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MATURITY-BASED SCALE FOR SMART CITIES: A CONCEPTUAL FRAMEWORK

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Abstract: As a response to the challenges of population and urban growth, the concept of smart city/community (SC) promises more intelligent, sustainable, and resilient communities that provide better services and quality of life. However, the SC as an ecosystem is an evolving concept; hence, there is no universally-shared definition or assessment tool. Additionally, each municipality worldwide has its own unique characteristics, challenges, and opportunities. Therefore, any SC definition and assessment method should be adopted or developed specifically for each city and agreed participatively by the SC initiative leaders. In terms of an SC assessment, most of the available tools are based on evaluating the performance of urban systems. Hence, the developed indicators are mainly used for ranking or comparison purposes. However, these performance and ranking indicators face many challenges due to the broad, multidisciplinary, and rapidly evolving and changing nature of SCs. For instance, due to the rapid technological evolution of SCs, some of the currently-accepted performance indicators will be obsolete in just a few years. Therefore, our research attempts to adapt a generic SC definition with three dimensions. These dimensions include the "connectivity" that can be achieved through intelligent technologies, "sustainability" in terms of long-term viable performance, and "resiliency" in terms of preventive and proactive considerations. Based on these dimensions, a maturity-based scale that is compatible with the evolving nature of SC is proposed for SC maturity assessment. The significance of the research outcome is that it will help the public and managers of the municipalities focus on advancing city maturity which is essential for continuously improving citizens' well-being.

1 INTRODUCTION

The world's population is expected to reach nearly 10 billion people by 2050 (United Nations 2017). By that time, urban areas will be home to 66% of the world's population (United Nations 2014). As a result, urbanization and population growth rates will increase dramatically leading to expanding existing cities as well as creating new ones. However, cities will face challenges concerning, but not limited to, growth, resources, performance, competitiveness, and residents' livelihoods (Ben Letaifa 2015).

Within the last two decades, the concept of the "smart city/community (SC)" has been introduced as a response to current and upcoming urbanization and population growth challenges. It represents a strategic solution that promises to provide more sustainable, resilient, and connected cities and societies with better services and improved well-being for inhabitants. The Canadian government, as a relevant example to this research, has recognized the importance of building smart communities; the Canadian Federal Budget included $300 million to support the Smart Cities Challenge – 2018, to come up with creative ideas to improve the lives of cities' residents through innovation and connected technology as well as to overcome the city-related problems that the traditional approaches have failed to solve (Canada 2017).

However, working towards a "Smart City" in itself is problematic because, despite many attempts by various research communities to develop a clear understanding of SCs, a universally-shared definition, or smartness assessment framework (scale, domains, and indicators), has not arrived yet (Neirotti et al. 2014, Bibri and Krogstie 2017). This is because the SC concept as an ecosystem is an evolving concept. Additionally, each municipality worldwide has its own unique characteristics, goals, problems, challenges, and opportunities. Hence, to accommodate this complexity, identifying the broad trends or dimensions of the SC concept is more important than the wording of a specific definition.

Assessing the smartness of cities is an essential component of any municipal transformation project or initiative. This is because regular assessments help city leaders identify gaps and set goals towards improving inhabitants' quality of life. However, all of the SC assessment models available in the literature were developed based on unique/specific SC definitions that control the design of the models and their areas of assessment. Thus, an SC definition and its corresponding assessment model should be adopted or developed specifically –based on broad dimensions– for each city in a way that accommodates the city's vision. The adopted definition and its corresponding assessment framework should reflect the identified broad areas/dimensions of smartness.

An SC assessment framework encompasses an SC scale, SC domains, and smartness indicators or measures. Scale systems represent the measuring scale for assessing SCs. They are critical components of any assessment framework because they reflect the selected SC concept and definition. As indicated by Albano (2017), scale systems are categorized in four classes that range, in terms of the conveyed information, from very general to specific scale values. These classes are: (1) nominal (descriptive names), (2) ordinal (ranking without meaningful intervals), (3) interval (meaningful intervals with relative benchmark), and (4) ratio (meaningful intervals with absolute benchmark) scaling systems. Due to the difficulty in identifying definitive SC's maturity stages and performance benchmarks, the vast majority of the scaling systems proposed for assessing SCs in the literature are performance-based city ranking systems (ordinal class). However, these systems face many challenges related to coping with the complexity and evolving nature of the SCs. On the other hand, maturity-based scaling systems (nominal class) are more adaptive/general to accommodate change and also more useful in identifying maturity gaps and setting goals.

Therefore, this paper aims at reviewing the SC definitions in the literature to identify the main smartness dimensions and domains of SCs. Accordingly, a maturity-based assessment scale is developed based on the identified dimensions. **Section 2** provides a literature review in terms of the SC definitions and assessment models. **Section 3** presents the developed maturity-based assessment scale. Finally, a discussion and conclusions are provided in **Section 4** and **Section 5** respectively.

2 LITERATURE REVIEW

The literature about smart cities (SC) was examined from different perspectives. These perspectives include research conducted on SC definitions and key dimensions, as well as the research projects aiming at developing both performance-based and maturity-based assessment frameworks.

2.1 SC Definitions and Key Dimensions

An extensive review of the literature relevant to SC definitions was conducted with the aim of identifying the broad dimensions of SCs proposed in the literature. This review included two categories of the developed definitions: (a) individual-based proposed definitions (almost 20 definitions) and (b) organization-based developed definitions (4 definitions). The organization-based definitions were developed, by organizations, based on analyzing hundreds of other definitions. For example, Kondepudi et al.(2014), ITU-T Focus Group on Smart Sustainable Cities, analyzed more than 115 definitions to come up with one definition.

Based on the conducted review, the authors identified three key broad dimensions for the SC concept: "Connectivity", "Sustainability" and "Resiliency". The most recent comprehensive institution-based definition found by the authors is the ISO37120 (2014) definition reported in ISO/IEC (2015). The authors found that this definition touches all of the three identified SC concept dimensions. **Table 1** provides the ISO adopted definition and the identified SC dimensions by the authors.

Table 1: The authors' identified key SC dimensions

The most recent comperhansive institution-based SC definition ISO37120 (2014)	**Identified dimension**
A 'Smart City' is one that…. dramatically increases the pace at which it improves its social, economic and environmental (sustainability) outcomes,	**Sustainability pillars**
responding to challenges such as climate change, rapid population growth, and political and economic instability	**Resiliency**
…… by fundamentally improving how it engages society, how it applies collaborative leadership methods, how it works across disciplines and city systems,	**Sustainability (Soft domains)**
and how it uses data, information, and modern technologies	**ICT**

……in order to provide better services and quality of life to those in and involved with the city (residents, businesses, visitors), now and for the foreseeable future, without unfair disadvantage of others or degradation of the natural environment	**Sustainability (Hard domains)**

These key SC dimensions are *Intelligent Connectivity Technologies* (ICT), *Sustainability* (Sus.), and *Resiliency* (Res.). Hence, regardless of the wording of an SC definition and accommodating the specific vision of any city, any definition being developed should consider these three dimensions.

2.2 SC Assessment Frameworks

As found in the literature, many SC models and assessment frameworks have been introduced. This review included the models proposed by Mahizhnan (1999), Giffinger (2007), Eger (2009), Thuzar (2011), Nam and Pardo (2011), Barrionuevo et al. (2012), Kourtit and Nijkamp (2012), Chourabi et al. (2012), and ISO37120 (2014). Each of these SC models introduced a number of city domains, to be assessed, that are more or less overlapping with the domains covered in the other SC models. Hence, based on this SC model review, all the proposed domains were aggregated in eight broad domains that cover almost all of the SC domains in the literature. These SC broad domains are: (1) Natural environment; (2) Built infrastructure and ICT; (3) Services, including education and health; (4) Mobility including transportation; (5) Economy and Finance; (6) Governance, policy, management and administration; (7) People, living, and society; and (8) Quality of life. These domains are identified, as a component of an SC assessment framework, in order to be assessed against an SC scaling system.

Among all the introduced attempts, two models are the most widely quoted, used, and applied SC assessment models in the literature. The first model is the European Smart Cities Ranking introduced by Vienna University and developed based on Giffinger et al. (2007). This model, which can be considered the first comprehensive attempt to develop an SC assessment framework, is based on six distinct city domains which are mobility, environment, living, people, economy, and governance. Each domain comprises a set of factors that is decomposed into indicators that evaluate success under that domain. The second is the ISO indicators for city services and quality of life (ISO37120 2014). This recent standard introduced a model consisting of 17 themes that comprise almost 100 performance indicators. The two models have been developed to enable comparison of cities and to assess their development, over time, towards the pre-set direction.

Both the Giffinger et al. (2007) and ISO37120 (2014) models include scaling systems for ranking based on domains' performance. Ranking systems will face challenges and limitations when the complexity and the evolving nature of the SCs are considered. Despite the benefits for city ranking, there are disadvantages, as outlined by Giffinger et al., (2007), including that (1) discussion focuses on final ranks and complex interrelations and causalities are unattended or neglected; (2) public attention is mainly focused on the final ranking without considering the methodological aspects behind the ratings; (3) the selective public perception of results enforces a confirmation of existing stereotypes and clichés; (4) rankings strengthen competition between cities, which may have negative consequences like deregulation, structural and spatial problems, risk for socially acceptable city development, etc.; (5) rankings are excessively acclaimed by the "winners" and ignored by the "losers"; and (6) cities (primarily poor performing ones) oppose comparisons with others ("benchmarking") in general. In addition to that; (7) rankings tend to follow a "generalistic" approach, as many financiers ask for clear results which can easily be communicated to the public and so most rankings aim at finding the "best" or "most attractive" city in general terms totally ignoring the fact that different activities need different conditions.

Considering the drawbacks of ranking systems, as well as the multidisciplinary, changing, and evolving natures of cities and societies, the nominal scaling systems are identified by the authors as the most suitable scaling system. When nominal scaling systems are based on levels of maturity, the assessment framework has several advantages over the other scaling systems including, but not limited to: (1) descriptive scaling levels, which are valid despite the future changes and evolutions of the city domains; (2) general measures which are valid despite advancement of the technologies in future times–hence, the indicators will not be considered as outdated; (3) benchmark-target systems–while initial level of maturity which sets a benchmark for the scaling system, the upper limit of maturity identifies a target for the city managers and policy-makers; (4) assessment result to direct the public discussions towards achieving maturity targets and filling maturity gaps rather than focusing on rank levels; (5) simplification of the identification of maturity gaps, which helps in quick prioritization by city managers; and (6) provision of clearer assessment results, which are preferred by financers.

2.3 Maturity Models for SCs

An early maturity model is the Capability and Maturity Model (CMM) released by the Software Engineering Industry (CMU/SEI 2010). The CMM was developed as a framework, based on a collection of best practices from the concerned domain, to support the process of improvement of an organization from the standpoint of their quality and effectiveness. The driver for such development is the premise that "the quality of a system or product is highly influenced by the quality of the process used to develop and maintain it" (CMU/SEI 2010). From then onwards, numerous maturity models have been developed in different areas including Smart cities and communities.

In the reviewed literature, very few maturity models were found for SCs. Identified models include: (a) IDC Smart City Maturity Model (IDC SCMM) (Clarke 2013), (b) Sustainability Outlook Smart City Maturity Model (SO SCMM) (Sustainable Business Leadership Forum 2014), and (c) Brazilian Smart City Maturity Model (Br-SCMM) (Afonso et al. 2015). These models were analyzed and assessed by Torrinha and Machado (2017). In comparison to our attempt: (1) none of them covers all of the three identified smartness dimensions, (2) none of them covers all of the eight identified city domains, (3) they are not applicable for high maturity levels, (4) they are developed for certain regions (e.g., Brazil or India) and based on certain SC model, and (5) they are designed for assessing specifically the current status (as-is situation). **Table 2** presents a few differences among the reviewed SC maturity models as modified from Torrinha and Machado (2017). Hence, due to this heterogeneity in assessing SCs, a maturity scaling model that is compatible with our SC concept perception, and the identified SC dimensions and domains needs to be proposed.

Table 2: Comparison of the reviewed SC maturity models

Item	IDC SCMM 2013	SO SCMM 2014	Br-SCMM 2015
Region	**Corporation**	**India**	**Brazil**
Purpose	Assessing the As-Is situation of the city.	Gauging preparedness of a city against a set of measures.	Measuring how smart a city can be. Measure and compare different levels a city can reach.
Scope	A framework defined for cities, for local governments.	Application of the model to key resource areas proposed by the Indian Government.	A model defined for the reality of Brazilian cities
Focus	Concerned with the governance process of the city and its improvement	Cities' basic infrastructure and urban resilience	The city basic infrastructure and social conditions
# Domains	**5**	**10**	**10**
Assessed domains	Strategic intent (vision, business case, leadership); Culture (innovation, citizen engagement); Process (partnerships, governance); Technology (architecture, adoption); Data (use, access).	Transport, Water Supply, Spatial Planning, Solid Waste, Environment, Sewerage & Sanitation, Storm Water & Drainage, Energy & Electricity, ICT & Sys. Intelligence, Economy & Finance.	Water, Education, Energy Governance, Housing Environment, Health, Security, Technology, Transport.
Maturity levels	Ad-Hoc; Opportunistic; Repeatable; Managed; Optimized	Access; Efficiency; Behavior; Systems; Focus	Simplified; Managed; Applied; Measured; Turned
Weakness	Limited number and coverage of domains. The identified three key SC dimensions were not covered. Concerned with the government process of SCs.	Focuses on cities' basic infrastructure and social conditions. Hence, the identified three key SC dimensions are not covered. Designed for specific region and not applicable for the high maturity levels.	Focuses on cities' basic infrastructure and urban resilience. Hence, the identified three key SC dimensions are not covered. Designed for specific region and not applicable for the high maturity levels.

3 PROPOSED SC CONCEPT AND MATURITY-BASED ASSESSMENT SCALE

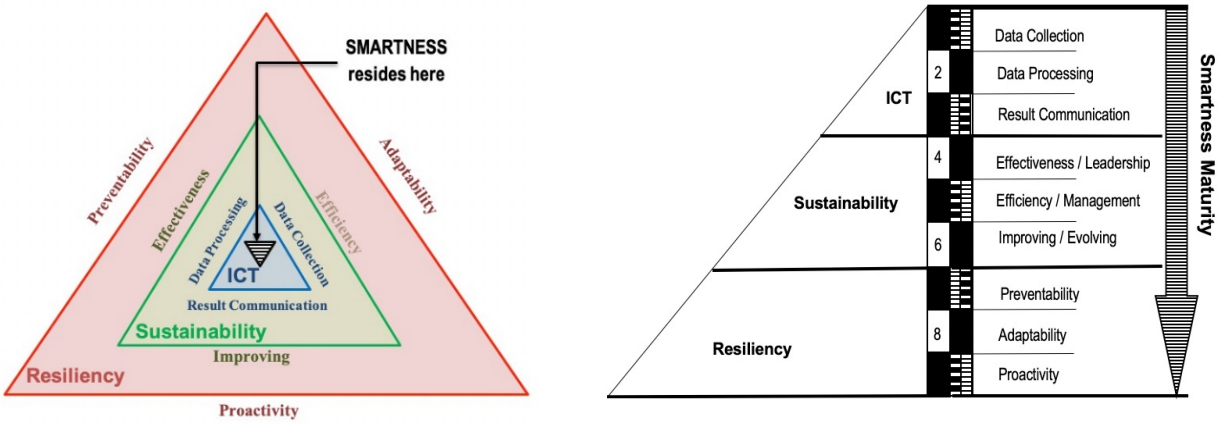
3.1 The Proposed SC and Maturity Concept

As mentioned above, three key dimensions were identified for SCs: Intelligent Connectivity Technologies (ICT), Sustainability, and Resiliency. **Figure 1 (a)** visualizes these dimensions as overlaid areas. The city smartness concept resides on the overlapping area of these three dimensions. The description of each smartness dimension is as follows:

- *Intelligent Connectivity*–The driver part of the smartness is the intensive use of the modern ICTs that enable modern and intelligent data collection, processing, and high connection and communication functionality among and within city systems.
- *Sustainability*–The viability/progress part of the smartness is to maintain (effective and efficient; zero negative effects) performance and continuous improvement (evolution; positive effects) without compromising the needs of future generations. This should be with respect to triple bottom line considerations (i.e., environmental, economic, social).
- *Resiliency*– The protection part of the smartness is to sustain/retain the achieved improvement and advancement levels of the quality of life against future shocks and changes. This requires systems with preventive, adaptive, and proactive functionality.

Figure 1 (a) illustrates each dimension of the three identified key dimensions as a triangle to represent its identified three pillars. While the ICT represents the intelligence and digital connectivity technologies that include digital data collection, data processing, and information communication; Sustainability represents the performance viability of the city systems under the restriction of minimized/zero negative impact on the environmental, social, and economic (the triple-bottom line) aspects. The viable performance is simply the effective, efficient, and improving performance. In contrast, urban resiliency represents the capacity to protect the city systems in order to function properly in situations of future changes, shocks and stresses. The protection of city systems includes preventing, adapting, and proacting planes or actions. Additionally, the figure shows that the expansion of the ICT technologies is restricted by the sustainability triangle and by the resiliency triangle. This means that the use of ICT should be toward enabling objectives of sustainability and resiliency while not disrupting their achievement. In the same illustration, the outer border resiliency represents the fence of protection to the whole system, as indicated above.

The city smartness model includes a smartness scale based on the concept of maturity as visualized in **Figure 1 (b)**. Hence, the figure shows that the well-being/quality of life of the inhabitants of SCs is first enabled by the extensive use of modern ICT. That is why the ICT is located at the start of the scale. Then, the achieved well-being is sustainable through viable (effective, efficient, improving) performance of all city systems based on the ICT enabling technologies. Finally, the resiliency considerations come at the end of the scale representing the protection of the viable city systems performance through preventive, adaptive, and proactive plans, designs, or actions. Therefore, for scoring purposes, the measuring scale system will be in the sequence of ICT, Sustainability (Sus.), and then Resiliency (Res.) to represent progress in the maturity levels/stages.



(a) (b)

Figure 1: The proposed city smartness model (SC and maturity concept): (a) the smartness concept of three dimensions, and (b) the smartness maturity scale.

Since ICTs are enabling technologies controlled by sustainability and resiliency aspects, one may argue that ICTs should be considered after identifying the controlling aspects. Hence, ICT should not be at the scale beginning. The answer is sustainability and resiliency are targets that are expected, in mature SCs, to be achieved through the use of ICTs. Therefore, in maturity assessment, the process starts from low maturity levels (ICTs) that represents the enabling tools to high maturity levels (Sus. & Res.) that represent the goals. However, in the case of developing an ICT-based solution for a sustainability or resiliency issue, the approach follows the opposite of the assessment processes. The issue is first defined to identify the right technology and needed data to be processed. Then, the ICT is applied to find decisions that align with resiliency/sustainability considerations.

3.2 The Proposed SC Maturity-based Scale System

The maturity scale implies that each level should include the characteristics of the previous levels or utilize the outcome from the previous steps. Hence, we propose, after an initial component, three components for each of the three SC dimensions. The resulting 10 components as defined in **Table 3** follow a waterfall sequence and at the same time represent stages of the maturity-based assessment model.

Table 3: The waterfall model for the components of the identified SC dimensions

SC Dimension	#	Dimension Component	Description
	0	Existence	The SC starts with the existence of an independent institute that represents a specific city or society domain or sub-domain.
Intelligent Connectivity	1	Data Collection	Then, this institute should collect data intelligently by means of the modern ICT technologies
	2	Data Processing	Then, these data should be intelligently processed and analyzed in order to obtain useful information and help in taking informed decisions.
	3	Results Communication	Then, the obtained information, results, or decisions are communicated with either other systems or the relevant stakeholders and policy-makers. This step is essential for a successful and viable domain performance (efficient, effective, and improving).
Sustainability	4	Effectiveness	Then, the communicated information should help in identifying the right factors that lead to successful performance and improvements in that specific SC domain.
	5	Efficiency	In addition to that, the obtained information should help in doing things right. The word "right" means that the process of doing things in a city domain should have minimized or no negative effects on the triple bottom line considerations (environmental, economic, social).
	6	Evolution / improvement	Furthermore, the process of doing things should consider the continuous improvement and advancement in the light of the obtained results and information. Improvements in a domain may be in terms of performance, quality of life, further minimizing the negative effects (or maximizing the positive effects) of the domain activities on the triple bottom line areas. This may require initiatives looking for opportunities for improvements at the current time.
Resiliency	7	Preventability	At any stage, part of the improvements should consider protecting the achieved level of life quality, successful performance, or minimized negative effects. The preventability is against losing that level of achievement. This means that the institute has developed and/or is developing backup plans. For example, no hunger is essential for life quality. The availability of active food banks for instance is a backup for anyone who cannot afford foods.
	8	Adaptability	The second way of protection is by accommodating changes. Hence, the adaptability is the capacity of accommodating changes and risks. For example, if the population of a city has increased suddenly (e.g., a big number of refuges/immigrant), city domains should have the capacity to provide satisfactory services and stay functional despite this population change. The required capacity amount is continuously monitored and controlled based on forward-looking initiatives within the city domains.
	9	Proactivity	At this stage, all the city domains should have forward-looking initiatives that are looking for identifying opportunities (trends) and risks (future shocks and severe changes). Based on these forward-looking studies, the city takes actions proactively rather than preventively.

Based on these ten components, a five-level maturity scale is developed based on these SC dimensions' components since they represent a waterfall model. This maturity model for each domain of SC is described in **Table 4** with further elaborations.

Table 4: The levels of the developed SC maturity model

#	Maturity level	#	Dimension Component	Maturity Level Description
1	**Initial**	0	Existence	The city covers the availability of the independent institutes for each city sub-domain.
		1	Data Collector	The city incorporates intelligent collection of the data regarding its domains
		2	Data Processor	The city analyzes collected data intelligently by means of modern ICT technologies.
	However, at this maturity level, the assessment does not consider intelligent communication of the obtained information among the city systems.			

2	**Improved**	3	Results Communicator	The city has intelligent communication of analysis outcomes among the city systems. The communication improves the quality of life.
		4	Effective/ leadership	The city incorporates the communicated information obtained from the intelligent analysis to perform processes successfully. The performance should improve the quality of life in terms of the triple bottom line considerations.
	However, at this maturity level, the assessment does not consider minimizing the negative effects of the domain processes and activities on the sustainability pillars (environmental, economic, social)			
3	**Sustainable**	5	Efficient/ management	The city uses the communicated information to do the processes and domain activities right. This means that the processes and performance consider minimizing or eliminating the negative effects of the environment, society, and economy.
		6	Evolving / improving	The city considers the use of the communicated information towards continuous improvements. The city domain has initiatives that look continuously for opportunities for further improvements. The opportunities are at the current time not in the future.
	However, at this maturity level, the assessment does not consider backup plans or preventing the changes from losing the achieved levels of life quality. It is possible to achieve level of quality and then losing it with the first change or shock.			
4	**Preventive**	7	Preventive	The city has backup plans in all of its domains to protect the institute from losing the achieved level of performance or protect the citizens from losing the achieved quality of life. These backup planes are for the currently identified risks not future risks.
		8	Adaptive	The city domains have additional capacity to accommodate changes such as sudden population increase in the city.
	However, at this maturity level, the assessment does not consider forward-looking initiatives that look to identify opportunities and risks in the future.			
5	**Proactive**	9	Proactive	The city has initiatives in all domains that look to the future towards opportunities to improve the current quality of life or identify risks in order to mitigate their effects and protect the achieved levels of performance and quality of life. In this context, the proactivity includes also designing and applying acts that demonstrate updates to the previous maturity levels to reflect that the identified risk or opportunity has been considered in assessment chain. This is to accommodate the SC changing nature dynamically.

As can be seen from the descriptions of the model levels, this maturity assessment model is descriptive (describing what should be available at each maturity level) not prescriptive (describing how to achieve each maturity level). In other words, the measures are in the form of questions that require objective answers from the managers of the SC domains. **Table 4** provides guides to these questions that should be applicable despite any future evolutions and advancements.

Table 5: The questions corresponding to the SC maturity levels

#	Maturity level	#	Dimension Component	Corresponding Level Question
1	**Initial**	0	Existence	Does the city have an independent institution for this (Sub-) domain?
		1	Data Collector	Does the domain collect and store/archive regularly (frequently) data relevant to improving the performance and life quality?
		2	Data Processor	Does the domain process and analyze regularly (frequently) data relevant to improving the performance and life quality?
2	**Improved**	3	Results Communicator	Does the domain communicate the obtained results or decisions-to the relevant stakeholders-regularly (frequently) relevant to enhance the life quality?
		4	Effective	Effective = doing the right thing Does this domain, based on the resulted information, identify and address the right factors to improve the life quality under the sustainability triple bottom line considerations?
3	**Sustainable**	5	Efficient	Efficient = doing the thing in the right way (no negative effects) Does this domain address the identified right factors based on following the best practices that have no negative effects with respect to the sustainability triple bottom line considerations?

		6	Evolving / improving	Evolving = continuous improvement and forward-looking for opportunities Does this domain follow practices or have initiatives that are looking for opportunities (in the present time) for improvements that serve the citizens' quality of life or positively affect the sustainability triple bottom line?
4	**Preventive**	7	Preventive	Prevention/protection = availability of backup plans Does this domain have backups to protect the city from losing the achieved level of quality of life?
		8	Adaptable	Adaptability = the capacity to accommodate changes (based on the forward-looking initiative) Does this domain have the capacity to overcome and accommodate future shocks and changes?
5	**Proactive**	9	Proactive	Proactive = forward-looking towards identifying Risks /Opportunities Does this domain have forward-looking initiatives to anticipate the future opportunities and risks (shocks/changes) and proactively design acts to improve quality of life and protect the city from losing the achieved level of quality of life?

4 DISCUSSION

The SC concept is introduced as a promising solution for the challenges of the population and urbanization growth. However, SC is an ecosystem and hence its concept is evolving. As a consequence, there is no universally-accepted SC definition. Hence, it was proposed in this paper to identify the key areas or dimensions of a city smartness. Based on these dimensions, generic SC models and assessment frameworks were developed.

In addition to the multidisciplinary, changing, and evolving natures of cities and societies, each city or municipality worldwide has its own unique characteristics, goals, problems, challenges, and, opportunities. Hence, the wordings of SC definitions and any specific model may be customized to meet an agreed vision of any specific city.

Several components of the SC concept have been mentioned in this paper: (1) SC key dimensions, (2) SC definition, and (3) SC assessment framework.

SC Key Dimensions –Based on the conducted review, the identified SC key dimensions are Intelligent Connectivity, Sustainability, and Resiliency. Intelligent Connectivity represents the enabling or the driver part of the city smartness based on intelligent data collection, processing, and high connection and communication functionality among and within city systems and domains. Sustainability represents the viability part of the smartness which ensures progression through effective, efficient, and improving performance of the city domains. Finally, the smartness should include a resiliency component that represents the protection against losing the achieved levels of the life quality and sustainable performances.

SC Definition –The three identified key dimensions should be covered in any SC definition regardless of its specific wording. Then, the SC definition should be modified to accommodate the defined vision of the leaders/managers of any city.

SC Assessment Framework– This framework has three components including (a) scaling system, (b) SC domains, and (c) smartness indicators/measures.

Scaling systems– The most critical component in SC assessment models is the scaling systems. This is because they provide the city smartness levels based on the key dimensions of the SC definition. Since we identified these three key dimensions, the scaling system was developed to reflect them. This system reflects also the relationship among these dimensions. Since we selected the SC model to follow the model of maturity, the developed scaling system was designed to reflect the SC model to be based on maturity. Hence, the proposed nominal scaling system became a maturity-based assessment scale.

SC Domains– Variety of SC domains were proposed in the literature as part of the SC models. In this paper, the SC domains proposed in the literature were aggregated in eight main domains that should be assessed against the developed assessment maturity-based scale. These SC broad domains are: (1) Natural environment; (2) Built infrastructure and ICT; (3) Services, including education and health; (4) Mobility including transportation; (5) Economy and Finance; (6) Governance, policy, management and administration; (7) People, living, and society; and (8) Quality of life. The subdomains and the lower levels should be further identified and agreed participatively by the SC initiative's and/or city/municipality's leaders.

SC Indicators/measures– Indicators are another essential component of the assessment framework. They

are measures of a city smartness. Hence, SC initiative's and city/municipality's leaders may be included in selecting the right indicators to measure the smartness maturity of their city and detect gaps and define goals. The development or selection of the relevant smartness indicators should be based on a set of guiding questions in order to ensure the compliance with the proposed maturity-based scaling system.

The proposed scaling system was developed based on ten items (as in **Table 3**) that cover the identified SC dimensions. The relationship of these items follows the waterfall model. This means that the output of each item is considered as an input for the subsequent one. This sequence has been selected to reflect the concept of maturity model which is based on accumulative stages. Based on the ten items and their inter-relations, a five-level maturity model was developed and presented in **Table 4**. The guiding questions to select or develop the needed measuring indicators are given in **Table 5**.

The maturity-based assessment scale introduced in this paper was developed to scale the smartness of cities and help the SC initiative's and municipality's leaders and managers as well as policy-makers in identifying gaps and setting goals. The scale presented was proposed to be generic and descriptive (not prescriptive), and to set the scope of work for identifying more specific items and indicators for SCs. This distinguishes it from other SC maturity models available in the literature. However, the missed item of this research paper is the validation part which should be performed through either expert interviews or case studies. Hence, the paper is proposing a generic conceptual framework for assessing SCs.

5 CONCLUSIONS

In this paper, the key dimensions of the SC concept have been identified based on reviewing and analyzing the relevant literature. These dimensions are ICT, sustainability, and resiliency. Accordingly, it was recommended that any SC definition should include these key dimensions in addition to the specific vision of the city under consideration.

An assessment framework is an important part of any SC transformation project or initiative. This framework is required to evaluate the city smartness, identify gaps, and set goals. Hence, a scaling system was proposed in this paper. Several scaling systems were found in the literature. Due to the complexity and evolving nature of SCs, it was found that nominal scaling systems are more relevant to the SC concept. Thus, this paper introduced a scaling system based on maturity models. This system is called Maturity-based Assessment Scale.

The developed maturity-based assessment scale includes five levels of maturity as follows: initial, improved, sustainable, preventive, proactive. These levels, as cumulative staged levels, are based on nine items that cover all the three identified key dimensions of an SC (ICT, sustainability, and resiliency). In more detail, the enabling SC dimension is ICT which includes stages of intelligent data collection, processing, and result communication. The sustainability dimension reflects the viable performance of city systems. This performance is defined as effective, efficient, and improving performance to maintain sustainability. Finally, the resiliency dimension represents the capacity of the systems to be functional in the cases of future shocks, stresses, and changes. It also represents the protection against losing the achieved levels of the life quality and sustainable performances. The stages of this dimension include preventive, adaptive, and proactive planes, designs, and actions for protecting the achieved life quality levels.

To partially compensate for the gaps in the existing SC maturity assessment models, this paper developed the maturity-based assessment scale. SC scaling frameworks are essential in helping policy-makers, SC initiatives' leaders, and municipalities' managers in detecting gaps and setting goals towards a pre-determined vision. The developed scale system is intended to be generic and descriptive to set a scope of work for identifying specific city smartness indicators. This paper is introducing a conceptual assessment framework. To identify the frame limitations, it is required to be presented to expert interviews or applied to multiple case studies. Hence, future work will include developing and adapting more detailed indicators and measures to assess city smartness and then applying the full developed assessment system on a pilot city and/or seeking critical reviews by experts for validating the developed system.

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