also municipalities with less experience in smart solutions.

Amsterdam's smart city ambitions are built on supporting bottom-up initiatives. Amsterdam Smart City online platform is an excellent example of including local communities and the private sector in becoming a smart city. The municipality's principles and objectives are listed in documents such as Digital Urban Agenda (Gemeente Amsterdam, 2019) and Data Strategy (Amsterdam Data Science, 2019). Brussels also developed an open, participatory platform (Brussels-Capital Region, 2021) to involve local citizens in developing smart city solutions. Their smart city ambitions were included in the Policy Statement text for 2019-2024 (Brussels-Capital Region, 2019), and related objectives can be found in their economic development strategy (Brussels-Capital Region, 2015).

Helsinki integrated its digitalisation and smart systems objectives into the City Strategy 2017–2021. Furthermore, the capital of Finland cooperates on different levels: on the one hand, they participate in the collaboration of the six largest Finnish cities (Brussels-Capital Region, 2015).), on the other hand, there is a cooperation between the city and its region. A smart region strategy for the Helsinki-Uusimaa region in 2018-2020 was also developed and revised in 2020 (Helsinki-Uusimaa Regional Council, 2020).

The objectives and priority areas of the smart concept of Copenhagen are available online (City of Copenhagen, 2017). Moreover, the implemented smart solutions aim to support Copenhagen's 2025 carbon-neutrality goal (Arup, CEDI. 2016).

Luxembourg and Dublin summarised their smart city solutions and local ambitions on their municipal websites (Administration communale de la Ville de Luxembourg, 2017) (Smart Dublin, 2020).

There are examples where capitals integrate their smart city visions into their other urban strategic documents, such as economic development plans or strategies. No specific smart city strategic document has been elaborated in Tallinn either. However, its "Tallinn 2035" development strategy, which focuses on becoming a greener and more citizen-friendly city, includes smart principles, too, such as implementing smart solutions for the economy or climate change mitigation and adaptation (Tallinna Linnavolikogu, 2020).

Lisbon defined smart city objectives in its 2018-2021 economic plan (Câmara Municipal de Lisboa, 2018), and its smart city ambitions were also included in its carbon neutrality vision set by 2050 (POCACITO project, 2016). The strategic goals of Warsaw towards a smart city are reflected in their current urban development plan ("Strategia #Warszawa2030") (Urząd Miasta Warszawy, 2018).

Smart city elements had been defined in the Sustainable Urban Strategy of the City of Ljubljana 2014 – 2020 (Mestna občina Ljubljana, 2015), which was amended in 2020 for the period of 2014-2030 (Mestna občina Ljubljana, 2020). Riga is working on becoming a "compact, resource-saving and smart" by 2030 as it is defined as a goal to achieve in its sustainable development strategy (Riga City Council, 2014).

Madrid prepared a sustainable environment strategy in 2019 in which one of the strategic objectives in the city's vision is to become a "smart Madrid" (Ayuntamiento de Madrid, 2019). The smart city ambitions of Sofia can be found in several of its strategic documents, such as the Innovation Strategy for Smart Specialisation and Digital Transformation Strategy (Komninos, Tchonkova, Gluhak, 2019).

Valletta implemented best practices into the centre of their smart city ambitions. The Maltese capital participated in the GrowSmarter Horizon 2020 project, where they developed a Replication Plan as a follower city, indicating the "Smart Island" concept (Battistino, 2019).

3. Methodology

Examining the smart city practices of the European Union (E.U.) capitals and their territorial analysis was based on desk research. In general, cities can implement smart solutions from their own contribution, with national co-finance, in public-private partnerships or even support bottom-up initiatives like in the Netherlands. Due to the divergent funding opportunities, the lack of complex databases and the language barriers, the study focuses only on the projects completed by the municipality of the capitals in the framework of transnational cooperations and partnerships. In the case of E.U. (co-)funded projects, there are requirements for sharing information and publicity. Thus, the available programme and project databases could contribute to collecting necessary data. In order to avoid the differences between programming periods, the study covers the 2014-2020 period.

The target group of the research was the municipalities of the E.U. capitals; projects carried out by district municipalities or municipality-owned service providers and companies were not counted as part of the analysis. As a result of narrowing down the beneficiaries, the results do not include all the smart projects implemented in the territory of each city. Therefore, general consequences regarding the level of smart city development cannot be drawn for the E.U. capitals.

Defining and searching relevant keywords in the project descriptions was applied to identifying the smart city projects, which is an available method form of research (Hsieh, Shannon, 2005), (Kong et al., 2019), (Nguyen et al., 2021). Related terminology (such as "smart", "intelligent" "I.C.T.", "artificial intelligence", "sensor", "data", "innovation") were searched for in the project descriptions/contents and, if there were no matches in the text, but it could be reasonably assumed that there might have been some connection, project websites were also examined.

The research was conducted using two databases: SEDIA and Keep.eu. Horizon 2020, the research and development programme of the European Union and several further programmes coordinated directly from the European Commission or other E.U. institutions are included in the SEDIA platform. Keep.eu platform includes the project information of interregional and cross-border programmes.

The collected smart city projects were categorised based on the Smart City Wheel developed by Boyd Cohen: Smart Government, Smart People, Smart Living, Smart Mobility, Smart Economy and Smart Environment (Cohen, 2012). Due to their complexity or size, some projects could have been able to sort into more Smart City Wheel categories. In these cases, a primary category was chosen for each project focusing on the participating municipalities' project objectives and results. The analysis also had to consider that more participating municipalities could have implemented different smart solutions in the same project. In order to clarify the different terminology, in the Results and Discussion part of the present paper, 'project' refers to the cooperation between different partner organisations. In contrast, 'smart solution' refers to the initiative a municipality implemented in the framework of the 'projects'.

During the categorisation of the projects, a seventh group has also been identified besides the Smart Wheel components, a so-called 'horizontal' one. Some initiatives support municipalities in the shift towards smart cities unequivocally. However, it cannot be sorted into any Smart City Wheel areas. These horizontal projects contribute to the technical framework of smart cities, such as developments in the next-generation internet, Internet-of-Things, big data or sensor technology.

In order to evaluate the results, the collected and filtered projects were analysed from four different aspects to be able to evaluate the performance of the capitals in the defined period regarding their smart city ambitions and sustainability:

- the sectoral and territorial distribution of the collected smart solutions and projects;
- comparison of the collected smart solutions and the level of digital development of the European Union member states;
- comparison of the collected smart solutions and the capitals' S.D.G. indicators;
- comparison of the collected smart solutions and the availability of smart city strategies in the capitals (2014-2020).

In order to illustrate the results of comparing different indicators, the B.C.G. matrix method was used, a planning tool for long-term strategic development based on a model considering any company's growth and market share (Udo-Imeh et al., 2012). The B.C.G. analysis was developed as a corporate tool which can integrate several different strategic and financial aspects of a company, and the visualised final result of the analysis can illustrate the business portfolio with four strategic areas of activities (i.e. 'stars', 'cash cows', 'question marks' and 'dogs'), (Duica et al., 2014). B.C.G. analogy was selected for illustrating the results of the present research as this model can consider different variables and visualise the characteristics of the capitals while evaluating and comparing them with each other. A 2023 study also used scatter plot visualisation method for their results when comparing the performance of sustainability and competitiveness in the Italian provinces. (Pane, 2023)

The values were established based on the desk research: the number of smart city projects in the capitals, the rate of smart city projects compared to all projects, the score of the E.U. Member States on the Digital Economy and Society Index (European Commission, 2020) and the capitals' score on the S.D.G. Index for European Cities – prototype version. For illustration, the values were normalised in each comparison, and statistical methods analysed the type of connection between the two factors. Pearson correlation was used to see the strength of the connection between the variables. In the regression case, a regression model's intercept was forced to equal zero, as allowing a non-zero intercept would lead to a nonsensical estimated intercept.

An analysis was also concluded based on the comparisons to find patterns in the capitals' performances. Territorial analysis was based on categorising the capitals into geographical regions (Northern, Western, Southern and Eastern Europe).

Although the analysis was conducted towards the collected smart solutions and projects, due to the research method and size, overall insight and conclusions cannot be drawn on the capital's complex ambitions and level of development.

4. Results and discussion

4.1. The distribution of the projects on the Smart City Wheel

From the databases of SEDIA and keep.eu platforms, 149 smart solutions implemented by the capitals were identified. Among these solutions, 21 can be considered horizontal smart city projects, i.e., cannot be classified in any Smart City Wheel domain.

The remaining 128 smart solutions were implemented in the framework of 102 projects in practice. There were no examples of different types of smart solutions in the same project. Thus, dividing the projects between the Smart City Wheel domains was possible. The results show that the most popular area among the identified projects was Smart Mobility, approximately 1/3 of which were related to transport. Smart Environment and Smart Living were also significant topics for transnational cooperation. These results can be derived from the priorities and objectives of the analysed 2014-2020 European Union transnational, interregional funds; the interests and functions of the municipalities; or the different development levels of the Smart City Wheel domains. The lowest number of projects implemented by the E.U. capital were identified in the field of Smart People. This result can be explained by several factors, such as fewer tangible objectives of the domain or the different type of beneficiaries in such projects (e.g. cultural institutions, schools etc) .

Further analysis was conducted to find any territorial patterns among the results. Smart solutions implemented by the capitals were categorised into the areas of the Smart City Wheel. Results based on the territorial division of Europe show that all smart city domains are geographically heterogeneous; solutions were developed in at least two regions in each category. Western and Southern Europe regions cover all six domains of the Smart City Wheel.

Due to their relatively high number of solutions, examining the two most popular categories – Smart Mobility and Smart Environment – can show further territorial patterns. The capitals with most found initiatives in Smart Mobility and Environment are located in Eastern Europe, so this region dominates the two categories noting that this region include the highest number of Member States according to the territorial categorisation of the EU. In addition, while the three capitals of Northern Europe implemented more solutions than Western and Southern Europe separately in Smart Mobility, they reached the least number of smart solutions in the Smart Environment domain (Kutasi, 2022).

4.2. Comparison of the collected smart solutions and the level of digital development of the European Union member states

Results of the secondary research show that Madrid, Amsterdam and Copenhagen were the most active capitals in the 2014-2020 period concerning smart city-related initiatives. In contrast, no smart solution was identifiable in the case of Luxembourg.

Although the collected solutions cannot constitute a complex indicator that would provide a clear picture of the capital's development level, it is worth studying the results further to put them into context. By comparing them with indicators measuring technology development, connections can be detected to see if capitals with higher levels of digitalisation implemented more smart solutions. The European Union's Digital Economy and Society Index (DESI) was used for this

analysis which evaluates the digital performance and follows the progress of the European Union Member States. The last index report in the covered period is from June 2021 which was elaborated based on data from the year of 2020. When calculating the index, many factors are considered such as human capital, use of internet services, integration of digital technology or digital public services (European Commission, 2020).

Considering the results of this comparison, it can highlight whether the capitals of the more digitally developed countries implement a higher number of smart solutions. When comparing the number of implemented smart solutions of the capitals and the level of digitalisation of the Member States, calculations show that the correlation coefficient is 0.298, which means a low degree of connection, while R^2 is 0.056. As a negative number for the level of development is not applicable, the model was adjusted so the estimated regression line would pass through the origin. With this modification, besides a low correlation coefficient, R^2 became 0.08, which means that the level of digitalisation explains only 8% of the heterogeneity of the project numbers.

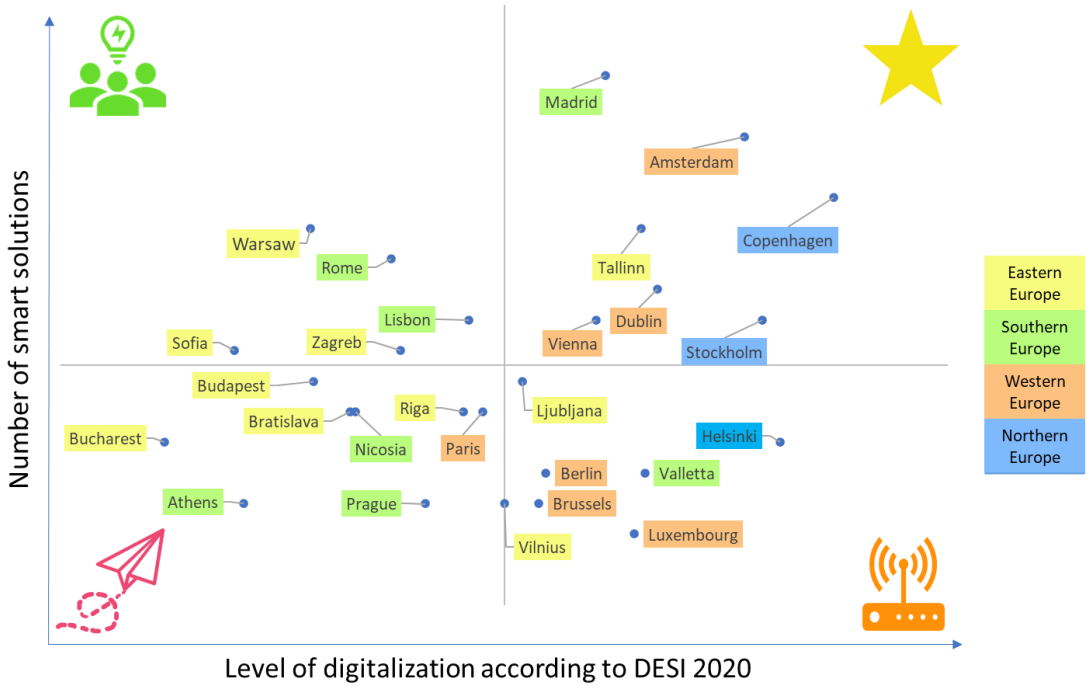

Fig. 2. B.C.G. matrix for the number of S.C. projects and level of digitalisation

Comparison results are illustrated in a B.C.G. matrix. The two categories containing the more digitally developed capitals (above average) include all four geographical regions of Europe. The category with digitalisation levels below average and smart city solution numbers above average includes capitals only from Eastern and Southern Europe. The largest category with eight capitals is where cities have digitalisation levels and implemented smart city solutions below average. While Luxembourg did not implement any solution related to smart cities in the examined European project, their level of digitalisation is above average. The three cities with the largest identified smart city solutions (Madrid, Amsterdam, Copenhagen) can also be considered digitally developed.

4.3. Comparison of the collected smart solutions and the capitals' S.D.G. indicators

Other conclusions can be drawn if we compare the implemented smart city solutions to all the transnational and interregional cooperations the capital participated in between 2014 and 2020 for each city. The highest rates of smart solutions were found in the cases of Valletta and Bucharest. No definite territorial pattern can be read on the map. All rate category (0-25%, 25-50%, 50-75%, 75-100%) covers at least two geographical regions.

Revealing the connection between the rate of smart solutions and the level of sustainability, the results can underpin whether cities with better attempts to become sustainable implement more smart solutions than all of their projects. "S.D.G. Index for European Cities – prototype version" was used in the analysis, which evaluates European cities based on the United Nations" Sustainable Development Goals. The elaboration of the Index did not cover S.D.G. 14 (Life Below Water) and S.D.G. 17 (Partnerships for the Goals) as data at the subnational level was not available (Sustainable Development Solutions Network & Telos, 2019).

Statistics show that the two variables have no connection (R^2=0.005), while the coefficient of determination is -0.07. When adjusting the estimated line on the model to go through the origin, results remain showing norelation (r=-0.07R^2=0.005). Latter means that 0.5% of the variation of the smart solution rates is explained by the level of sustainability in the regression model.

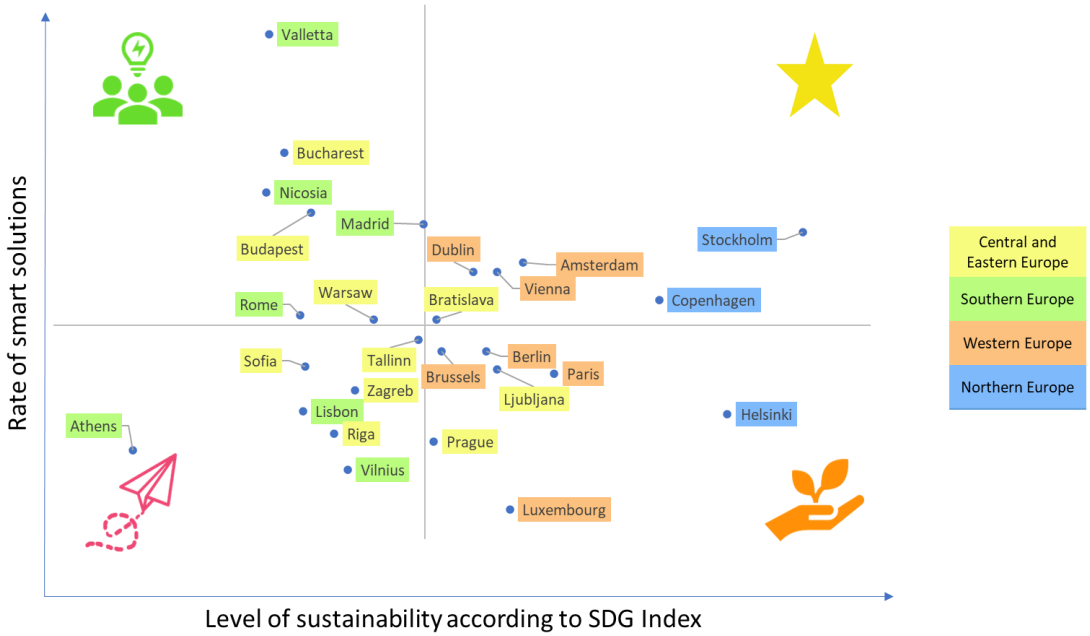

Fig. 3. B.C.G. matrix for the rate of S.C. projects and level of sustainability

The territorial comparison of the two data types is illustrated in another B.C.G. matrix. The dispersion of cities in the matrix is balanced; the number of capitals in the four categories is almost equal. The two capitals with the highest rate of smart solutions (Valletta and Bucharest) had both lower-than-average performances on the S.D.G. Index. The two categories where cities have lower performance on the S.D.G. Index cover Southern Europe and part of Eastern Europe. Only six capitals can justify the original suggestion, i.e., if a city is more sustainable, they are more likely to implement smart city solutions.

4.4. Complex Analysis of the Smart Urban Performance Evaluation of the European Capitals

In order to get an overview of the introduced calculations and be able to evaluate the performance of the cities, a complex matrix was elaborated. Based on the present paper's research, Amsterdam, Copenhagen, Dublin, Stockholm, and Vienna performed above average in the case of all examined indicators. In contrast, Athens and Riga need to improve in all aspects. From a regional aspect, the matrix also shows that Northern European capitals performed well in all examined indicators.

Results for number of SC projects and level of digitalisation / Results for the rate of SC projects and SDG level				
	Athens Riga	Lisbon Sofia Zagreb	Vilnius	Tallinn
	Bucharest Budapest Nicosia Warsaw	Rome	Valletta	Madrid
	Paris Prague		Berlin Brussels Helsinki Ljubljana Luxembourg	
	Bratislava			Amsterdam Copenhagen Dublin Stockholm Vienna
	Eastern Europe	Southern Europe	Western Europe	Northern Europe

Fig. 4. Complex matrix of the E.U. capitals.

The challenges of the research were mostly based on the availability of data. The sources of information were publicly available platforms which only contained a limited number of projects, i.e. the municipalities' participation in transnational and other European Union-funded cooperations. Therefore, the research was limited, complex description of the capitals and their level of smart city development could not be provided. Such complex but still project-based performance evaluation could be conducted if data on all initiatives in the cities' territory (independently from the beneficiaries) was available for the research.

Although the data availability can challenge the research, the project-based approach can provide interesting conclusions for evaluating smart city performances while considering their characteristics. On the one hand, the examined European Union programmes offer high or 100% funding rates for projects to carry out local initiatives in transnational partnerships. Project partners can share their knowledge and experience, leading to the spread and dissemination of smart solutions. Interregional and cross-border cooperations can foster the interconnectivity and interoperability of neighbouring areas. In addition, smart city solutions can contribute to the cities' sustainable development ambitions.

On the other hand, administrative burdens, and programme conditions, especially the priorities and objectives of the funding programmes, can challenge the applicants and beneficiaries and limit the opportunities of the funded projects. However, the next programming period has just started with some expected changes in the programmes, such as priorities, hopefully putting more opportunities for smart city developments.

General urban challenges can be determined based on the project-based evaluation of smart and sustainable urban performances. Firstly, city-level policymaking is required to define mid- and long-term vision and objectives, plan and implement investments and projects in line with the smart city and sustainability strategies, and consider local characteristics. Secondly, there were differences in the number of EU-funded smart city projects in the examined programmes during the period considered. This inequality in project performance can be derived from different aspects according to the authors' experience in transnational projects: lack of experience in the city to participate in transnational projects, lack of knowledge and/or ambition from the decision-making level to participate in smart city projects, lack of knowledge on the lower level to implement and participate such projects, language barriers, lack of potential partner network etc. Thirdly, the lack of a complex and unified follow-up of smart city projects at the local level prevents the availability of a transparent and searchable project database at the European Union level.

5. Summary and conclusion

This study assessed the European smart city ambitions through the relevant urban planning strategies and 130 related projects of the E.U. capitals in the programming period 2014-2020. More and more studies are trying to define the terminology of „smart city", which indicates clearly that there is no universal description accepted by everyone (Albino, Berardi, Dangelico, 2015), (García Fernández and Peek 2020), (Toli and Murtagh, 2020) In the paper, instead of comparing the different available definitions, the strategic documents of the European Union were used to establish a theoretical framework for the smart city definition. This way, the connection of sustainability to smart cities could also be justified.

As the capitals of the European Union were chosen as subjects of the research, their policy background was mapped by exploring the availability of any specific strategic documents. The results show that in the previous E.U. programming period (2014-2021), nearly half of the capitals currently own a specific document in which their ambitions and goals towards becoming a smart city are collected. In contrast, others summarised their priorities and objectives in different forms, such as including them in other urban development strategies or plans, developing a dedicated smart city platform primarily for their solutions, or introducing their vision and ambitions on the municipality's official website.

The smart city experiences of the capitals were described by the number of transnational and interregional projects implemented in European cooperation (in programmes like Horizon 2020 or Interreg Europe) in the previous programming period (2014-2020). The methodology was chosen due to the research limitations, language barriers, legislative differences and data availability. Among all the projects, smart city solutions were labelled "manually" by keyword-based identification.

The 130 smart solutions were then organised on the "Smart City Wheel"; initiatives were sorted into six domains and examined based on their possible contribution to achieving sustainability. By comparing the different descriptions and goals, it is presumable that each domain can support at least two of the United Nations Sustainable Development Goals. In addition, another category of the collected projects was also established (Horizontal solutions) for projects that did not fit in any of the "Smart City Wheel" areas.

The present research attempted to find a new way of comparing European capitals and visualising the results based on their smart city ambitions. The B.C.G. method analogy allowed the results to illustrate the examined cities' different performances and to be able to categorise the capitals instead of ranking them. In order to find solutions to the research questions, the level of digitalisation and level of sustainability was chosen to complement the data of the capitals' smart city project experience at the European Union level.

In evaluating the smart urban performance of the capitals, it can be stated that in the previous period, the analysed cities implemented the most smart city solutions in Smart Mobility and Smart Environment. At the same time, the Smart People category provided the least projects. These results can be evaluated only by considering that the European Union programmes had defined priorities to which the objectives of the supported projects have to correspond.

In order to interpret the number of smart city projects, further investigation was conducted based on the methodology

of the B.C.G. matrix. Firstly, the number of smart solutions was compared to the level of digitalisation to see if capitals with higher digitalisation levels would implement more smart solutions which exploit I.C.T. The three cities with the largest identified smart city solutions (Madrid, Amsterdam, Copenhagen) can also be considered digitally developed. Statistical calculations (forcing the trend line through the origin) show a strong correlation and a medium value coefficient of determination. Secondly, an analysis was taken to understand if capitals with higher levels of sustainability would carry out a higher rate of smart city solutions. Results indicate a low correlation and a low coefficient of determination value as forcing the Regression model's trend line through the origin.

When comparing the two developed matrices, territorial patterns can be determined. Capitals from Western and Northern Europe are more likely to perform better, while capitals from Southern and Eastern Europe should improve to reach their smart city and sustainability goals.

Based on the experiences of the present research, general recommendations can be set up for cities to improve their performances in smart and sustainable urban development. Our in-depth urban-level evaluation highlighted that the potential sustainability-related co-benefits of smart city actions are significantly underrepresented in the evaluated planning documents and projects. It is pivotal to embed this aspect into urban planning and development-related strategies.

Firstly, developing urban strategies focusing on smart city and sustainability objectives is highly recommended to map the city's challenges and strengths and set up a vision and definite goals with deadlines and possible resources. Integrating the different urban strategic documents, at least by cross-referencing each other, should also be considered for a more transparent urban development policy. Expanding the horizon of the local decision-makers and staff members by awareness-raising and knowledge transfer can be crucial for preparing and realising such urban strategies.

Secondly, applying for transnational projects in smart cities and sustainability should be encouraged. Participating in European projects can contribute to the defined urban strategies while also getting familiar with best practices, sharing experiences with other similar cities, accelerating technology transfer, and fostering further investments. Without adequate skills and experiences, municipalities should allocate capacities to raise awareness on the topics in-house, improve staff members' knowledge, and expand the workforce. European Union should consider supporting measures for such municipalities to eliminate inequalities regarding participation in transnational projects.

Thirdly, using urban monitoring tools can contribute to the follow-up of the implemented project and the completion level of the urban strategies. The monitoring phase can also be seen as a turning point in further planning processes and developments for a more smart and sustainable future on the urban level. A European-level urban monitoring system could not only support cities to follow their smart and sustainable performance but could also allow decision-makers to intervene if necessary and flexibly modify the progress directions. A European database based on urban performances could facilitate research that could identify common challenges and contribute to finding local and European Union-level solutions.

Future research should also evaluate the co-benefits of smart city solutions related to urban sustainability to foster positive synergies between digital and sustainable transition processes at the local level. In addition to a city's smart city strategy and smart implementations, which can trigger the digital transition in the urban environment, it will be important to explore other potential factors that can contribute to enhancing the co-benefits of smart, sustainable solutions. According to the smart city development-related co-benefits, the knowledge about the perception and attitudes of the local inhabitants can also be informative and valuable for the municipalities. A more in-depth assessment of the impacts of smart, sustainable developments also deserves further attention as it can deliver useful information for urban planning experts, decision-makers, and local inhabitants.

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智慧城市规划能够增强欧盟首都的可持续转型吗？基于项目和策略的智慧、可持续性绩效分析，时间跨度为2014年至2020年的规划期

關鍵詞

智慧城市政策,
智慧城市,
基于项目的评估,
智慧,
可持续城市绩效评估

摘要

全球各城市都在考虑数字化转型的机遇。本文针对欧洲联盟首都的可持续城市发展路径，提出了一个基于项目和策略的智慧城市雄心评估。考虑了2014年至2020年的规划期，旨在更好地了解欧洲的智慧城市趋势，并通过欧洲首都之间的智慧城市和可持续发展雄心之间的相关性来进行识别。研究的基础是欧洲基金官方项目结果平台，重点关注与智慧城市相关的优先事项。

跨国智慧城市项目的收集到的最佳实践提供了来自上一个规划期的统计数据，并关注欧洲首都在数字转型方面智慧城市功能和活动水平的发展趋势。结果显示，在2014年至2020年间，将近一半的首都拥有特定的智慧城市战略文件。评估首都的智慧城市绩效时可以说，大多数智慧解决方案是在前一时期与移动性和环境相关的。

此外，还考虑了智慧城市项目是否能促进向可持续发展的转变。基于对其规划战略的评估，揭示了欧洲首都在智慧城市发展理念上的复杂形象；更好地理解了其战略级别规划，这对于数字化时代的政策制定、识别与可持续城市发展雄心的协同以及在城市层面监测已达到的目标至关重要。