Knowledge-Based Approach to Sustainable City Management: An Example of European Smart Cities

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Abstract: This study aims to examine the relationships between the use of knowledge-based approach in key areas of sustainable city management (urban planning, mobility and transportation management, and environment protection) and city's position in the global smart cities ranking (the IESE Cities in Motion Index). A case study methodology is adopted to examine and compare the possibilities of implementing knowledge-based approach in sustainable city management, in order to gain a better understanding of this new urban phenomenon. Data and information about knowledge-based smart city initiatives have been collected from secondary sources. The presented case studies were explored through desk research using online resources, such as the web pages of smart city initiatives. Smart Cities were selected based on their rankings in the IESE Cities in Motion Index. In addition, multiple regressions were used to identify the relationship between the independent variables (environment protection, mobility and transportation management, urban planning) and dependent variable-value of city's ranking in the IESE Cities in Motion Index . The results illustrate that the majority of cities use smart-city solutions in all categories to improve city management, efficiency and achieve sustainability goals. All research hypotheses have been accepted, therefore knowledge-based smart city solutions implemented in all key areas of sustainable city management (urban planning, mobility and transportation management, and environment protection) positively influence performance of achieving sustainability goals. The selection of a limited number of case studies is a limitation of this research. It is therefore important to explore the potential of knowledge-based approach in urban development and city management in more detail by considering more cases. Future research should explore the impacts of other variables related to sustainability, which can determinate performance of sustainable city management. A future study should try to validate the result by using a wider sample. The research combines quantitative and quantitative analysis in order to identify the determinants of effective achievement of sustainable development goals in city management. This study provides a form of grounding for further discussion to debate over of the operational functioning, planning, design, development, and governance of smart sustainable cities in the future.

Keywords: Sustainability, Sustainable Urban Development, Knowledge-Based Approach, Sustainable City Management, Sustainable Smart Cities, the IESE Cities in Motion Index

1. Introduction

Knowledge-based development is a vision of development that considers knowledge as the central structuring element of a development strategy. The smart city must be able to exploit knowledge that result from data management. This knowledge will result in better decisions in order for the modern city to address its main challenges. Smart cities are exposed to technological issues tied to the huge mass of data which pass within them. These data can carry knowledge and, by the way, the city authorities aware of the existence and of the potential of this knowledge, can exploit and use them.

The basis for efficient sustainable city management are effective information flows and ability of knowledge extraction from the fast growing data resources.

The most important challenge for cities authorities now and in the future, in the context of development of sustainable city management, is to integrate the data resources and to deliver valuable information flows for the efficient knowledge management processes for urban development.

The literature does not pay much attention to the organizational and managerial solutions during the transition from a classic city to a smart city, therefore the paper try to explore the potential of the knowledge-based managing of urban development.

The motivation for this study is to identify the main dimensions of the sustainable city management and their influence on a city's position in the global smart cities ranking.

This study aims to examine the relationships between the use of knowledge-based approach in key areas of sustainable city management (urban planning, mobility and transportation management, and environment protection) and city's position in the global smart cities ranking (the IESE Cities in Motion Index).

A case study methodology is adopted to examine and compare the possibilities of implementing knowledge-based approach in sustainable city management, in order to gain a better understanding of this new urban phenomenon. Data and information about knowledge-based smart city initiatives have been collected from

secondary sources. The presented case studies were explored through desk research using online resources, such as the web pages of smart city initiatives. Smart Cities were selected based on their rankings in the IESE Cities in Motion Index. In addition, multiple regressions were used to identify the relationship between the independent variables (environment protection, mobility and transportation management, urban planning) and dependent variable-value of city's ranking in the IESE Cities in Motion Index .

The paper will enable researchers and scholars to direct their future work to the emerging paradigm of knowledge-based smart sustainable urbanism, and practitioners and experts to identify common problems and potential ways to solve them, all as part of future research and practical endeavours. It give also an opportunity to identify areas for further improvement while leveraging areas of strength with regard to the future form of such urbanism.

The paper is structured as follows: After this introduction the next section presents the literature review with discussions of the research model and hypotheses development. Then research methodology is presented in detail. Finally, research findings are outlined and discussed, implications are explored, limitation and futures research are described.

2. Literature Review and Hypotheses Development

Concepts linked to environmental protection to characterise cities have given rise to initiatives and experiments such as green city, eco-city, low carbon city, smart city, evolving towards more integrated approaches to sustainability (Yigitcanlar and Kamruzzaman 2015; Trindade et al. 2017). Mori and Yamashita (2015) view a sustainable city as the one that can generate the maximum socioeconomic benefits for its population without losing the environmental and equity parameters, measured by appropriate indicators.

A smart city, for instance, will seek the goal of achieving its sustainability with the support of modern technologies. In fact, information and communication technologies (ICTs) can bring numerous benefits to cities, but its implementation as an end in itself is not enough to make it a sustainable city (Ahvenniemi et al. 2017).

Knowledge-based development (KBD) is a vision of development that considers knowledge as the central structuring element of a development strategy for cities and regions (Lönnqvist et al. 2014).

Knight (1995) envisioned knowledge-based development of cities as basis for sustainable development, emphasising the relevance of the process of transforming know ledge resources into local development. Following this view, cities should build their own unique knowledge stock by identifying their own particular strengths. This statement on knowledge-based urban development (KBUD) seems very adequate to describe actual challenges. The increasing importance and complexity of the city and the requirement that development is sustainable calls for a new integrative framework for thinking about the development of cities. Urban planners are facing new issues and need new approaches in order to facilitate new forms of development (Knight, 1995).

To construct a knowledge-based social structure, urban planning also needs to incorporate knowledge creation (May and Perry, 2011). Knowledge has become critical to social and economic development, while promoting economic growth and increasing competitiveness.

The integration of technology into urban infrastructure is a significant aspect of a Smart City. This involves the use of Information and Communication Technology (ICT) and other innovative technologies to manage the city's assets, including transportation systems, power plants, water supply networks, waste management, and other community services. The aim of technological integration is to improve the quality of services, reduce costs, optimize resource consumption, and enhance interaction between citizens and the government.

The concept of Smart City seeks to make maximum use of modern technologies, mainly information technologies with the aim of achieving sustainable development goals. Social and environmental sustainability is a major strategic component of smart cities (Lee et al., 2023).

The concept of a Smart City extends beyond mere technological integration. It also encompasses sustainable practices Sustainable practices involve the implementation of strategies aimed at improving environmental sustainability, including the promotion of renewable energy sources, waste management, water conservation, and sustainable urban planning. The goal is to create a city that is not only technologically advanced but also environmentally friendly (Rahmat et al. 2023).

Improving environmental sustainability through anti-pollution plans, support for green buildings and alternative energies, efficient water and waste management, and policies that help counteract the effects of climate change

are essential to ensure the sustainability of cities over time (Su, Hu and Yu, 2023). In light of the aforementioned evidence, the initial hypothesis of this study can be formulated as follows:

H1: Knowledge-based solutions in area of environmental protection positively influence sustainable city management

The application of data-driven solutions within the domain of transport and traffic management is a particularly prevalent phenomenon in the context of both smart cities and sustainable smart cities (Savastano et al., 2023).

The future of urban mobility and transportation is confronted with two significant challenges: facilitating travel over vast territories and ensuring access to public services. The quality of life of a city's inhabitants is affected by mobility and transportation, which encompasses road and route infrastructure, the vehicle fleet, public transit and air transport. These factors can be key to a city's sustainability over time (da Silva, Santos and Setti, 2022).

Artificial intelligence (AI) is now playing a pivotal role in the advancement of urban development. Furthermore, it is assisting local authorities in the collection of data regarding the inhabitants of a given city, thereby facilitating the efficient management of resources. To illustrate, a city that employs AI to mitigate traffic congestion is well-positioned to address its mobility challenges. The utilisation of AI tools facilitates the real-time collection of traffic data, enables the prediction of traffic congestion, enhances mobility and alleviates congestion in key areas (Singh et al., 2022; Cruz and Paulino, 2022). In light of the aforementioned evidence, the second hypothesis of this study is thus proposed:

H2: Knowledge-based solutions in area of mobility and transportation management positively influence sustainable city management

The field of urban planning has historically been regarded as a key driver of sustainable development in urban areas. Consequently, urban planning is inextricably linked to the concept of sustainability. In order to enhance the liveability of any given territory, it is essential to consider local master plans and the design of green areas and spaces intended for public use, while also prioritising smart growth strategies. The objective of new urban planning methods should be the creation of compact, well-connected cities with accessible public services (Son et al., 2023). The management of urban infrastructure represents a significant application of the Internet of Things (IoT) and big data analytics, facilitating monitoring, control, automation, and optimization. This encompasses the operation of roads, railway tracks, bridges, and tunnels (Sanchez et al., 2023). This is pertinent to the occurrences and alterations pertaining to the structural characteristics of urban infrastructure, which have the potential to elevate risk and expenditure, and ultimately compromise safety and service quality. In this regard, the Internet of Things (IoT) devices can be employed to enhance incident management, optimise emergency response coordination and service quality, and reduce operational costs across all infrastructure-related domains (Wang and Yin, 2023). In light of the above, the third hypothesis of this study is as follows:

H3: Knowledge-based solutions in area of urban planning positively influence sustainable city management

Knowledge-based, smart and sustainable city is a conceptual framework that displays a knowledge- based urban development strategy aimed to promote smart and sustainable cities through the operationalisation of a knowledge management integrated approach (Yigitcanlar and Lönnqvist, 2013).

3. Research Methodology

The presented study was conducted in June 2024. Its purpose was to determine the relationship between datafication and a city's position in the global smart cities ranking (IESE Cities in Motion Index 2024).

The IESE Cities in Motion Index is a study published annually by the business school of the University of Navarra (IESE) that aims to evaluate the development of the world's cities. It assesses several socioeconomic aspects of development, including human capital, social cohesion (which includes employment, female participation in the work force, etc.), governance, sustainable development, mobility and transportation, urban planning, international outreach, and technology. IESE Cities in Motion Index offers a platform for a comprehensive initial diagnosis of the cities and, through comparative analysis, aims to serve as the first point of reference. The index compares 183 cities globally, looking at 114 criteria grouped into nine dimensions: human capital, social cohesion, economy, governance, environment, mobility and transportation, urban planning, international profile, and technology (Lai and Cole, 2023).

IESE Cities in Motion Index defines smart city as a way of city governance to maintain future sustainability and the quality of life of inhabitants, which generate business opportunities for collaboration between public and private sectors. (Berrone & Ricart, 2020).

A case study methodology is adopted to examine and compare the possibilities of implementing knowledge-based approaches in sustainable city management, in order to gain a better understanding of this new urban phenomenon. Data and information about city initiatives have been collected from secondary sources. The presented case studies were explored through desk research using online resources, such as the web pages of smart city initiatives. Smart Cities were selected based on their rankings in the IESE Cities in Motion Index 2024.

In addition, multiple regressions were used to identify the relationship between the independent variables (environment protection, mobility and transportation management, urban planning) and dependent variable - value of city's ranking in the IESE Cities in Motion Index. The IESE Index were selected on the basis of temporal and thematic relevance, as it reflects the current results in several indicators, which are the priority indicators of city's technological development and sustainability.

The table below (Table 1) presents the values of dimensions related to sustainability according to IESE Cities in Motion Index 2024.

Table 1: The results from the IESE Cities in Motion Index 2024- the value of dependent and independent variables

City	Value of IESE Cities in Motion Index (dependent variable)	Value of independent variables according to IESE Cities in Motion Index indicators		
		Environment protection	Mobility and transportation management	Urban planning
Amsterdam-Netherlands	72.21	21	28	5
Barcelona - Spain	64.17	68	11	15
Berlin-Germany	75.66	10	9	4
Bilbao - Spain	47.66	61	55	93
Brussels-Belgium	56.04	72	23	33
Copenhagen-Denmark	70.68	3	19	39
London - United Kingdom	100.00	24	4	1
Paris- France	84.29	53	6	13
Stockholm - Sweden	66.64	6	14	60
Turin - Italy	48.49	81	36	40
Vienna - Austria	65.86	17	12	10

Source: The IESE Cities in Motion Index 2024

Environment protection refers directly to the notion of sustainable urban development. Green technologies, green buildings, renewable energy, efficient waste management, reliable water supply, and methods to counter climate change are essential. These measures determine the long-term sustainability of smart cities. It is also essential to consider elements such as the promotion of environmental sustainability through anti-pollution strategies, measures to support green buildings and alternative energy sources, adequate water and waste management, and the implementation of policies that mitigate the impacts of climate change to ensure the long-term resilience of cities.

Urban planning means the design process that determines the components required for the construction of a city. Planning enables the efficient construction of a city while ensuring a high standard of quality of life. Currently, urban planning is inextricably linked with sustainability. To enhance the quality of life in any urban area, it is crucial to consider local master plans and the design of green spaces and public areas, and to promote sustainable and intelligent urban development, with convenient access to essential public services.

Transportation management and smart mobility are core elements of sustainable city management. Smart mobility is also one of the main areas of the smart city concept. Mobility represents, in a narrower sense, the movement of inhabitants. In a broader sense, it refers to access to services, health, and social care, but also, for example, the ability to commute for education, work, family, recreation and so on. The difference between mobility and smart mobility lies in the public's access to different information in real time. In the short term, the goal of smart mobility is to manage and monitor the transport of the population in real time. As for the long-term goal, it is about developing innovative and sustainable transport systems and making the transport and logistics solution of a given smart city more efficient. Smart mobility priorities include, for example, reducing environmental pollution, reducing traffic congestion, making citizens' mobility more efficient or reducing noise in the city (Simonofski, A., et al. 2023).

4. Results and Discussion

This section presents data obtained through secondary analysis of best practice strategies from selected sustainable smart cities. A case-study approach was used to explore the role of knowledge-based solutions in sustainable city management.

A sample of 11 case studies that use knowledge- based solutions (in form of data-driven applications) deployed in real-world settings were identified from secondary sources. All analyzed cities are included in the IESE Cities in Motion Index 2024 and they have been also included in the regression analysis. The results are presented in the Table 2.

Table 2: Knowledge-based smart city solutions (in form of data-driven applications) related to sustainable city management – results of case study analysis

City	Examples of knowledge-based solutions (in the form of data-driven applications) related to sustainable city management
Amsterdam- Netherlands	• Smart lighting controls for energy efficiency and saving • Traffic reduction
Barcelona - Spain	• Communication and green technologies • Smart water efficiency • Smart public transportation • Smart noise control solutions
Berlin-Germany	• Smart metering • Smart transport systems
Bilbao - Spain	• Smart parking systems
Brussels-Belgium	• Energy efficiency through smart sensors • Smart mobility systems • Real-time transportation information • Waste management • Environmental monitoring
Copenhagen- Denmark	• Smart energy incubators and energy labs smart transport systems • Smart noise control solutions
London - United Kingdom	• Green and smart technology application in transport and parking -pollution and congestion control • Smart noise control solutions
Paris- France	• Smart applications for lighting, road circulation, waste management and environment monitoring • Online transportation control system
Stockholm - Sweden	• Fiber optic communication network • Smart noise control solutions
Turin - Italy	• Smart meters
Vienna - Austria	• Energy efficiency via smart sensors • Smart mobility systems

Source: own study

The results demonstrate that the majority of smart cities employ knowledge-based solutions in the form of data-driven applications across all categories with the objective of enhancing city management efficiency and achieving sustainability goals. The most prevalent data-driven solutions identified include transport and traffic, mobility, energy, power grid, environment, buildings, infrastructure and urban planning.

A variety of data-driven traffic control systems have been implemented with the objective of optimising the performance of city services. These include systems which provide interactive notifications of parking availability and distribution, as well as bike and car sharing, digital public transit payment, predictive maintenance of transportation infrastructure, real-time public transit information, and road navigation. These applications facilitate agent-based simulations of transport systems and the myriad of scenarios they may encounter. This enables the development of sophisticated systems capable of integrating and responding to a multitude of entities, including the shortest routes, minimal waiting times, and diversions that are aware of traffic congestion, thereby providing optimal traffic solutions.

Cities employ data-driven technology for the management of transport and traffic. This encompasses the administration of transport services based on the data received, as well as the automated control of traffic signals based on data collected on traffic congestion using sensors embedded in the traffic lights.

The utilisation of advanced technologies, facilitated by the city's Wi-Fi network, enables the real-time monitoring of air quality in terms of the presence of various substances. This allows for the implementation of timely preventive measures and the monitoring of the condition and composition of green space in urban areas. The real-time data collected about the air quality in the city are subjected to analysis in order to determine the impact of the solutions that have been adopted in terms of improving environmental conditions, as well as to identify the areas where further actions are needed. The deployment of low-cost sensors in urban areas enables the detection of noise levels and pollution, facilitating the identification and mitigation of violations pertaining to municipal policies on these matters. The implementation of smart noise control solutions in urban environments facilitates the optimisation and centralisation of data collection, integration, processing, analysis, and dissemination by unifying the information obtained from noise sensors produced by different suppliers and sound level meters distributed throughout the city.

The application of a knowledge-based approach to urban planning, coupled with an analysis of data pertaining to the population, enables the consideration of emerging demands for the development of various venues. In other words, the utilisation of data-driven technology in planning is associated with the planning of districts, streets, and urban infrastructure based on the collection of information on the movement of residents and their activities.

In addition, multiple regressions were used to identify the relationship between the independent variables (environment protection, mobility and transportation management, urban planning) and dependent variable - value of the IESE Cities in Motion Index 2024 .The results of regression analysis have been shown in the table 3.

Table 3: The results of regression analysis

Independent variables	Standardized coefficients	t	Significance level
	Beta		
Environment protection	0,386	4,367	0,000
Mobility and transportation management	0,369	3,841	0,000
Urban planning	0,391	4,673	0,000
Dependent variable: value of the IESE Cities in Motion Index 2024 . R^2 = 0,827, F = 28, 394, significance level = 0,01.			

Source: own study

The result shows that R-square was 0,827, which demonstrates that independent variables explain 82,7 % of the variance in value of the IESE Cities in Motion Index. The linear relationship between independent variables (environment protection, mobility and transport management and urban planning) with value of the IESE Cities in Motion Index is significant with an F-value of 28,394 at the 0,01 significance level. Therefore, the model fits this study.

The significance level of environment protection with value of IESE Cities in Motion Index was 0,000, which is less than 0,05. Therefore Hypothesis 1 is accepted. Environment protection was the second highest coefficient (beta = 0,386), hence, higher level of data-driven solutions related to sustainability positively influences the value of the IESE Cities in Motion Index and a city's position in the global smart cities ranking.

The significance level of mobility and transportation management with in value of IESE Cities in Motion Index was 0,000, hence, Hypothesis 2 is accepted. The beta value for this variable was 0,369. Therefore, higher level of level of data-driven solutions related to mobility and transportation management has a significant positive effect on the value of the IESE Cities in Motion Index and a city's position in the global smart cities ranking.

The significance level of urban planning with the value of the IESE Cities in Motion Index was 0,000, therefore, Hypothesis 3 is accepted. The test also showed that urban planning had the highest coefficient (beta = 0,391) compared to others independent variables. In other words, sustainable urban planning has the highest positive impact on city's position in IESE Cities in Motion Index.

This study demonstrates that the cities exhibit a high level of advancement in knowledge-based solutions, manifested in the form of applied data-driven technologies. However, there is a slight discrepancy in the implementation of such technologies across different city systems and domains with respect to sustainability areas. Furthermore, there is a moderate discrepancy in the level of preparedness with regard to the availability and advancement of the competencies and infrastructure required to generate, transmit, process, and analyse vast quantities of data in order to extract valuable insights for improved decision-making and a deeper understanding of urban operational functioning, management, and planning in relation to sustainability.

5. Conclusion

The potential of knowledge-based solutions lies in their capacity to facilitate the development of smart sustainable cities. By leveraging their informational landscape, these solutions can enable cities to understand, monitor, probe, and plan their systems and environments in ways that facilitate the achievement of optimal sustainability. Furthermore, they are providing novel avenues for more judicious decision-making with regard to the knowledge required to monitor, comprehend, and plan the development of cities in a more effective manner.
A considerable number of smart cities around the world have initiated investigations into the potential of knowledge-based solutions for addressing and overcoming the significant issues and complex challenges associated with sustainability and urbanisation.

In terms of the value of this work, the outcome will assist strategic city stakeholders in understanding the potential actions and investments that could be made to advance smart sustainable urbanism on the basis of knowledge-based solutions and approaches. Furthermore, it will provide an opportunity to identify areas for further improvement while leveraging areas of strength with regard to the future form of such urbanism. Furthermore, it will facilitate the direction of future research and practical endeavours by scholars and practitioners towards the emerging paradigm of knowledge-based sustainable urbanism.

Finally, this paper provides a foundation for further discussion and debate regarding the operational functioning, planning, design, development, and governance of smart sustainable cities in the future. Furthermore, it provides a foundation for further research, including both qualitative and quantitative studies, on the relevance of knowledge-based solutions and their role in accelerating sustainable development.

The research presented here combines quantitative and qualitative analysis in order to identify the factors that contribute to the effective achievement of sustainable development goals in city management.

It is evident that the choice of a restricted number of case studies represents a limitation of this research. It is therefore important to explore the potential of knowledge-based smart city solutions in urban development and city management in greater depth, with a view to considering a larger number of cases. Nevertheless, an analysis of the best practices identified in the selected case studies can provide valuable insights and practical guidelines for the development of a smart city model.

Further research is required to investigate the influence of additional variables associated with sustainability, which can be used to assess the efficacy of sustainable city management practices. A subsequent study should endeavour to corroborate the findings by utilising a more extensive sample.

Moreover, as this study has demonstrated that applied technological solutions already exist in many cities, it would be highly beneficial to conduct a more expansive and diverse comparison involving a greater number of cities with the aim of elucidating the most pervasive trends in knowledge-based sustainable city management.

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