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Alessandra Battisti · Cristina Piselli · Eric J Strauss ·
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Greening Our Cities: Sustainable Urbanism for a Greener Future

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Alessandra Battisti • Cristina Piselli •
Eric J Strauss • Etleva Dobjani •
Saimir Kristo
Editors

Greening Our Cities: Sustainable Urbanism for a Greener Future

A Culmination of Selected Research Papers from the International Conferences on Green Urbanism (GU)—6th edition and Urban Regeneration and Sustainability (URS)—2022

Springer

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Preface

Adaptation of Urban Environments Through Regeneration

It is with great pleasure and anticipation that we present to you the Springer Book of Conference, "Adaptation of Urban Environments through Regeneration." This compilation of articles brings together an array of distinguished researchers and practitioners who have delved into the pressing topic of urban regeneration—an imperative aspect of sustainable urban development.

Cities, with their dynamic and ever-expanding nature, are the epitome of human progress and civilization. However, rapid urbanization has brought about numerous challenges, including environmental degradation, social inequalities and the loss of cultural heritage. In response to these pressing concerns, urban regeneration has emerged as a powerful tool to breathe new life into cities, reinvigorate communities and harmonize the relationship between urban spaces and nature.

This book is not merely an assortment of academic papers; it represents a collective endeavour to understand and address the complexities of urban regeneration. Each article offers unique insights into various aspects of the subject, encompassing green urbanism, nature-based solutions, challenges of regeneration, design methodologies, developmental strategies and preservation of cultural and natural assets.

The articles within these pages transcend the conventional boundaries of urban planning and engineering. They exemplify the interdisciplinary nature of urban regeneration, drawing upon expertise from architecture, environmental science, sociology, economics and beyond. As we navigate through the sections, readers will discover innovative approaches and practical solutions that can foster sustainable urban development across different contexts and regions.

The authors dedication to their respective fields is evident in the depth of research, the rigor of analysis and the clarity of presentation. We express our heartfelt gratitude to each of them for their invaluable contributions, which have enriched this compendium and will undoubtedly stimulate interest in the subject matter.

As editors, it is our hope that this book becomes a source of inspiration for researchers, policymakers and urban planners alike. By assimilating the knowledge shared in these pages, we can collectively pave the way for cities that are ecologically balanced, socially inclusive and culturally vibrant.

"Greening Our Cities: Sustainable Urbanism for a Greener Future" embarks on a journey to reimagine cities as sustainable and resilient hubs of human civilization. Let us embrace this endeavour, fostering a future where urban environments flourish in harmony with nature, heritage and the aspirations of their inhabitants.

Tirana, Albania

Etleva Dobjani, Ph.D. Arch.
Saimir Kristo, Ph.D. Arch.

Acknowledgements The book Editors would like to thank the authors of the chapters of this book for providing high-quality research discussions. They would also like to thank the scientific committee of the reviewers for contributing with their knowledge and constructive feedback to improve the papers and ensure they are of the best quality possible. Finally, the Editors would like to express their appreciation to the IEREK team for supporting the selection of the best research papers submitted to the conference and the successful publication of this book.

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Introduction

Fragments of a World We Would Like to Live In

Alessandra Battisti

Abstract

The recent global transformation is leading us toward an unpredictable future, an unknown territory in front of which there is a need for a global vision that underpins a new humanism and a complex network of objectives in coherence with international and European targets. The goal of sustaining human life on this planet implies intertwined objectives, including improving quality of life through energy, ecological, and digital transitions, limiting resource, land, and energy consumption, ensuring the sustainability of buildings and infrastructure, and adapting and mitigating climate change.

In light of current global events such as climate change, diseases, and conflicts, it is more important than ever to rethink human habitats and carefully reconsider "how we would like to live" in the future. A multidisciplinary approach set at the intersection of exact sciences, human sciences, urban planning, and technology is required to drive research in this direction, in order to study architecture and cities in a global context and to intervene correctly on them by interpreting history and society through the lens of spatial and social justice.

This book seeks possible answers to the question of what happens to the built urban environment and the landscape in times that require urgent and effective responses to global challenges, a time when information and communication technologies not only redesign the transformations occurring in our social system, but also force to rethink the places of politics, to break down borders, and deny the very constraints of space and time. Extremely urgent responses are required, considering that 7 years have already passed since the Paris Agreement on the occasion of COP21 (Moosmann et al., 2017), and that in 7 years time, we extremely urgent responses, given that it has already been 7 years since the Paris Agreement was signed on the occasion of COP21 (Moosmann et al., 2017), and in 7 years time, in 2030, the signatory nations are expected to have reduced emissions of 43% and have change their energy-intensive and polluting lifestyles (IPCC: Summary for Policymakers., 2023).

The essays, divided into six parts, retrace, articulate, and introduce solutions for achieving the ecological, energy, and digital transition in a phase in which downscaling processes, fine-tuning the current vast area strategies, require us to act urgently on the future of the built environment in relation to the capacity for resilience and adaptation to climate change, as well as that of resilience and adaptation to problems related to the progressive limitation and non-renewability of resources. The contributions provide us with a framework in which cities, the highest and most tangible expression of human effort on the planet, are called upon to address these critical challenges immediately in a line with an imperative resilient approach (Lewis & Conaty, 2012).

In this logical framework, the book attempts to provide fragments of visions through which we imagine the future of our living environment, our lifestyles within cities and in rural environments anywhere in the world, and that reflect different cultural, environmental, economic, and social conditions capable of ensuring an architecture of humanity. The essays in this volume deal with ambitious goals, describing practices and experiences in line with the Paris agreements and the European New Deal, ranging from energy and ecological efficiency to digitalization, from culture to sustainable mobility. All local governments are expected to address these topics with the creation of services and policies oriented toward environmental sustainability, circular economy, and social inclusion, through medium and long-term planning.

In relation to the urban regeneration design research experiments illustrated in this volume, several reflections arise. The most important one concerns the governance of complexity, relationships and location, functions and

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intended uses, which, in order to become environmentally sustainable and enhance diversity, requires addressing and controlling the systemization of territorial networks at all levels: social, cultural, anthropic, biophysical, and bioclimatic. Taking into account, the territory not only implies paying attention to the context but it also becomes the real driver for enhancing the urban identity in which the settled community may recognize itself. Hence, the importance of building an infrastructural network designed with the inhabitants, involving the reorganization of the mobility network, urban voids, margins, and collective services in order to weave significant relationships, able to influence the inhabitants' forms of life and relationships.

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Green Urbanism

Evaluating Sustainable Urban Mobility Strategies as a Tool to Provide Balance of Centrality Levels in Budapest City

Ola Qasseer and Gábor Szalkai

Abstract

The absence of balance among different urban areas and the centralization/decentralization aspects is one of the challenges that the cities have been facing. The level of centrality affects the distribution of the activities in the city. It also results in the marginality of other areas which face serious problems and may cause an obstacle to the development of a sustainable city. Transportation networks play an essential role in enforcing or weakening the level of centrality. This could be found in the proposed case study of Budapest where the distribution of transportation networks is a major contributor to the different levels of centrality among various urban areas. But, is Budapest city capable of overcoming the different levels of centrality, limiting the centrality problems; congestion, pollution, inequality, etc., and moving toward a more balanced city with strategies of Urban Sustainable Mobility? This will be examined in the proposed research by measuring the centrality levels via transportation networks, specifying the levels of the centrality of the different urban areas, evaluating the situation, and revising the plans of the responsible agencies of transportation for promoting sustainability. Achieving the previously mentioned steps and defining the path of Budapest towards more sustainable transport will help in providing an introduction for developing transportation strategies and improving Sustainable Urban Mobility criteria to provide balance for the different urban areas and reduce the problems of centrality.

Keywords

Sustainable urban mobility • Centrality • Transportation networks • Transportation strategies • Budapest city

1 Introduction

Cities are complex component of human activities including commercial, touristic, and cultural events (Neal, 2013; Öğdül, 2010). The concentration of activities in urban areas made cities more important and central. This centralization led to the migration of poor people to the city's surrounding areas (Deffner et al., 2012). As a result of the different characteristics of centrality in each urban place (Abdullahi et al., 2017), the centrality level limits the residential use in central areas in some cases (Bunting et al., 2000), and affects the growth of the city (Porta et al., 2009). Replacing the concentrated urban shape with decentralized development after the Second World War affected the distribution of different functions in the city (Garreau, 1991), and encouraged exclusiveness and exclusion (Mace, 2009). In other words, the differences in centralization levels among urban areas caused uneven possibilities and unequal distribution of suitable opportunities (Gutierrez, 2009). One of these opportunities is the access to transportation modes (Hine, 2009). Accessibility and the characteristics of transportation systems affect the centrality level (Abdullahi et al., 2017; Porta et al., 2009) and the attractiveness of a specific place (Banister & Lichfield, 1995). Central places are more likely to be close to street intersections (Porta et al., 2009), due to the important role of road networks in influencing the locations of activities (Miranda et al., 2020). These networks could make a location more central by improving its closeness to other locations (Li et al., 2017). In other words, geographical locations and the development of transportation systems affect the accessibility level by enforcing the central positions for some areas and resulting in the

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peripheral locations for other places (Gutierrez, 2009). Hence, the development and rapid increase of urban transportation has caused many problems for the city. These problems could be summarized as follows; congestion, crowding during peak hours, difficulties in walking, pollution, road accidents, and parking shortage issues (Pacione, 2005). Here, the role of transport planning appears by providing safety, security, equity, environmental protection, and accessibility for all residents (Deffner et al., 2012). Hence, transport planners and urban designers have the responsibility of providing a balanced environment and improving transport for healthier cities (Giles-Corti, 2006), especially with the development of working styles, technological solutions, big data, and the changes in mobility attitudes for the young generations (Stadt Wien, 2014a).

After designing the cities to suit cars, there is a chance now for people to move toward more eco-friendly mobility by using public transportation, cycling, and walking (Stadt Wien, 2014b). Using cars and planning new streets were considered modern during the 1960s, while cycling and walking were considered outdated. It was considered smart for planners to design cities around private cars, remove the cycling and tram lines, and encourage the development of automobility. All that has led to many troubles and consequences in our current cities (Knoflacher et al., 2018). Utilizing land-use planning has a significant role in this regard by reducing traffic, the length of trips, and motorized transportation. It encourages walking, cycling, and developing public transportation facilities which represent the basic concepts for sustainable transportation planning (Deffner et al., 2012). Sustainable Urban Mobility (SUM) could provide equality and improve the quality of life (European Economic and Social Committee, 2022). It improves the accessibility of urban areas and provides more balanced and integrated modes (Interreg Europe, 2018), which could contribute to more balanced and sustainable cities.

2 Budapest City

Similar to what happened in other cities after the spread of the motorized automobile, Budapest also witnessed the removal of tram lines and the planning of its areas according to the movements of cars. This has resulted in a high level of fragmentation, pollution, and lack of cooperation (Budapest Főváros Önkormányzata & BKK Budapesti Közlekedési Központ, 2019). The agglomerations around the city generate a high number of daily car trips. People living in these agglomerations around Budapest are more likely to work, study, and do plenty of activities in Budapest city every day (H2020-Flow, 2015; Budapestvasut, n.d.). The capital city also faces many challenges like congestion and poor level of intermodal interchanges and connections (H2020-Flow, 2015). It has faced real problems regarding pollution, weak cycling services, undeveloped transportation in suburban areas, and the focus on motorized mobility more than the sustainable approaches (Budapest Főváros Önkormányzata & BKK Budapesti Közlekedési Központ, 2019). With more than 1.7 million of population and the daily commuting inside the city and from the surrounding agglomerations, will Budapest be able to control its varied levels of centrality and move to becoming a more balanced and sustainable city?

3 Methodology

The research starts with measuring the centrality of urban areas through public transportation networks. To start the process, all the needed data was requested and collected from the transportation agencies (the public transportation company in Budapest city, the railways company, and the regional buses company); BKK, MÁV-START, and Volánbusz. The data includes the shape files of all routes and stops inside Budapest city and its agglomerations, the number of trips on each route per day, the average number of passengers per day, the average number of boarding passengers per day at each stop, and the average number of alighting passengers per day at each stop. The measurements start with building the network by defining its nodes (the stops and stations of the public transportation) and its edges (the route between every two consecutive stops), then applying the centrality measurements with the help of the GIS environment using Arc Map 10.5 version. To measure the centrality, six measurements are applied. The first measurement includes the visualization of the boarding passengers at each stop (node) and categorization the percentage of the passengers. The second measurement applies the same aforementioned criteria to the number of alighting passengers. The third measurement is concerned with degree centrality to measure the number of connections with each node. This was achieved with the help of Arc Map to produce the count of connections to each node and then to visualize them on the map. The last three measurements are the measurements of Multiple Centrality Assessments (MCA); closeness centrality, betweenness centrality, and straightness centrality. The MCA measurements represent the level of the centrality of each node by its closeness to other nodes in the network, its location between other nodes, and its position on straight routes that connect it with other nodes in the network (Porta et al., 2009). These MCA measurements were measured by calculating the real distances and Euclidean distances between all nodes using network analysis tool in Arc Map, then calculating the level of centrality by applying the needed mathematical equations, and finally visualizing the results of different levels of centrality via maps.

The levels of centrality through the six measurements are visualized and categorized to define the areas with the highest levels among the other nodes of the network. The results are compared with the distribution of land use in the city by observing the connectivity of these nodes, the activities and functions in the surrounding urban areas, and the locations of the nodes in Budapest city. This comparison could represent the related factors causing the differences in centrality level throughout different urban areas and the role of transportation systems in enforcing or weakening this centrality.

The final step in the analysis contains the revision of the suggested published plans by the agencies of transportation and the municipality to propose a roadmap of enhancing the sustainable urban mobility. Defining the main steps and initiating an evaluation of local strategies will help in understanding their role in providing a more balanced urban structure and overcoming the different levels of centrality toward a more sustainable city.

4 Results and Discussion

4.1 Centrality Levels in Budapest

The analyzed network contains 8128 nodes and 57,902,649 edges. The centrality measurements of the built network shows significant differences in centrality levels between different urban areas in the city. The spatial distribution of the nodes with the highest levels of centrality also varied between the six measurements, see Fig. 1. Despite these differences, significant similarities are found in the distribution of the nodes that achieve the highest levels in the number of boarding passengers (Fig. 1a) with the nodes that achieve the highest levels in the number of alighting passengers (Fig. 1b). This could be related to the importance of the locations of these nodes to the daily commuting of passengers to and from these locations. The nodes with the highest levels of degree centrality (Fig. 1c) are also similar in their spatial distribution to the nodes with the highest levels of betweenness centrality (Fig. 1e). As the measurement of degree centrality deals with the number of connections of each node, these connections could support the location of the node between other nodes and increase the level of betweenness centrality. Other similarities are found in the spatial distribution of the nodes with the highest levels of closeness centrality (Fig. 1d) and the nodes with the highest levels of straightness centrality (Fig. 1f). This could be explained by the fact that the nodes that are located on the straightest routes could be closer to other nodes in the network.

It could be noticed that some nodes with a high level of centrality are located in the outer parts of the city. This could be a result of the disconnectivity in some sections of the network and the concentration of nodes in other sections of the network because of the several networks that were considered in the analysis. As a result, some nodes in these parts have a higher level of centrality according to their adjacent urban areas. However, these nodes do not have a great effect when considering the combination of the six measurements to find the nodes that achieve higher levels according to different aspects.

Out of 8128 nodes, the numbers of nodes with the highest levels of centrality according to the applied measurements are as follows; 18 nodes with the highest number of boarding passengers, 17 nodes with the highest number of alighting passengers, 138 nodes with the highest level of degree centrality, 88 nodes with the highest level of closeness centrality, 112 nodes with the highest level of betweenness centrality, and 181 nodes with the highest level of straightness centrality. As a result of the combination of the six measurements, only 7 nodes score the highest level of centrality among several measurements, see Fig. 2.

Two nodes of the final seven nodes, node number 1 and node number 2, represent the main centers in Budapest city. They are located in the central areas of Budapest where the commercial and services sectors are. They also represent important squares that attract transportation and where different modes of several essential routes intersect. Node number 1 is the intersection of three different metro lines out of the four metro lines in the city, one trolley bus line, three tram lines, and six bus lines. The average number of passengers who cross this node exceeds 1,100,000 passengers per day. Node number 2 is an intersection of two metro lines, two trolley bus lines, three tram lines, and four bus lines. This node is also crossed by more than 880,000 passengers per day. On the other hand, the other five nodes are not central in their locations in the city but they scored a high level of centrality according to their position in the network. They are mainly located on the railways that connect the city with other Hungarian cities and with the Budapest agglomerations or close to these routes. Node number 3 is located or close to several public transportation lines that connect the southern parts with the main centers of the city. This area is crossed by two tram lines and 16 bus lines in addition to a regional bus line. Around 165,000 passengers use the lines through this node. Node number 4 is located on one of the main suburban railway lines. This line connects Csepel (the southern island) with the city. It is also close to one of the railways that connect Budapest with the southern cities in Hungary. In addition to one suburban railway line, 12 bus lines, three tram lines, and regional bus lines are crossing this area. Some of these routes also connect the area with the main centers in the city. More than 155,000 passengers cross

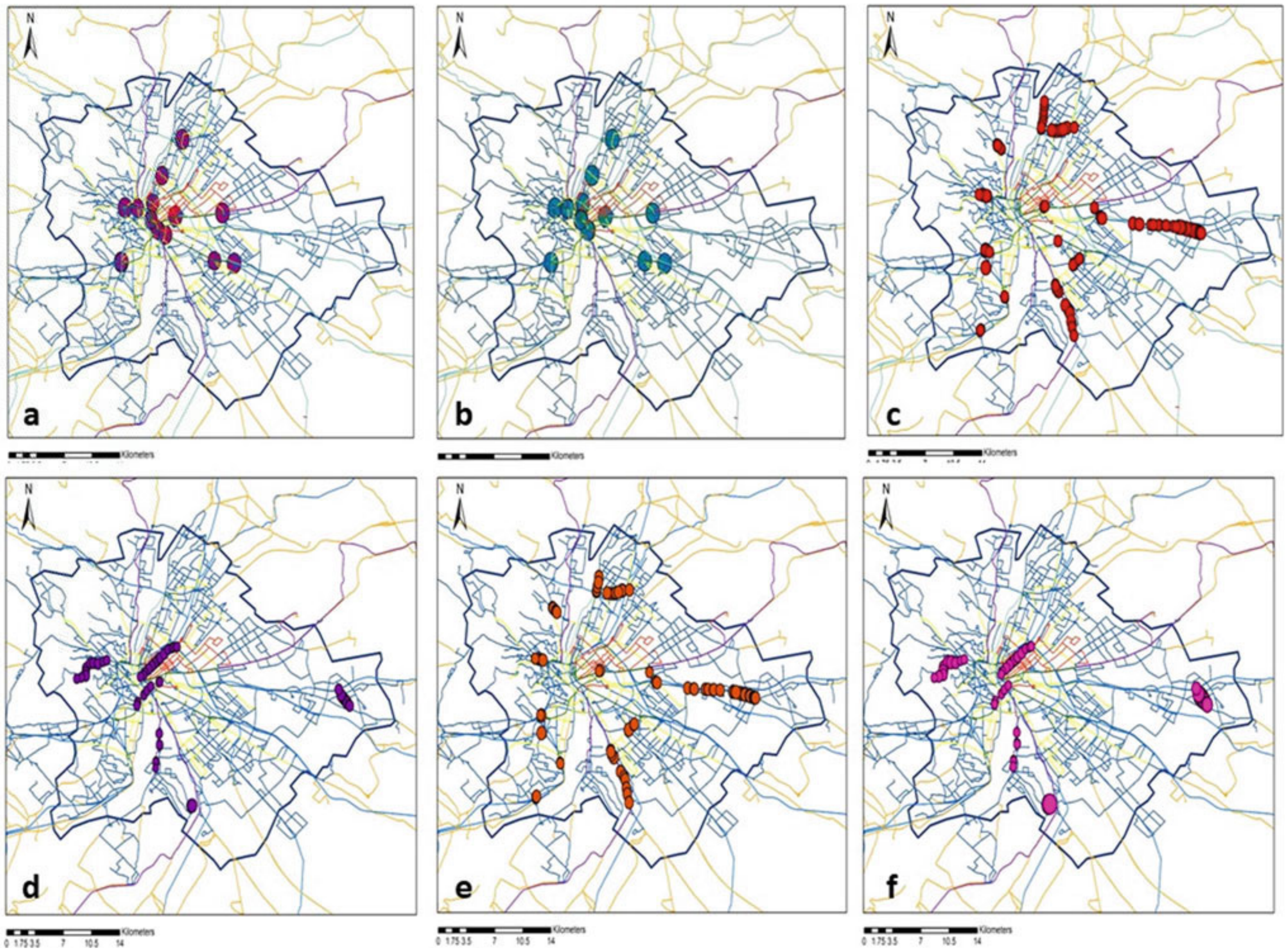

Fig. 1 The spatial distribution of the nodes with the highest levels of centrality according to the six measurements; **a** boarding passengers, **b** alighting passengers, **c** degree centrality, **d** closeness centrality, **e** betweenness centrality, **f** straightness centrality. *Source* Authors

this area per day. Node number 5 is also close to the railway lines and regional buses that connect Budapest with the southeastern cities in Hungary. It is the connection point of five trams and 16 buses. Every day, around 160,000 passengers pass by this area. The last two nodes also represent important nodes along the railway lines to the eastern part of Hungary. They are linked to 10 bus lines and are crossed by more than 150,000 passengers per day.

It was noticed that the highest number of nodes is located on the eastern side of the city (Pest side) where the highest percentage of non-residential activities is located, and the commercial and service functions are concentrated. It was obvious from the analysis that the railways and regional bus networks affected the results of the centrality measurements. The analysis presented the nodes that represent the surrounding connections of the city with its central locations. This shows the important effect of the daily commuting of the suburbs and agglomeration residents to Budapest city and presents the necessity of developing the transportation networks for these areas to reduce the urban problems. Considering only the public transportation network inside the city might highlight more results about the different levels of centrality in the parts of the inner city. This will be presented in the future research to acquire a more comprehensive perspective of the different levels of centrality by the effect of the local public transportation network in Budapest city. Achieving this measurement might help consider all the aspects in the analysis process.

4.2 Sustainable Urban Mobility Strategies in Budapest City

The main strategies for Sustainable Urban Mobility in Budapest city were initiated by the "Balázs Mór Plan" (USER-CHI, n.d.; Budapest Főváros Önkormányzata & BKK Budapesti Közlekedési Központ, 2019). This plan aims to provide integrated network development, green

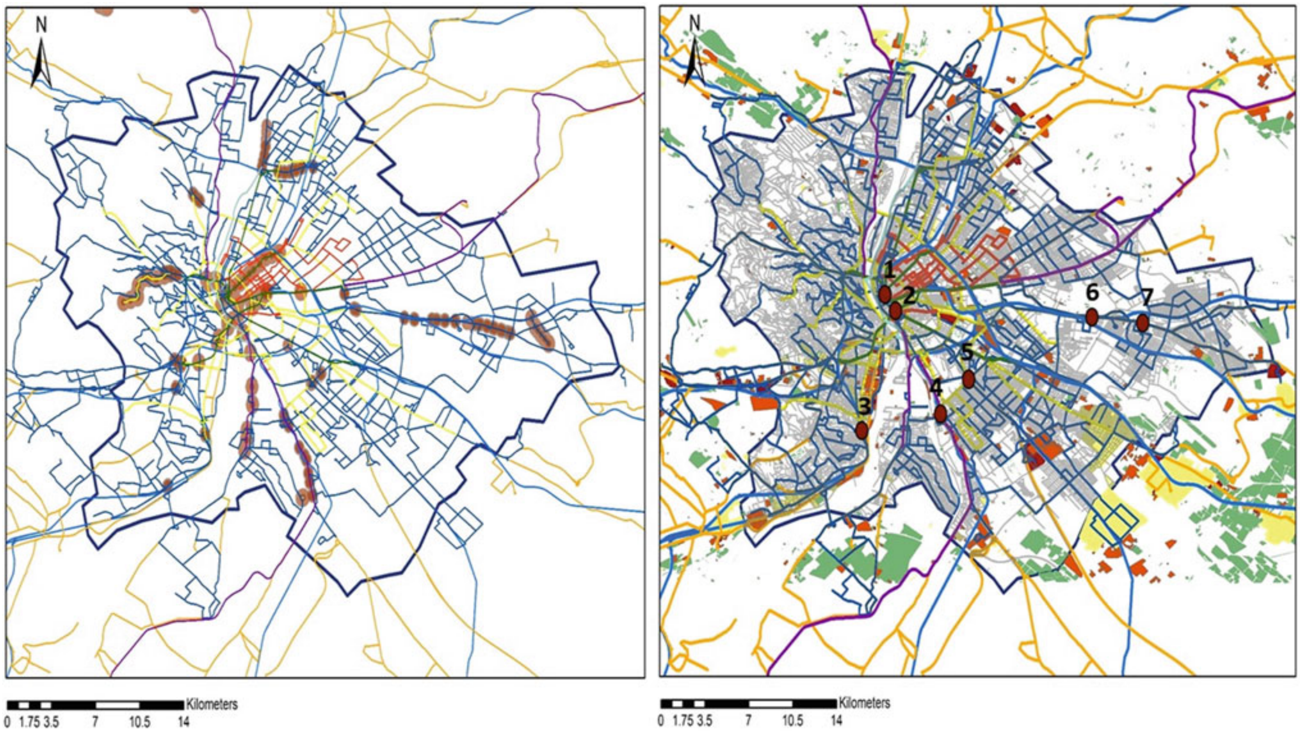

Fig. 2 The nodes with the highest levels of centrality after combining the six measurements and choosing the nodes that achieve the highest level of centrality among several measurements. *Source* Authors

technology, environmental-friendly vehicles, and regional cooperation. It opens a new chapter of transport planning in Budapest to improve urban life and to limit the pollution of the different transport modes. Providing more connectivity, more availability, and a more integrated network are the main directions of this plan. One of the main objectives is to develop the network in suburban areas on an equivalent level to the inner city, to provide more connections via different modes in the outer parts of the city, and to integrate the bike routes with the public transportation network. Another focusing point is to improve accessibility and restore the unity of the city's network. It also focuses on developing the radial connected routes to decrease the movements through the center when it is not needed for the passenger and equipping the city's transport structure with more Danube crossings. Regarding cycling activities, the plan aims to increase the cycling routes, to develop their connections with the transportation network, and to improve their connectivity with regional areas (Budapest Főváros Önkormányzata & BKK Budapesti Közlekedési Központ, 2019). This is what BKK aims to achieve through its service MOL Bubi to provide a fast and eco-friendly alternative by using bike sharing which could be combined with other forms of public transport (MOL Bubi Budapest, n.d.). Another strategy for sustainable urban mobility is the integrated e-mobility concept to reduce the emissions of transport vehicles (USER-CHI, n.d.). Improving cycling networks in Budapest agglomerations connecting them to the city network was also one of the strategies toward more sustainable mobility (Mobilissimus, n.d.). This strategy also aims to connect the cycling network with the railway network, so users can reach close train and bus stops easily (NKK, n.d.). This is accompanied by the development of suburban railways which, started in 2019, and aims to increase the total number of passengers on suburban railway lines by 80% by 2040. It also aims to develop the connections of railways inside the city and increase the capacity so suburban commuters can reach more points than a few limited terminals. Developing the southern rail belt that passes on one of the city's southern bridges is also one of the main goals of this strategy. It aims to increase the capacity of the bridge and to establish more stops inside the city in order to increase the connectivity with other modes of transportation. Another proposal in this strategy was initiating the railway tunnel under the Danube to raise the capacity of railways too and to develop and improve two of the main train stations in Budapest (Budapestvasut, n.d.). Building more connections between Buda and pest sides is also one of the major concerns to increase connectivity and develop accessibility in the city. The project of the new Budapest bridge aims to achieve this goal by improving the connectivity in the southern part of the city (UNStudio, 2018). It is also important to mention the

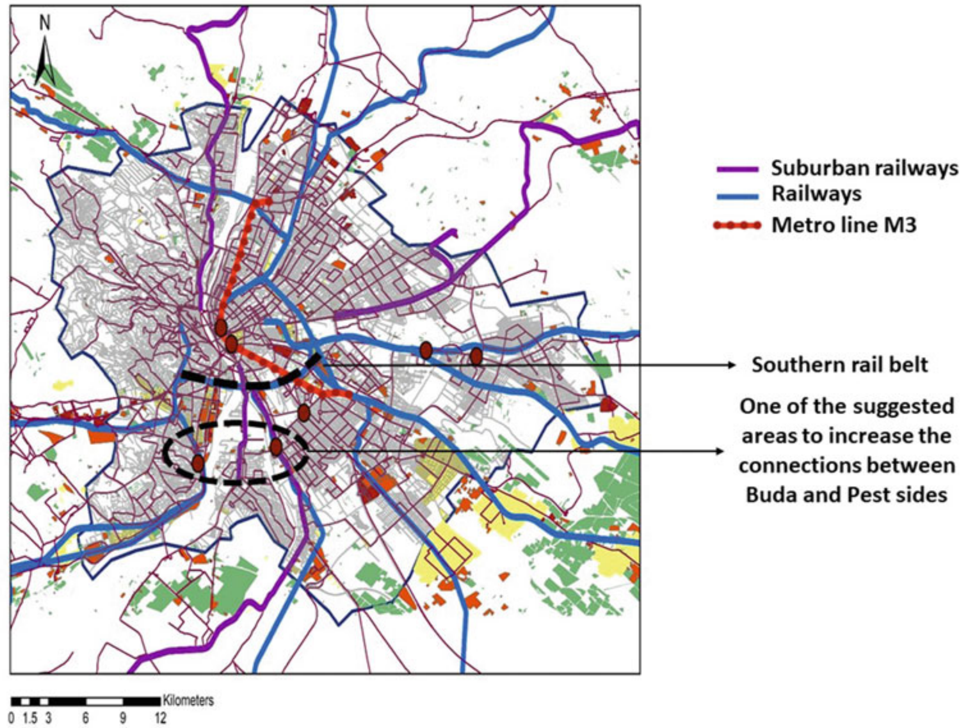

Fig. 3 The relation of the suggested strategies with the network of transportation. *Source* Authors

reconstruction project of metro line M3 that started to develop one of the main lines in the city in order to provide more comfortable service and to improve its connectivity with other routes of public transportation (Official Website of the Reconstruction Project of Metro Line M3, n.d.).

When comparing these strategies with the results of centrality measurements, the importance of developing transportation networks in suburban areas could be noticed. As presented in the measurements, the suburban and outer parts of the city play an essential role in affecting the centrality levels between different nodes because of the high commuting percentage from and to these areas. Developing the transportation networks in these areas could provide more balance to the different parts of the city. In addition, the strategy to develop cycling networks in these areas could also help reduce the high numbers of daily trips by public transportation or traffic. This might reduce the city's congestion and pollution. As presented, most of the nodes in the outer parts of the city are located or close to the railways and suburban trains that connect the commuters with the city. However, these routes are not well connected to the main centers and destinations. Developing and increasing the terminals of these routes, which is suggested in one of the strategies, could also be a helpful factor for more balance and connectivity of all parts of the city. The plans that aim to develop the connections between Buda and pest sides are also essential in providing more balance to the different nodes of the city which is missing between the two sides as the measurements of centrality show. Regarding the central parts of the city, developing metro line M3 which crosses two nodes of the highest node in centrality level (node number 1 and node number 2) is also a good step in the direction of achieving more efficient service across the whole route. Developing the cycling network inside the city is also another aspect for more balance and stability in the central areas of the city, see Fig. 3.

5 Conclusion

It could be concluded that transportation networks have an essential role in affecting the centrality of urban areas. The distribution of these networks could result in more centrality in some areas and less centrality in other parts of the city. The results of the case study of Budapest show that unbalance and different levels of centrality could be a result of the relation between the suburbs or the surrounding areas of the city and the central urban areas. This was obvious when including the railways and the regional bus networks in the analyzed network. The presented strategies and plans show a real concentration on developing the commuting of the residents of agglomerations and suburban areas in addition to applying more sustainable solutions. This could control the problems of centrality and pave the road for Budapest to become a more sustainable and balanced city. However, it is a matter of question if these strategies will be as fast as the continuous changes in commuting attitudes and the new working style, especially with the rapid development of

Information and Communications Technology (ICT) and the recent effects of COVID-19. We are planning to explore these effects in future research and to investigate the changes in commuting patterns. We also suggest that responsible authorities should consider these rapid change into their strategies by conducting regular assessments and developing of these plans to cope with the continuous changes.

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Formal Model for Green Urbanism in Smart Cities

Luca Lezzerini

Abstract

The paper deals with the formulation of the principles of Green Urbanism in a smart city. According to some scholars, the main values provided by a smart city can be summarised as Sustainability, Quality of Life, Equity, Livability and Resilience. Most of these values have the green dimension as a foundation element. Measuring this green dimension can be fundamental to evaluating a smart city's effectiveness in terms of provided values. The research question is how to formally and in a measurable way define the Green dimension in a smart city. Expected results are an improvement of the formal definition of Green Urbanism in the smart city context and, in general, of Green aspects of any built space. Another important result is a first theoretical core to plan and evaluate progress in the development of the Green dimension in a smart city. In this sense, the research results can be considered the starting point to develop a descriptive theory of Green Urbanism. The methodological approach starts by exploring the main business models, in a wider sense, applicable to a smart city, identifying the stakeholders and a framework to define, measure and develop the green dimension of a smart city. KPIs and concepts to be measured are derived from worldwide used standards. A peculiarity of the research is the use of a software engineering standard as a language and an approach to describe such a Green dimension. The standard is an Object Management Group official standard, Essence 1.2, the first formal descriptive theory in software engineering, and it has been applied and customised during the research to enhance the ability to implement, through the software and hardware elements of a smart city continuously keeping into account the Green requirements.

Keywords

Green urbanism • Smart city • Essence • Formal model • Business model • Software engineering

1 Introduction

One of the most famous smart cities is the Korean Songdo. According to its creators, it is one of the greenest smart cities in the world (Townsend, 2015). According to many scholars (for example Mullins, 2017) or Korean activist Edelston (2012), it is not as green as stated above. Simply considering raw figures could be impressive: replacing over 600 hectares of coastal wetlands, populated by shore birds and other life forms typical of such ecosystems, with over 22 thousand apartments and over 460 hectares of commercial space, even if they have been built along a golf course, does not sound green.

This example has been considered to put evidence that it is not easy to objectively measure the "green" dimension of a smart city.

Simply reading the figures above will easily lead to defining Songdo as a complete failure from a green point of view. But considering the opposite solution, leaving the coastal wetlands unchanged, simply cannot be considered a green solution but only doing nothing. Smart cities, whatever definition is used to describe them, are built because they satisfy some needs. Not building a smart city but a normal city will create or leave many problems unresolved.

In a few words, we must consider the global effect of building a smart city, considering the problems it solves. We have to compute a detailed balance, and, in the end, we can state if the smart city is greener or not than other alternatives (and feasible) solutions.

To compute such balance, we must take into account all elements of the smart city development according to a

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specific business model, demonstrating that the balance is positive even if some natural space has been destroyed and replaced with built space or, on the contrary, that it is negative because it has not increased the values of the business model. Obviously, the business model must consider the "green factor" as an essential element of its structure.

In this paper, we will search for a possible approach to computing such balance and, also, provide a methodology to state at which point of the development of the smart city we are. This will be done with an interdisciplinary approach derived from the software engineering formal theory named Essence, a formal standard of the Object Management Group, issued in 2014, following the so-called SEMAT Initiative (Jacobson et al., 2012). The Essence 1.2 standard (Object Management Group, 2018) will be used because the smart city must combine urban planning, architecture and other kinds of "soft" requirements with technological systems' "hard" requirements, essentially made by hardware and software requirements. This issue will be further explained in the methodological section but a few words can be spent on it now.

Essence 1.2 is a standard for software engineering defined by the Object Management Group, a worldwide referred authority in the field of software standards. With Essence, it is possible to describe any kind of software engineering process and also state at which point of its completion a project development is. Although a smart city is made of buildings, what makes it smart is the correct and effective application of ICT technologies. So, from this point of view, a smart city is mainly dependent, for its success at implementation time, on software engineering. In this perspective, software engineering is the tool that makes possible what urban planners, architects and urban designers have conceived, often considering requirements that are difficult to be measured.

2 Research Question

The research question is how to formally and in a measurable way define the Green dimension in a smart city, keeping into consideration all the values expected from smart city development, according to the given business model.

Some hypotheses have been done to develop the research:

- The business model is not focused only on economic values but it also considers other values that can be considered "green".
- The approach is followed for one specific business model but it can be applied to any other business model if the previous hypothesis is respected.

3 Expected Results

Expected results are an improvement of the formal definition of Green Urbanism in the smart city context and, in general, of Green aspects of any built space.

Another important expected result is a first theoretical core to plan and evaluate progress in the development of the Green dimension in a smart city. In this sense, the research results can be considered the starting point to develop a descriptive theory of Green Urbanism.

4 Methodological Approach

4.1 Methodological Strategy

The research is a step in wider research that aims to create a formal model for smart cities that can describe, using a formal descriptive theory, urban planning requirements, urban design requirements, architectural requirements and Information and Communication Technology (ICT) requirements, connecting these worlds into a common vision using the same language, each of them for its own competence. In this paper, this main research will not be addressed but it is cited to ease the understanding of the whole picture where the content of this paper is located, underlining the interdisciplinarity of the followed approach.

The methodological approach followed in the research was to define a set of "values", measure them and then calculate the balance. As a reference model for Green Urbanism, Lehmann (2010, 2014) has been chosen but the approach can be also applied to other models (e.g. Sustainable Cities Platform, 1994). Then a smart city framework has been identified. For this framework, having extracted its values, for some of them a specific set of concepts to be measured has been extracted. The selected values have been chosen to aim to consider elements that are difficult to be measured objectively.

Starting from these values, coming from both the Green Urbanism model and smart city model, the "essentialisation" process, defined in Essence 1.2, has been applied to such concepts, transforming them using the language of the standard (named Essence Language) and using the elements of the kernel of the standard. For this paper, only alphas and alpha states elements of Essence will be used, with some exceptions, though also other elements can be used in practice.

After essentialisation, the smart city framework and Green Urbanism model elements (values) have been converted into alphas (sub-alphas) and a set of alpha states, for each of them, has been defined.

Once having defined alphas, alpha states and their relationships, the resulting Essence extension has been evaluated together with the process to obtain it. Using the chosen framework, all possible elements of the smart city implementation have been generated by software but, considering their huge number (over 25 thousand in its basic version), only a few of them have been made explicit in this paper. Nevertheless, the main reasoning remains valid. In further studies, a ranking algorithm will be used to let emerge the most important elements according to some criteria. In research yet in progress, the fitness function of a genetic algorithm has been considered as the possible ranking criterion but results will not be available before the end of 2023.

All these activities have been done concerning Green Urbanism's key concepts.

After the research activity, an additional result has been detected and it will be further investigated in a successive study. This result was about the possibility of using the same Essence 1.2 meta-structure, changing what needed to be, to formally describe the method to develop green urbanism in a specific case, even outside the smart city. This last result can be considered a foundation for a formal descriptive theory of urbanism and other urban planning key concepts.

4.2 Methodological Details

Essence 1.2 is based on 5 "areas of concern" that are the main areas that must be satisfied to have a complete and effective product of a software engineering process. These areas are depicted in Fig. 1.

In the topmost area of concern, there are two elements (they are called alphas): Opportunity and Stakeholders.

Fig. 1 Essence 1.2 areas of concern. *Source* Object Management Group (2018)

Essence states that to provide an effective software engineering activity, the Stakeholders must be completely identified and involved in the development process. This is represented by the Stakeholders' alpha. In addition, Essence states that also the values that each stakeholder wants to get from the software engineering activity (i.e. the software development process) must be identified and checked throughout the entire process. These values are represented by the Opportunity alpha.

The Requirements alpha represents the requirements to provide the software system (i.e. the smart city).

Stakeholders have been directly taken from the smart city framework, while the Opportunity has been detailed in sub-alphas to support their complete identification. The same sub-alphas detail has been done for the Requirements alpha too. Other alphas have not been considered in this paper because not applicable (Way of Working and Team) or too specific (Work, Software System) so, for the sake of simplicity, they have been omitted. In the wider research cited above, all of these elements have been considered.

5 Research Problem Elements

5.1 The Smart City Framework

Many smart city frameworks have been considered (for example Azizalrahman and Hasyimi, 2019) and other smart city concepts and business models have been evaluated (Townsend, 2015).

The chosen smart city framework was Ramaprasad et al. (2017) because it is flexible and represents an ontology to describe elements of any smart city. In this paper, no changes have been done to this framework. In his vision, Ramaprasad states that the outcomes (i.e. the values provided by the smart city) are:

- Sustainability
- Quality of Life
- Equity
- Livability
- Resilience.

According to this model, the smart city is defined as a function of two elements: "smart" and "city". These two elements will be separately analysed in the following, starting from "city".

The City is defined, in Ramaprasad's framework, by Stakeholders and Values (Outcomes). This is acceptable because The City has the mission to provide some values to the stakeholders. We do not build cities for the sake of building. We build cities to provide what is required by the city's stakeholders.

In Ramaprasad's framework, the Stakeholders are Citizens, Professionals, Communities, Institutions, Businesses and Governments. This set is not important and can be expanded as desired but what is important is that Stakeholders exist and are correctly identified.

In Ramaprasad's vision, the values provided to the Stakeholders are the outcomes described above. In our analysis, we will later add new outcomes (i.e. new values) further detailing those defined by him.

In the framework, the "smart" element of The City, i.e. the Smartness of The City, can be defined as "being able to intelligent sense and respond through semiotics".

Semiotics is defined by Ramaprasad as "an iterative process that generates and applies intelligence". In his idea, Semiotics is Data, Information and Knowledge. Data is the raw, symbolic representation of sensations and measurements. It is a mere recording of something that has been sensed. Data can be considered the raw material from which information is extracted. Information, in fact, in Ramaprasad's vision, is made by the relationships that exist (or are discovered) among the (raw) data. As a general definition from Information Theory, the concept of Information can be considered as the ability to remove uncertainty thanks to the analysis of the relationships among data elements. If before something was not known, after having analysed data relationships, it becomes known. Understanding the meaning of this information is knowledge. Knowledge is, then, the meaning, i.e. the semantic value, of the Information, which is the semantics of the relationships discovered among the data elements. Knowledge is giving a sense of what, being uncertain before, is now known.

According to Ramaprasad, Smartness is defined again as a function, a function of four variables:

$$\text{Smart} = f(\text{Structure, Functions, Focus, Semiotics})$$

where structure is the "artefact" needed to manage the semiotics. To handle data, information and knowledge, some artefacts (physical, like computers or abstract, like processes) are needed.

Architecture (the overall organisation of the space) is the first type of Structure. Architecture is needed because the Smartness of a City needs to shape the space intelligently.

Infrastructure is the structure that relates to physical and virtual connected elements. It provides physical relationships among the components of the City. Infrastructure can be used to support physical communications (e.g. roads, pipelines) or digital communications.

Another infrastructure is called Systems and describes all elements that have their dynamics to process some inputs providing some outputs. Systems can be of three types: computer systems, social systems, and paper-based. They are focused mainly on internal dynamics and represent the intrinsic behaviour that complex aggregations of elements (including stakeholders instances) can generate.

Services are another type of Structure and are used to describe the functions provided by the Systems just described. Services are the general relationship between input and outputs provided by systems and do not consider systems' internal dynamics but only input–output relationships.

To represent regulation activity, an important Structure is one related to Policies. They are, essentially, laws, guidelines and/or rules, and are the result of a governance framework.

Processes and Personnel are two other Structure types. The people are responsible for the processes execution, i.e. they are involved in the processes. Processes are the description at the organisational level of what happens in the city. Often processes involve many systems. When describing a smart city, processes and persons (roles) are essential to its smartness.

In this vision, Structure is what is needed to provide the functions, which are the second variable.

Functions are the functions that are provided by the structure and required to handle the semiotics. They are related to a typical life cycle of semiotics. Semiotics have to be, detected/measured, supervised in their dynamics during the time, processed according to some algorithm, converted into actions by actuators or other forms of control and transferred from one side to another. According to this life cycle, Ramaprasad defines five types.

The first type is the capability to measure something. This first type is called Sense because represents the ability to "sense" what is happening. Sense is the Function that generates the semiotics.

Another function is to observe the semiotics over time to detect patterns in them. Pattern detection is the basis of a reaction schema. This function has been called Monitor.

All the semiotic elements are gathered and monitored to apply some sort of transformation over them. This function has been called Process. It is essential because it allows the generation of added value from the semiotics to get the outcomes.

Many processing need to move out from the semiotics domain (i.e. data, information and knowledge) and become actions to provide results in the physical world or control some variables. This kind of function is called Translate because translates the semiotics (that are intangible) into an interaction with the physical world.

A last function is an ability to exchange semiotics. This function is called Communicate.

Each function applied to semiotics has a specific domain which is the Focus. It targets a specific dimension of the city's dynamics.

One dimension is the Cultural one. It relates to semiotics that is related to culture, including art.

The Economic focus is related to economic semiotic elements and is the most obvious to be managed. They include semiotics about energy, raw materials, basic supplies and similar that influences economics.

In Ramaprasad's vision, also Demographic focus is important. This focus also includes health data (both physical and mental) and probably the name should be changed but, in this research, we have kept it unchanged.

The focus on the environment is another one that must be considered. Environmental focus means considering elements that are related to environmental management and preservation. This focus has gotten a growing interest in the last decades, arriving to be considered one of the important and peculiar of a smart city.

The political focus should be considered in the etymological sense, i.e. "solving problems of the polis", but really can focus even on other elements, like personal opinions.

The focus on Social context is necessary to consider the sociological sphere of the smart city.

The technological focus is on all elements that are strictly related. It is semiotics serving applied technologies. It is to be underlined that new technology trends and general knowledge about technology, including research and innovation, should be included in the culture focus.

Focus is the centre of convergence of the intelligent sense and response, which Ramarasad calls "smartness".

All the framework elements can be used as an ontology to describe the smart city. Combining the various elements of the framework, it is possible to generate a high number of "illustrative elements" that represent, each, single aspect of the smart city.

A single illustrative element can be generated by combining the framework's elements according to the following schema:

$$
\begin{aligned}
&<\text{Structure}> \text{ to } <\text{Functions}> + <\text{Focus}> \\
&\quad + <\text{Semiotics}> \text{by/from/to} <\text{Stakeholders}> \\
&\quad \text{for } <\text{Outcomes}>
\end{aligned}
$$

An example of an illustrative element obtained by applying the above schema could be "Services to Monitor Demographic Data from Citizens for Resilience".

5.2 Smart Cities Standards

International standardisation bodies have proposed various standards for sustainable cities and communities and many of them can be applied (and are applied) to smart cities (Huovila et al., 2019; Midor & Płaza, 2020), even if a common, definitive, definition of smart city has not yet been achieved.

According to BSI (The British Standards Institution, 2014), standards for smart cities can be defined at three different levels in its 2014 view. These levels are strategic, process and technical specifications.

At the strategic level, standards provide high-level guidelines aimed to support governments and other organisations on how to conceive and develop smart city strategies. At this level, priorities are identified, roadmaps developed and progress can be monitored in its evolution along the roadmap.

Standards at the process level provide good practices in project procurement and management for projects that are achieved in smart cities. They contain best practices and guidance also about funding and financing.

The last level, the technical, contains all specifications (i.e. technical requirements) for both products and services needed to implement smart cities projects.

Following such schema, the standards have been grouped and classified in Fig. 2.

The three levels talk different languages and do not have a formal descriptive common language that, indeed, could be very useful to allow easy tracing of requirements implementation from one level to another. Even the risk management group, which spreads over all three levels, is described in different ways through the layers.

The technical committees' framework proposed by BSI in 2014 was organised as in Fig. 3.

Let's consider, as an example, the ISO/TC 268 managed standards. The typical applicable ISO standards coming from ISO/TC 268 and suitable for smart cities are shown in Fig. 4.

ISO 37120 is the central, key, standard and, even if not specifically designed for smart cities but for a wider concept (sustainable cities and sustainable communities). It defines methodologies for a set of indicators that can be used to drive and measure the sustainability of the city/community. Sustainability is defined, in this case, in terms of the city services' performance and quality of life.

ISO 37122 and ISO 37123 are complementary sets of indicators that provide a wide range of capabilities to measure the "smartness" of a city and its "resilience". ISO 37122 goes further than the simple KPIs list and also provides important methods and practices that can have a serious impact on the smart city context (i.e. its social environment and its sustainability from economic and environmental points of view).

ISO 37101 provides requirements for the development of a management system to continuously improve the sustainability dimension of the community. As with any other ISO management system requirements set, it contains the foundation principles that must be satisfied in such a management system. Using this standard with the other three

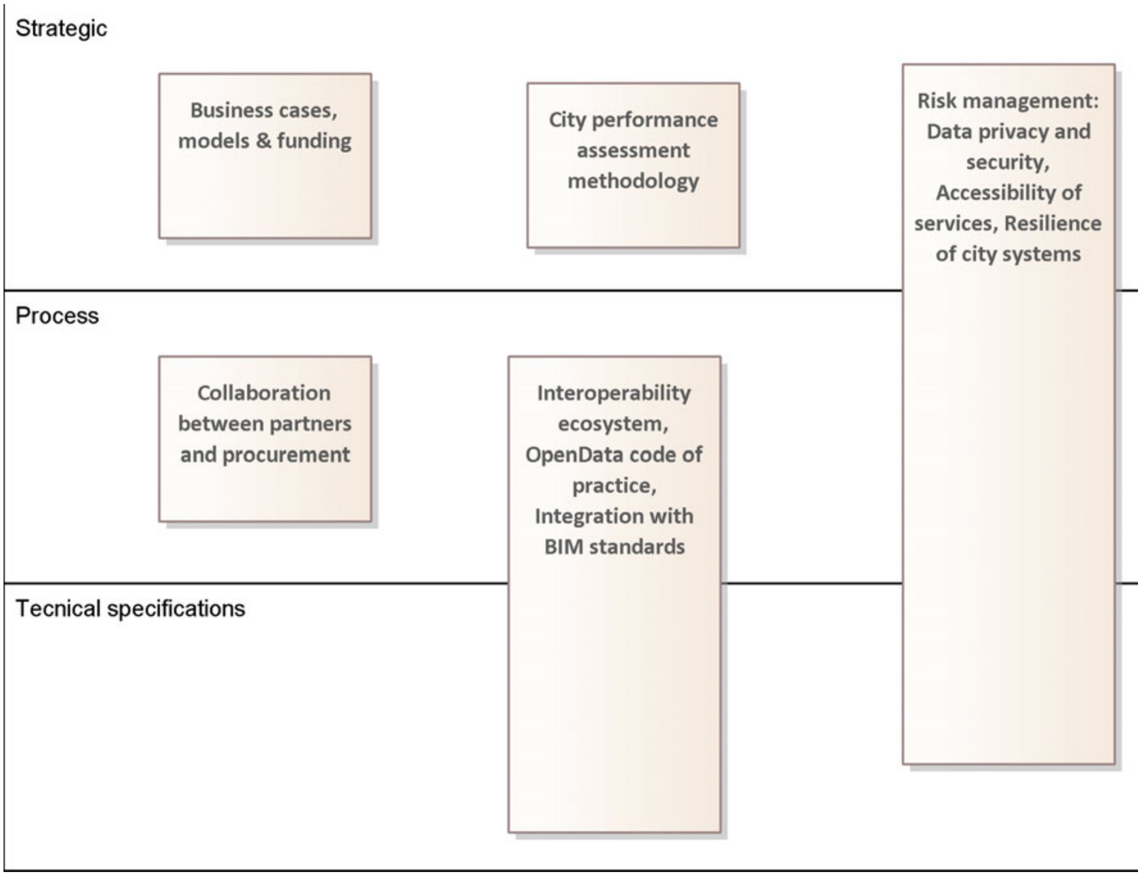

Fig. 2 Level of standards according to BSI 2014 (image of the author)

described above usually gives the ability to implement it effectively and efficiently. ISO 37101 can also be used not only to improve sustainability, smartness and resilience through an interdisciplinary and holistic approach but also to create clearness and consensus about the need (and the opportunity too) to implement sustainable development in a community.

The standards above spread from strategic to process level but they have some common issues.

The first issue is about ISO 37101, i.e. at the strategic level. Its requirements are in a general form and do not provide enough details to implement and measure the progress other standards have been used for doing this task. ISO 37101 is too general and does not take care of the existence of a custom or peculiar requirements like democracy or social engagement.

The other standards define the level of the implementation through indicators that are correlated with the required feature (e.g. sustainability) but that do not measure it. In a few words, KPIs have been defined to measure, in a quantified way, something that, often, is not quantifiable. Some examples of these KPIs are reported below with explicit criticism of their limits.

For example, ISO 37120 indicators are partitioned into two levels: core and support indicators.

Environment core indicators are particulate matter concentrations and greenhouse gas emissions per capita. Environment support indicators are concentrations of NO_2, SO_2, O_3, noise pollution and relative changes in native species (% of number). Although these parameters are important from the environmental point of view, they are not enough to quantify the environmental dimension of the community.

But the real issue comes when a more complex (and effective) model is considered. If the discourse is moved towards Green Urbanism, it becomes clear that something is missing. Not only in the indicators that can be updated or increased in number and detail but in the real approach.

5.3 The Green Urbanism Principles According to Lehmann

The green principles have grown in importance in the last decades, especially in the first years of the XXI century. This importance has been reflected in both urban planning and urban design, becoming essential to any study done in these

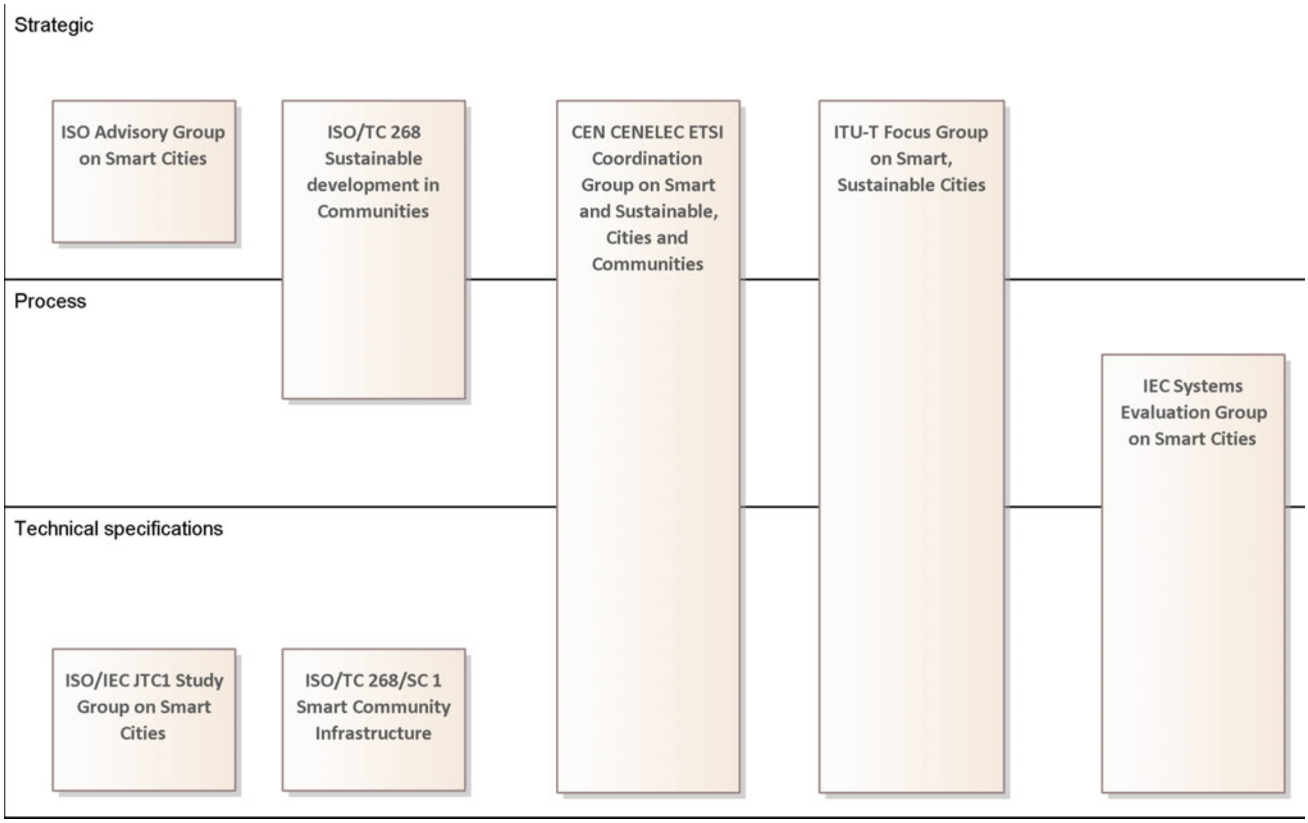

Fig. 3 Technical committees' framework according to BSI 2014 (image of the author)

Fig. 4 ISO/TC 268 suitable standards for smart cities (image of the author)

disciplines. Many movements have arisen along this time and have analysed the change in urbanism, moving towards green principles and sustainable growth. These movements can be considered a new, wider movement that has evolved to converge into green urbanism. This "green urbanism" was aimed to develop human communities that had qualities like sustainability and a lower impact on the environment (Beatley, 2000). Since its beginning, this new kind of urbanism, exposed concerns about the environment, starting from land and energy consumption, and moving towards a more generalised perspective. One approach that these new generations of urbanists proposed was a regional approach to development management. Katz (1994) proposed to move people into more liveable communities (more precisely "small towns"). Ewing (1996), considering the case study of Florida, proposed a set of best practices to both assess the quality of existing or guide new development plans. These guidelines were focused on four main axes: land use, transportation, environment and housing but founded on the concept of "green fields". Calthorpe and Fulton (2001) studied the most diffused form of settlements in the USA which was an aggregation of cities and suburbs defining them as "regional cities".

But not only urban planning issues have been developed. Also, the background philosophy and best practices of this new "green" trend in urbanism have been explored by many scholars. In addition to the already cited Calthorpe and Fulton (2001), Duany et al. (2000) considered the need to move from automobile-centred urban planning to a more human-friendly and sustainable vision. In Steuteville and Langdon (2003) there is an important effort to try to change settlement evolution from a "natural" chaotic sprawl into a planned approach, considering many case studies and organising a collection of best practices and philosophical concepts behind them. With Grant (2006) the green urbanism movement got a strong analysis of both theory and practice in green urbanism. To create good communities, Grant criticises in a constructive way current approaches in many parts of the Western countries, Japan included. He also analyses and opens a debate about the concerns that are being applied to new urban planning philosophies, focusing on aesthetics topics too. In other cases, these strategies are more tied to the so-called "smart growth policies" that, essentially, require considering efficiency in using natural resources. Examples of these cases are the studies of Gordon (2003) that even propose preemptive planning focusing on small communities. Their most important concern is to conjugate the New Urbanism movement they were experiencing everywhere with the preemptive planning to protect and preserve the ecosystem. So, their focus is to improve the New Urbanism adding to it a stronger dimension along the environment, letting it become a Green New Urbanism. Another example can be found in White and Ellis (2007).

In these documents, we can see how the New Urbanism, thought to reduce sprawl and increase social-well being evolves into Green Urbanism where the "Green Agenda" becomes prevalent.

While this movement was arising in the USA, the same happened in Europe during the '80s and '90s. An example could be the Brundtland Commission which defined sustainable development as the result of "balancing economic, social, and environmental objectives to preserve options for future generations" (WCED, 1987). This definition contributed to spreading, at the European level, these ideas and increased their relevance in the New Urbanism trends.

In the 1990s, a strong movement started opposing growth evidencing the issues caused by chaotic sprawling. These pressures to avoid, for example, traffic congestion, or air and water pollution forced some local governments to try to even decide to brake or stop development. To solve this conflict, alternative growth strategies were proposed. An example could be the already cited Ewing (1996) with its 12 principles, another is Cervero (1986) that focused his analysis on business complexes and proposed solutions to suburban congestion, focusing on suburban transportation planning. In Downs (1994) the topic of collaboration between suburbs and city centres to find a common "win–win" strategy is analysed defining a very detailed and persuasive proposal of a regional approach to planning.

Also, organisations like the American Planning Association, the Urban Land Institute, the National Governors Association, and the Congress for the New Urbanism quickly became promoters of a new form of growth, that they called "smart growth".

The results of this process have led to many different frameworks for planning. One is Ewing's (1996), another is the one from Gordon and Tamminga (2002). Jabareen (2006) and White and Ellis (2007) are two other examples.

Unfortunately, these frameworks were conflicting. Often, they gave opposite evaluations of the same result. Often some of them proposed strong criticism of others' work, for example affirming that the results of new urbanism trends were poor from the environmental perspective. Most of these critics were focused on missing a real, true, holistic and green vision. For example, Audirac et al. (1990) evaluated some neo-traditional projects in Florida and observed that a compact development policy was an excessive simplification of reality and led to poor results. Reasons underlined by them were the unsatisfactory protection of the environment or the slowness of change adaptation of the local development regulation. Grant et al. (1996), as already cited above, criticise the real application of the most important values for urban stakeholders. In their vision elements like democracy, globalisation, spatial patterns and more are checked against their impact on the New Urbanism movement and they conclude that there is yet a lot to do, especially considering the need to build with high urban densities. Many studies (Durack, 2001; Till, 2001; Zimmerman, 2001) underlined, demonstrating that, that New Urbanism often used environmental issues as a marketing strategy, not based on a real sensitivity to the problem but only targeted to "sell" their projects. Even scholars that favoured the high-density strategies proposed in urban planning, like Gordon and Vipond (2005), evidenced that biodiversity preservation and land preservation were a requirement to be satisfied.

In this paper, the Green Dimension of a smart city is defined as having implemented, in the smart city, the concepts of Green Urbanism. To have a reference framework for it, in this paper we will refer to Lehmann's model for Green Urbanism in the 2010 version. The reason is that this study is well-structured and, for this paper, has a high coherence and a completeness level that allows a comparison with ISO standards. In his studies, Lehmann proposed some principles organised in groups that cover all the elements of Green Urbanism.

The fifteen principles of Green Urbanism according to Lehmann, in its 2010 formulation (Fig. 5), are a good example of the mismatch between them and the ISO standards referred to before.