Smart Sustainable Cities: A New Perspective on Transformation, Roadmap and Framework Concepts

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Abstract—**The unprecedented rapid urbanization will affect the sustainability of cities around the globe. City leaders are currently seeking to transform their cities into Smart Sustainable Cities to face this global urbanization trend and its related challenges. To ensure the effectiveness and efficiency of a transformation process, current city needs, future trends, readiness of a city for the change, quality of life of citizens, and the set of smart and sustainable initiatives and solutions should be considered. The latter could be achieved through a comprehensive roadmap and framework to guide the transformation process. Developing such a roadmap and framework require a deep understanding of the concepts of transformation, roadmap, and framework in the context of Smart Sustainable Cities. Definitions that currently exist in the literature do not take into consideration the different objectives of a Smart Sustainable City. This constitutes a gap in knowledge. This research paper bridges this gap by highlighting the weaknesses and deficiencies in existing definitions and introduce new definitions for the three concepts, taking into account the specificity of a Smart Sustainable City as a solution for the rapid urbanization while maintaining the sustainability of a city and ensuring a high quality of life for its citizens. The proposed comprehensive definitions of these three concepts namely transformation, roadmap, and framework aim at guiding city planners, policy makers, and key stakeholders in developing and designing Smart Sustainable City initiatives and programs.**

Keywords-Smart Sustainable Cities; Transformation; Roadmap; Framework; Innovative Solutions.

I. INTRODUCTION

The world is experiencing the largest wave of urban growth in the history. Over half of the world's population is now living in cities. According to the United Nations estimates, by 2050, 66% of the total world's population is expected to be urban. With this rapid urbanization, cities will face sustainability challenges especially in the lower-middle-income countries where the urbanization speed is fast [1]. The challenges include (but not limited to) the social stress, poverty expansion, spatial dynamics, natural resources shortage, and urban pollution with its effects on the climate change [2].

Given this unprecedented global urbanization growth and the need for sustainability at all aspects of a city, the concept of "Smart Sustainable Cities" (SSCs) emerged as a desired goal for future urban development and attracted the attention of many researchers and practitioners in the field [3]. Their challenge is to ensure that cities are offering improved living conditions for their citizens by solving a set of sustainability challenges at the economic, environmental, and social levels. The Information and Communication Technologies (ICTs) offer high potential for solutions to many of these challenges while ensuring that they are environmentally friendly and viable [4].

The International Telecommunication Union Focus Group on Smart Sustainable Cities (ITU-T FG-SSC) analyzed nearly one hundred definitions of smart cities, sustainable cities, and SSCs to introduce a new definition for a SSC. This new definition refers to a SSC as "an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects".

Additionally, as illustrated in Fig. 1, a SSC is defined along six dimensions named: Smart Economy (competitiveness), Smart Environment (natural resources), Smart Governance (participation), Smart Living (quality of life), Smart Mobility (transport and ICT), and Smart People (social and human capital). Each dimension is described by a set of factors, used to identify where the smart and sustainable initiatives are needed under that dimension. Table 1 [6] lists these factors.
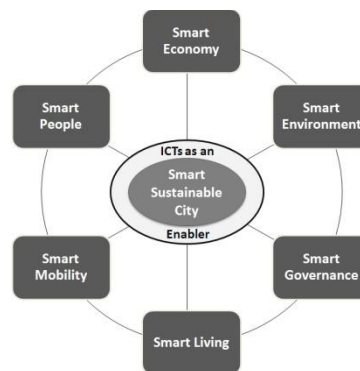

Figure 1.   A SSC, its six dimensions, and the role of ICTs

TABLE I.   DIMENSIONS AND FACTORS OF A SSC

Dimension	Related Factors
Smart Economy	Innovative spirit Entrepreneurship Economic image and trademarks Productivity Flexibility of labour market International embeddings Ability to transform
Smart Environment	Attractive natural conditions Pollution Environmental protection Sustainable resource management
Smart Governance	Participation in decision-making Public and social services Transport governance Political strategies and perspective
Smart Living	Cultural facilities Health conditions Individual safety Housing quality Education facilities Touristic attractivity Social cohesion
Smart Mobility	Local accessibility (Inter)-national accessibility Availability of ICT infrastructure Sustainable, innovative, and safe transport systems
Smart People	Level of qualification Affinity for life-long learning Social and ethic plurality Creativity Flexibility Cosmopolitanism/open-mindedness Participation in public life

The main objectives of a SSC are to improve the quality of life of citizens, urban efficiency, and competitiveness, while taking into account the sustainability aspects of a city at all levels. The latter could be achieved through the use of ICTs and other means (e.g., policies) across various and interrelated systems, such as the provision and access to energy, education, transportation and mobility, water resources, waste management, housing and livelihoods (e.g., jobs), environment, local economic, and others [7].

To face the rapid urbanization and its related challenges, city leaders are currently seeking to transform their cities into SSCs. To ensure effective and efficient transformation process, the current city needs, future trends, readiness of a city for the change, quality of life of citizens, and the set of smart and sustainable initiatives and solutions should be considered [8] [9].

A transformation process, as illustrated in Fig. 2, consists of a high-level view roadmap that is used to identify the transformation process activities [30] (e.g., outline the need for defining a transformation plan). The roadmap, in turn, provides a framework(s) for strategic creation and turning strategy into actions [31] [32]. A framework often has a layered structure indicating what kind of initiatives can or should be developed and how they would interrelate. It provides the needed solutions to achieve the transformation activities (e.g., a recommendation to hospitals to develop

online applications that allow patients to track their illness at any time). Developing such a roadmap and framework requires a comprehensive definition of a SSC transformation and a full understanding of the concepts of roadmaps and frameworks in the context of SSCs.

Different definitions of the concepts of SSC transformation, SSC roadmap, and SSC framework exist in the literature. The majority of these definitions do not take into consideration the specificity of a SSC as a solution that ensures the sustainability of a city at all levels while providing a high quality of life for its citizens through the use of ICTs and other means.

Using definitions that do not take into account all aspects of a SSC leads to an incomplete city transformation from one state to another. Without clear definitions of a SSC transformation, SSC roadmap, and SSC framework, city planners, policy makers, and key stakeholders will not have a concrete base to follow in designing their transformation roadmaps and frameworks. Consequently, the possibility of neglecting essential aspects while transforming a city into a SSC becomes high. Therefore a comprehensive definition for each of these three concepts is needed.

The aim of this research paper is to study and analyze existing definitions of SSC transformation, SSC roadmap, and SSC framework in the literature, highlight their weaknesses and deficiencies, and introduce new comprehensive definitions for these concepts. The proposed definitions could assist city policy makers and key stakeholders in developing and designing smart and sustainable initiatives that meet the objectives of a SSC. The research follows the literature based research methodology through which a gap in knowledge in relation to defining the concepts of transformation, roadmap, and framework in the contexts of SSCs is identified.

In what follows, a literature review on existing definitions of SSC transformation, SSC roadmap and SSC framework concepts is highlighted in Section 2. Section 3 provides a discussion on existing definitions of the three concepts and introduces new ones. The paper concludes with Section 4.
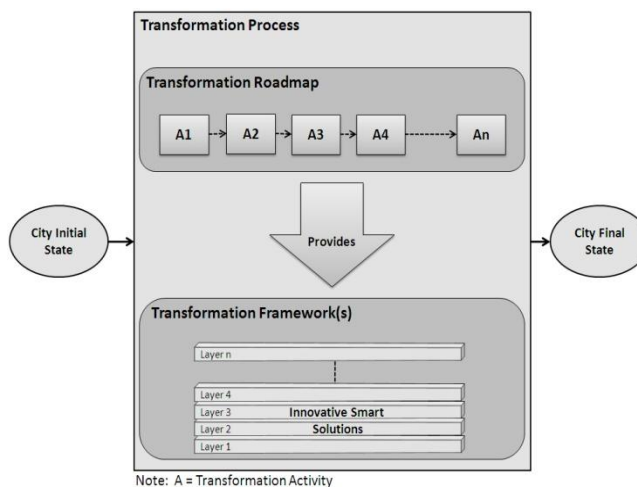

Figure 2.   Concepts of a SSC Transformation, Roadmap, and Framework

II. LITERATURE REVIEW

Understanding the concepts of transformation, roadmap, and framework in the context of SSC is essential and dependent on their definitions. More clear definitions are used; more comprehensive transformation roadmap and framework could be developed and designed. However, the existing definitions of these concepts in the literature do not consider all objectives of a SSC.

The aim of this Section is to highlight the existing literature on a SSC transformation, SSC roadmap and SSC framework definitions.

A. Transformation Concept in SSCs

The rapid urbanization is a significant challenge facing cities around the globe. City leaders need to address this phenomenon by increasing the efficiency of existing city's systems, services and infrastructures to a level that have never been achieved before. The latter would be realized through a holistic transformation process to enhance the sustainability of a city at all levels and improve the high quality of life of citizens, such as the case of the transformation towards SSCs. For this transformation to be consistent with the objectives of a SSC, a comprehensive definition of a transformation concept is needed.

Generally, various definitions of the transformational change exit in the literature with no agreement yet about what could be and what could not be considered as a transformation [28]. The "Transformation Theory", proposed by Daszko and Sheinberg [18], defines a transformation as a "change" to create something new that has never been existed before. This change could not be predicted from the past and it leads to a change in the whole system structure, function and/ or form. Geels and Kemp [10] define a transformation as a continuous process (i.e., it is difficult to tell when a transformation process will end) that leads to changes in a direction of trajectories. During this process, a new system may be created from the old one, through changes that are being taken in a new direction.

For Satterthwaite and Dodman [25], a transformation is used to represent both the substantial activities and fundamental changes that affect economic, political, and social systems. The latter requires adaptation of policies and investments and integrates them with the development process of a city to meet its needs and to address the massive ecological footprint. A transformation in Harrington et al. [12] helps to divide the scope of change into manageable segments. It assists in identifying the key behaviors that are necessary to sustain the change and modifying and reinforcing positive behaviors through changing the structure of the system while measuring progress toward the previously identified goals.

Last but not least, a transformational change from the United Nations Development Program (UNDP) perspective [29] is a process by which positive development results are achieved and sustained over time through institutionalizing projects, policies, and programs within national strategies. It ensures the consistency of achievements over time, and does not include short-term transitory impacts.

In the context of SSCs, a transformation occurs at every level of a city, ranging from economic, social and environmental structures to the ways that form citizens' everyday lives. It is a long term process that cannot be achieved overnight. The Department of Business, Innovation and Skills (BIS) [24] does not provide a clear definition for a SSC transformation process; however, it shows a lack of absolute definition for a SSC that could be seen as a series of steps through which cities will be able to become more resilient and livable, hence, being able to respond quicker to new challenges.

A SSC Transformation in De Santis et al. [14] is a complex multidimensional process that changes over time as all involved stakeholders will work to achieve more and better results. The transformation will affect many aspects of city operations including government, mobility, energy, services, buildings, and environment. The ITU-T FG-SSC [19] defines a SSC transformation as a long-term process that consists of a series of generic steps. These steps are defined to allow compatibility and promote sustainability of a city as time passes.

Finally, Smart Dubai [23] defines a transformation as a process that focuses on four main issues: (1) efficiency through optimizing the use of city resources; (2) safety through protection of information and people and anticipating risks; (3) seamlessness through integrating daily services of life; and (4) impact through enriching business and life experiences.

B. Roadmap Concept in SSCs

Generally, a transformation roadmap is a high-level view of key activities that are required to change a situation from one state to another through defining a set of milestones that are needed to close a gap between the current and desired future situation [30]. A transformation roadmap in SSCs has almost the same meaning; with some specificity related to the nature and complexity of a transformation process in the context of SSCs.

In Schaffers [27], a transformation roadmap is required to realize the aspiration of SSCs as innovation ecosystems. It presents the state of the art, trends, and developments, as well as identifies challenges, obstacles, and gaps related to the transformation towards SSC. It reflects the vision of a SSC's socio-economic and cultural development.

Komninos et al. [21], define a SSC transformation roadmap as a blueprint that provides recommendations for urban development by using of future technologies. It allows formulating of some policy recommendations to city authorities for mastering the new interdisciplinary planning for SSCs. A transformation roadmap main purpose is to show how to control the interlinked city layers of infrastructure, digital technology, people-driven innovations ecosystems, and urban activities.

For the European Platform for Intelligent Cities [15], a transformation roadmap supports cities in their transformation towards SSCs operating environments. It includes various aspects of the transformation process including strategy development, program management, business case creation, and implementing and operating SSC

services. The British Standards Institution [13] does not provide a specific definition for a transformation roadmap. It indicates that a SSC roadmap could be seen as a realistic framework that aims to deliver clearly identified results in achievable stages. From their point of view, each city in the United Kingdom (UK) should develop its own transformation roadmap based on its vision and goals. A roadmap is not a master plan and it should be deliverable. To be effective, a roadmap should take a phased and incremental approach and there is no need to over-plan at the beginning but instead provides a framework to support the transformation process to deliver the city vision over time.

For the ITU-T FG-SSC [20], a SSC roadmap is a process that can be followed by city leaders and managers to transform their city into a SSC. It provides a framework to guide the transformation process, identify a set of SSC services, and focus on different ICT infrastructures. It also consists of a security framework to protect citizens, and provides monitoring techniques and ways to include citizens in the transformation process.

Finally, the Smart Cities Council [26] defines a transformation roadmap as a bridge between ideas and actions. It is linked directly to the city vision document and/or development plan; therefore; it is neither a vision document nor a master plan. A transformation roadmap is a simplified outline that shows the major steps of how to become a SSC and could overcome the obstacles to a SSC transformation. The benefits of a SSC transformation roadmap include identifying the best place to start from, enabling cities to build in stages, maximizing synergies and minimizing cost, increasing public support, and attracting talent and businesses.

C. Framework Concept in SSCs

Transforming a city into a SSC requires a comprehensive framework to guide the transformation process. While a transformation roadmap provides a high-level view of changes that are needed to shift a situation from one state to another, a framework provides a set of tools that can be used to get there [30]. A transformation framework, in general, is a structure that can be used as a guide to build systems from scratch or modify existing ones into something useful.

Although there is frequent use of the term "Smart Sustainable City" in the literature recently, there are still few attempts to provide a definition for its framework concept. To start with, a SSC framework has been defined by CISCO [11] as a process that helps city key stakeholders and participants to understand how cities operate, define city objectives, understand the role of ICTs within the city physical assets, and define the role of stakeholders within a city. It is a step-by-step process of how to implement SSC initiatives. It allows cities to create a standard index system to record, collect, and measure city data that could be used to manage and implement SSC solutions for the purpose of economic, social, and environmental gains.

Chourabi et al. [17], define a SSC framework as an integrative framework that can be used to assist government professionals on how to establish SSC initiatives. From their point of view, a SSC framework should be based on eight critical factors that are: economy, governance, policy context, technology, built infrastructure, management and organization, natural environment, and people and communities. A SSC framework should clarify the influences and relationships between any suggested SSC initiative and these eight factors. Lee and Hancock [22], define a SSC framework as a conceptual framework that provides a holistic view of a SSC development. It is a tool that can be used to classify different initiatives and implementation practices.

The British Standards Institute [13] defines a SSC framework as a guide used by UK city leaders of SSC programs, at all levels and from all sectors. The focus of a SSC framework is to enable processes by which new smart technologies could be coupled with organizational change to help deliver the different visions of UK future cities efficiently, effectively, and sustainably. The framework captures the current good practices and provides "how-to" advices to help city leaders in developing and delivering their own SSC strategies.

The International Organization for Standardization (ISO) and the International Electrotechnical Commission (*IEC*) indicates that a SSC framework could be seen as a layered structure that captures different cross-city governance processes aiming to deliver benefits based on core guiding principles while taking into account the critical success factors. It provides a valuable set of tools for scenario-building to guide the transformation process through participative decision making [16].

Last but not least, the Smart Cities Council [26] defines a SSC framework as a guide through which cities can plan and implement their SSCs. It captures the relationship between city responsibilities (i.e., what should be accomplished for citizens) and its enablers (i.e., the use of smart technologies to make these tasks easier). A SSC framework could transform a city into a SSC while ensuring that individual projects are compatible with each other even if they have been developed separately and at different times.

III. DISCUSSION AND NEWLY INRODUCED DEFINITIONS

The objectives of a SSC are to improve the quality of life of citizens, urban efficiency, and competitiveness, while ensuring the sustainability aspects of a city at the economic, social (i.e., including cultural aspects), and environmental levels [5]. This could be achieved through providing innovative solutions, using ICTs and other means, on the dimensions of Smart Economy, Smart Environment, Smart, Governance, Smart Living, Smart Mobility, and Smart People [6], as illustrated in Fig. 3.

Any attempt to design and develop a transformation process towards SSCs should take into consideration the objectives of a SSC and explicitly reflected in the definitions of a SSC transformation, SSC roadmap, and SSC framework concepts. In the following sub-section, new comprehensive definitions for these concepts capturing the objectives of SSC are introduced.
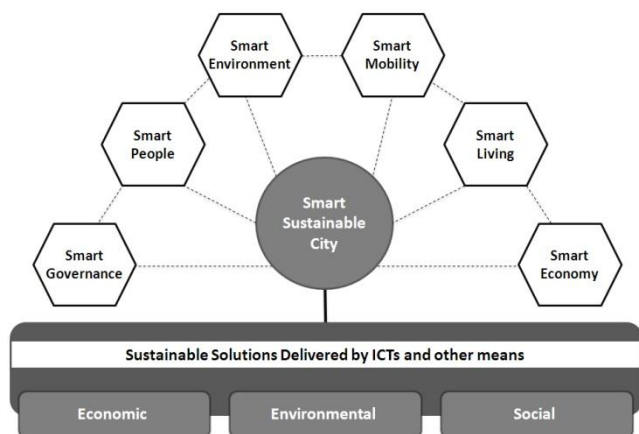
Figure 3.   Overview of relationship between a SSC and City's Sustainability

A. SSC Transformation Definition

The analysis of existing definitions of a SSC transformation concept in the literature shows that there is no standardized, commonly accepted set of terminologies to describe and define a SSC transformation. Depending upon the lens with which it is viewed, there are different definitions of the concept in the literature. None of the studied definitions take into account all aspects of a SSC. For example, some of the listed definitions consider the quality of life as important objective of a SSC while others do not. Some definitions indicate the significance of improving the sustainability of a city while others neglect this issue. Also, as shown through the analysis of the listed definitions and keywords used, the use of ICTs as an enabler to reach the SSC objectives is not highlighted.

The list of extracted keywords used to define or describe a SSC transformation in the studied definitions is as below:

- Process
- Series of steps
- Series of generic steps
- Complex
- Multidimensional
- Change over time
- Compatibility
- Sustainability
- Resilient
- Livable
- Efficiency
- City resources
- Safety
- Seamlessness

Analyzing the above listed definitions shows that the objectives of a SSC are not properly considered. The role of ICTs, as an enabler to SSC, is also not highlighted. Therefore, believing in the need to highlight these elements, this research defines transformation towards a SSC as "*a complex multidimensional process through which changes are applied at all city levels; aiming to enhance the sustainability of a city and provide a high quality of life for its citizens through the use of ICTs and other means*".

B. SSC Roadmap Definition

The existing definitions available in the literature of a SSC roadmap have been studied and analyzed. As in the case of a SSC transformation, the results show that there are no common set of terminologies to describe and define a SSC

roadmap. Each definition defines the concept from its point of view. None of the studied definitions take into account the objectives of a SSC. For instance, the sustainability of a city, which is one of the important objectives of the transformation towards SSCs, is not considered in any of the studied definitions.

The list of keywords used to define or describe a SSC roadmap in the studied definitions is as below:

- Outline
- Process
- Blueprint
- Phased and incremental
- Realistic framework
- Show how
- Support transformation
- Provide recommendations
- Technology
- Not a vision
- Not a master plan
- City layers
- Urban development
- Cultural development
- Socio-economic development

Given the analysis mentioned above, this research paper introduces a new definition for the concept of a SSC roadmap in line with its main objective, which reads as follows: "*A SSC roadmap provides a high-level view of the objectives and goals of the transformation process and identifies the transformation activities and milestones in order to realize the city's vision for being smart and sustainable*".

C. SSC Framework Definition

The studied definitions of a SSC framework concept in the literature do not follow a standardized, commonly accepted set of terminologies to define and describe the concept. Each study defines a SSC framework from its perspective or depending on the needs of a city over which a framework will be applied. None of the listed definition takes into account all aspects of the objectives of a SSC. For example, the quality of life of citizens is not highlighted in any of the listed definitions.

The list of extracted keywords used to define or describe a SSC framework in the studied definitions is as below:

- Process
- Integrated
- Conceptual
- Layered structure
- Provide tools
- How-to
- Plan and implement
- Government professionals
- Stakeholders
- Change
- Services
- Deliver vision
- Strategies
- Initiatives
- Sustainability
- ICTs

Examining the readiness of a city for a change is essential before starting a transformation process. Any change programs or initiatives are likely to lead to only failure if they start before ensuring the readiness of a city for a change [33]. According to the Community Tool Box of the University of Kansas, the readiness for change differs from one city to another depending on its context and varies across city levels as well [34]. Some cities may be more than ready for the desired change while others being at a very earliest stages of readiness for that change. Therefore, any transformation process should take into consideration the

city capabilities and adapt the transformation framework accordingly.

The analysis of studied definitions of a SSC framework shows that the readiness of a city for a transformation process, which is assessed using tools identified by a transformation framework, is not taken into account in any of the listed definitions.

Accordingly, a new comprehensive definition of a SSC framework that takes into account all aspects of a SSC and the need for assessing the readiness of a city for a transformation process is introduced. This research considers a SSC framework as "*a layered structure that leads city planners and relevant stakeholders throughout a transformation process by providing guidance on city readiness for change and the innovative solutions needed to grant urban sustainability and high quality of life for citizens*".

IV. CONCLUSION AND FUTURE WORK

To face the rapid urbanization and its related challenges, city leaders are currently seeking to transform their cities into SSCs. The latter could be achieved through a comprehensive transformation process and its related transformation roadmap and framework. Developing such a roadmap and framework requires complete definitions of the concepts of transformation, roadmap, and framework in the context of SSCs. The main objectives of a SSC should be explicitly reflected in these definitions to avoid neglecting any essential aspects while transforming a city into a SSC. Studying and analyzing existing definitions of these three concepts in the literature shows that some of the important objectives of a SSC are not considered which constitutes a knowledge gap. This research bridges this gap by introducing new comprehensive definitions for the concepts of SSC transformation, SSC roadmap, and SSC framework, while ensuring that they are consistent with the main objectives of a SSC. The proposed definitions of these three concepts aim at guiding city planners, policy makers, and key stakeholders in developing and designing SSC initiatives. In the future, this work will be used as a base for developing and designing a conceptual framework that assist in the transformation towards SSCs.

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