The European Concept of Smart City: A Taxonomic Analysis

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***Abstract*—The concept of "Smart City" became widely debated, including different components for building a truly sustainable urban environment. In the literature, there is a huge number of contributions inherent to the definition of a smart city, however, a broad view of the field is still missing. The aim of this paper is twofold. Firstly, to provide a repeatable and scalable methodology that can be applied to unstructured documents on smart cities projects considering all the multi-facet aspects of a smart city (e.g., business model, technology). Secondly, to propose an analysis carried out with a taxonomy to a database of 25 outstanding smart city projects in Europe, to discuss the current direction in which they are moving, identifying success factors and analyzing new trends and future paths.**

***Index Terms*—Smart cities, Smart City Projects, Taxonomy**

I. Introduction

According to a study of the United Nations, the urban population of the world increased rapidly, and by 2050, 66 percent of the world's population is predicted to be urban [20]. In this context, several initiatives, known with the term "Smart City Projects" (SCPs), arise to ensure sustainable, responsible and inclusive growth of urban areas.

In the literature, there is a huge number of contributions and case studies inherent to the concept of smart city. Many attempts have been made to investigate the numerous existing definitions of a smart city and the conceptual variants obtained by replacing the term "smart" with alternative adjectives, as "intelligent", "digital", "cyber", "informational", and "wired" [1, 18, 28, 27, 6, 16, 12, 21, 19, 40]. In fact, within the different definitions of a smart city, a consistent part of the literature is focused on proposing infrastructure for urban metabolism [10] and ICT solutions in smart cities using, for example, big data analytics, Internet of Things (IoT) and Blockchain [7, 30, 23, 38]. In particular, the authors in [41] stated that technology helps the city to develop a smart approach to the design of urban policies and fostering citizen cooperation.

Several studies have proposed different methodologies, including taxonomies, for the measurement "smartness" and the smart city categorization [32, 34, 31, 8, 43].

Despite the advances in the literature on smart cities, to our knowledge, just a few works have been done to give a holistic vision of the topic and to classify existing SCPs. In particular, we identify the following issues:

- a commonly accepted and diffused definition of what a smart city is and which is the meaning of smartness is still missing;
- the methodologies and taxonomies proposed are focused on particular and restricted aspects of the smart city (i.e., only on the application domains or even more stringent, on transportation), and on a specific geographic area. Thus, all these contributions do not consider a fully-comprehensive vision of smart cities [24];
- several contributions are still too focused on the technical details of smart city, disregarding the requirements of stakeholders involved and the managerial aspects [14];
- there is a lack of gathered information concerning the characterization of projects and a database of the lessons learned from each SCP. Indeed, regarding the projects already developed, no formally recognized entities gather their results in a consistent and structured way. This makes difficult the identification of the key factors determining the success of an SCP and of how the initiatives are dependent on the geographical and socio-politic environment in which they arose.

This study aims to fulfill these gaps by presenting a taxonomy considering all the multi-facet aspects of a smart city. The taxonomy provides a framework for classifying the projects, becoming a guide for the researcher who chooses to analyze SCPs with an interdisciplinary view, providing numerical analysis and a way for characterizing the projects. The educator can use this taxonomy to introduce the subject comprehensively, letting a newcomer have a depiction of the broad spectrum of possible research lines. Finally, institutional managers and stakeholders can use it in developing new strategies.

More in detail, in this paper we want to answer the following questions:

- Can we find a series of keywords/axes such that we can categorize any project dealing with a smart city?
- Can we organize the projects in taxonomy and, by that taxonomy, highlight the research mainstreams and future directions?
- Can we see any lack in current frameworks, in terms of

the global view of the smart city, current trends and future paths?

We then use the taxonomy to draw a picture of the smart cities scenario and recent practices in Europe.

To answer our research questions, we structured this paper as follows. In Section II, we introduce the methodology adopted and we present the taxonomy for SCPs categorization. Section III contains the results of empirical analysis of smart city definitions and the key outcomes obtained by applying our taxonomy to 25 outstanding European SCPs, analyzing the trend, pattern, future direction, and current issues.

II. Methodology adopted

This paper proposes a cluster analysis of European SCPs, based on a taxonomy with polythetic classes [4, 3]. The taxonomy completes the original work [37]. In particular, this study extends the prior work concentrating on a larger set of SCPs in Europe and considering also their value propositions and business models.

From a methodological point of view, we built it following the three-step method described in [3]. Firstly, we began with an empirical analysis of a database of SCPs. In the second stage, we represented the cluster on paper. Finally, the third stage was visualizing a mental concept for the cluster, often by rationally generating a name or label for the cluster (such as "Description").

We started to retrieve information about projects from peer-reviewed journals and conference proceedings as the source of smart city literature, using the keywords "smart city", "smart city projects" and "intelligent city". Moreover, we reviewed the deliverables of the SCPs, governmental and consulting reports available on the websites of the principal entities, which are fostering smart city initiatives under National, European and International calls. For example, we consulted the websites of the European Commission, the Smart Cities and Communities and Social Innovation call of the Italian Ministry of Education, University and Research, the Intelligent Community Forum and the Smart Cities Council [22, 44].

Firstly, we reduced the entire set of selected projects by restricting the topic area. Then, we performed screening to remove projects for which all the information is not fully available, taking into account only SCPs ended, ongoing, or at least already funded. This process yields a selection of about 25 outstanding SCPs, making our analysis, even if not exhaustive, the largest screening of SCPs in Europe.

Moreover, following the GUEST methodology [26], for each selected SCP in the sample, we produced a short document, composed of an executive summary, a discussion of the value proposition and the business model related to the project. In particular, in our paper, we added to the taxonomy a further level of analysis based on a managerial perspective. With this purpose, we designed the Business Model Canvas and the Value Proposition Canvas [35, 36]. The aim is to highlight the needs, gains and pains of the primary stakeholders involved in the project, including all the components needed to make the project works, as the costs and revenues structures. This further analysis represents an added value for future real case studies and research projects. Considering these results, government and project initiators should be able to define more appropriate business models and policies for smart city applications, anticipating the stakeholders' requirements in the early stage of the project, with benefits regarding the success and financial sustainability of the initiatives, in the long run.

A. Taxonomy

The taxonomy (Figure 1) is composed of three different axes, which represent the three main criteria used to classify the different aspects of the SCPs. They are Description, Business Model, and Purpose.

In the remaining part of this subsection, we provide a general description of the taxonomy. The interested reader could refer for a detailed discussion of each axis, and category to the original work [37].

In particular, the three main axes are the following:

- **Description**. It provides an overview of the project and its context, with particular regard to its categories: to the objectives faced and the industry (Objectives), the tools and the technologies adopted (Tools), the nature of the project initiator (Project initiator) and finally, the key actors involved in an SCP (Stakeholders). Concerning the objectives, some goals are present as, within the several fields of activities connected to the term "Smart City", we have identified the eight major fields. Moreover, given the strong interconnectivity and integration between these fields within urban areas, several SCPs cover more than one objective. In these cases, the most relevant and impacting goals usually belong to the identified categories.
- **Business model**. This axis addresses the aspects related to the project management and the business and governance models. In particular, one identifies the nature of the project manager (Management) and the providers of infrastructures, equipment and financial resources (Infrastructure financing and Financial Resources).
- **Purpose**. This axis classifies the SCPs according to their final goal. It identifies the user that will adopt and benefits of the solution developed by the project (Client), the type of product (Product) and the geographical target (Geographical target).

III. Key findings and discussion

This section aims to discuss the European vision and concept of smart cities. In particular, we first provide consistent evidence on the different attempts to define a smart city in the European literature on this field. Then, we provide an analysis carried out with our taxonomy to a database of 25 real SCPs in Europe. Our purpose is to derive trends and patterns, and investigate whether the projects aiming at building smart cities are aligned with the different definitions in the literature.

Description

Objectives	Key Enabling Technologies	Project initiator	Stakeholders
Water	*Cloud Computing*	*Private*	*City*
E-Governance	*Data Base*	*Public*	*Consumers / Citizens*
Buildings	*DSS*	*Mixed*	*Administration*
CO_2 Emissions	*ICT*		*SMEs*
Energy	*Innovative Sensors*		*University*
Security	*Legal and financial tools*		
Social Innovation	*Other new technologies*		
Transportation	*Portable Smart Devices*		
	Smart Grids		

Business Model

Management	Infrastructure financing	Financial Resources
Private	*Private*	*Private*
Public	*Public*	*Public*
Mixed	*Mixed*	*Mixed*

Purpose

Client	Product	Geographical target
Private	*Specific*	*Urban*
Public	*No Specific*	*National*
Mixed		*International*

Fig. 1. Taxonomy

A. The European definition of a smart city

To clarify the concept of SCPs, we first need to understand what European scientific communities define as a "Smart City". To this end, we reviewed the recent literature published from 2000 to 2019 in different sources (i.e., scientific journals, conferences proceedings, textbooks, and doctoral dissertations). In general, for our analysis, we used the Scopus bibliographic database. Many journals are also recognized by the ERA 2012 Journal List evaluation across eight discipline clusters [2]. Then, we adopted a keyword extraction approach [42] to select the most significant and representative words present in the definition.

Many definitions of a smart city in the European literature include the adoption of new technologies to solve and manage the several challenges related to the efficient city development, as liveability, mobility, governance, sustainability, and economic growth. Indeed, observing the most frequent keywords along with related percentage used in the literature (Figure 2), we outline that 83 percent of papers focus on the technological aspect of smart cities, involving the adoption of digital tools, big data or information and communication technologies (ICTs) [9, 5, 33, 31, 11, 45, 27]. For example, the authors in [37] defined smart cities as future communities where new intelligent technological tools, services and applications are integrated into a unique platform, providing interoperability and coordination between the several sectors.

The authors in [5] stated that a smart city implies a high-tech intensive and an advanced city that connects people, information and city elements using new technologies.

Other authors focused on the adoption of ICT tools to speed up the economic growth, as we can notice in the definition provided in [27].

Another definition of smart city links technology to transportation and the concept of sustainability. It has been provided in [11]. The authors stated that a city, to be smart, needs investments in human and social capital, and in traditional (transport) and modern (ICT) infrastructures, fostering the sustainable economic growth and high quality of life, with a wise management of natural resources, through participatory governance [11].

It is worth mentioning that the European concept of the smart city is often (50 percent of definitions) related to the environment and natural resources, and their sustainability [5, 11, 31]. A possible reason is a high interest in environmental protection, resource efficiency, and ecosystems fostered by the Horizon 2020 programme.

A great part of definitions (61 percent) emphasizes the concept of people and social relations, including social and cultural development [27], education and social learning [29, 13], social sustainability [46] and citizens engagement and inclusion. This outcome is connected to European historical behavior, which has been more welfare-oriented in urban policy-making and social inclusion. In fact, according to different authors [34, 11, 9], a smart city is a means of enhancing the quality of life of citizens. Indeed, the term "quality of life" represents another important keyword, being present in 44 percent of definitions.

Finally, since a holistic definition of a smart city and an official institution that regulates the recent smartness trend does not exist, different contributions in the literature debate on the future of smart cities. For example, the author in [27] provided a preliminary critical polemic against some of the more rhetorical aspects of smart cities. Moreover, Battarra et al. [6] stated that technology may be perceived as a panacea, thereby "smart" initiatives may be isolated and have a characteristic of episodic experiments.

B. Taxonomy results

This section presents the results obtained by applying our taxonomy to the selected SCPs.

Starting from the first axis named Objectives, 92 percent of European SCPs involve multiple objectives, as shown in Table

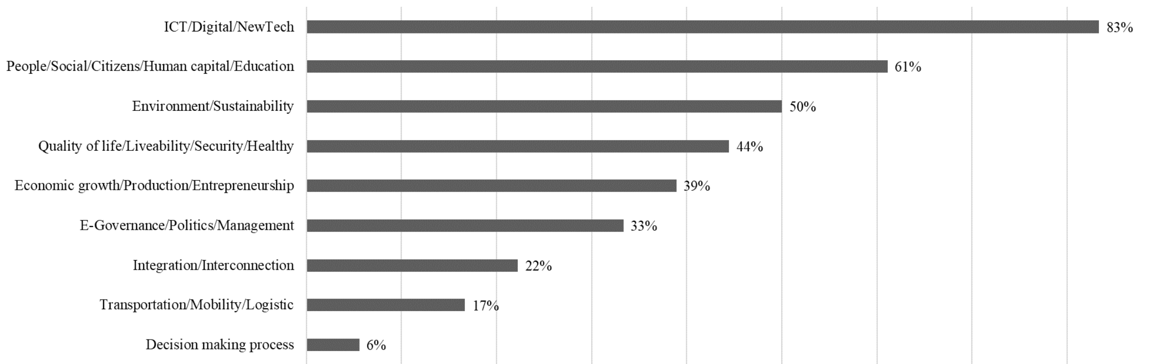

Fig. 2. Smart City keywords in the European literature.

TABLE I
OBJECTIVES OF THE EUROPEAN SCPS. NOTICE THAT THE SUM OF THE PERCENTAGES IS MORE THAN 100% DUE TO THE MULTI-OBJECTIVE PROJECTS.

Objectives	%	Objectives	%
Transportation	52%	Water	8%
Energy	68%	Security	12%
Building	56%	E-Governance	24%
CO2 Emissions	68%	Social innovation	32%
Multi-Objective	92%		

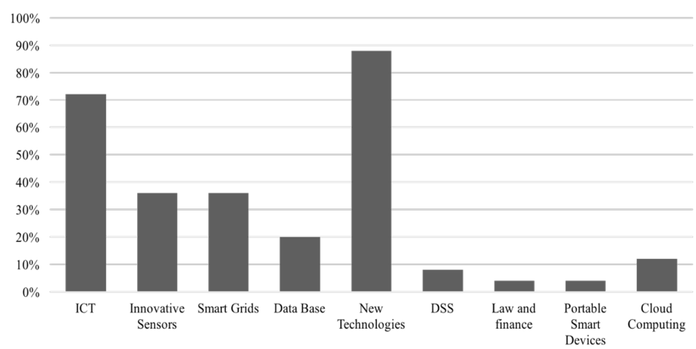

Fig. 3. Key Enabling Technologies adopted in European SCPs.

I. It is due to the multi-facet nature of smart cities and the need for urban planners to take into account the several aspects and services of city management. In particular, the main trending topics are Energy and CO2 Emission reduction, where the latter is increased from 11 percent to 68 percent, compared to the prior work [37].

Generally speaking, Transportation, Building and CO2 Emissions are the most frequent topics in the multi-objective SCPs, which are concentrated on reducing greenhouse gases, enabling refurbishment and energy retrofitting in existing residential buildings (e.g., City-zen project), purchasing of electric and clean fuel fleet of cars, bikes, and buses (e.g., Ele.c.tra project, URBeLOG [17]), fostering the synchromodality in freight transportation (e.g., Synchro-net [39, 25]) and finally, using smart grid networks (e.g., Grid4eu project) to storage and resell extra energy produced and control energy consumption.

Analyzing the Key Enabling Technologies, we obtain the impressive result that most of the European SCPs are devoted to the application of new technologies (e.g., RFID, GIS and innovative daylight collectors), followed by the ICT-based decision support systems, 88 and 72 percent respectively (Figure 3). Other frequent technologies are Smart Grids and Innovative Sensors (36 percent). This finding reflects that European countries are prone to use innovative technologies (e.g., sensors) due to the increasing diffusion of the IoT for smart mobility and City Logistics issues [15].

Focusing on the Business model and Purpose axes, we notice that SCPs are usually initiatives under government programs, as shown in Figure 4. In particular, European SCPs mainly arise as responses to government calls or public-interest challenges. Indeed, the percentage of SCPs in which public entities participate as Project Initiator rises from the 56 percent of the original study to the overall sample estimated in this paper. This is due to the high number of European-funded projects under the Horizon 2020 Programme. In Europe, the participation of the public entities is strategic as providers of financial resources, infrastructures, and equipment as well. In particular, in 52 percent of the total projects, the infrastructure financing comes from the public sector, eventually under Public-Private-Partnerships (PPPs) form of cooperation (32 percent), while, in the remaining 48 percent the infrastructures are only private.

This large involvement of the public bodies could be justified by the aim of using the outcomes of the initiatives for future city management and planning purposes. Indeed, 68 percent of the projects have public or mixed customers.

In conclusion, results obtained from the taxonomy application to the chosen sample of projects show that a significant part of current initiatives addresses different objectives in the same project, reflecting the interest of the local government in the multiple facets of city management. In Europe, the different objectives are associated with the reduction of CO2 Emissions due to the pressure of the European Commission that, through several calls, aims to achieve environmental

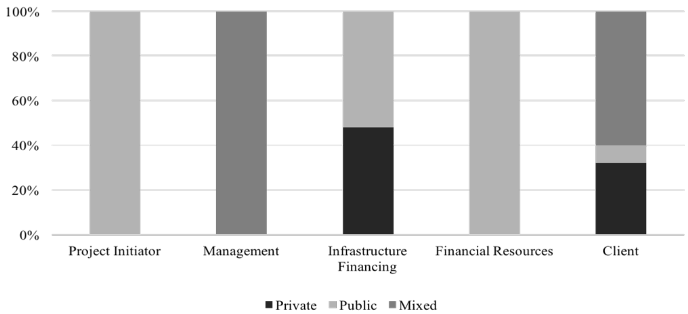

Fig. 4. Role of the Public Sector in European SCPs.

integrity, resilience and sustainability of activities.

In general, this work highlights the maturity of the SCPs from a technological point of view since most initiatives aim to improve the cities conditions, proposing advanced solutions with high technological content. On the contrary, although recent projects promote new collaborative business models, the integration of the business and governance models is still limited, compromising the feasibility, profitability, the scalability and thus, the sustainability of the project.

In particular, concerning the scalability, our results show that the European Commission, with several calls, is explicitly fostering the creation of European SCPs that embrace more than one country, with most of the time few lighthouse cities at the early stage of the project and then sharing the solutions with the other cities acting as followers. However, more attention should be paid on urban diversity and business matters that may vary from state to state and city to city.

From a methodological point of view, the main challenge encountered in our study was the fragmented process for retrieving information and data. In particular, there are no formally recognized entities storing and organizing information. It comes mainly from sources as the European Commission and the Smart Cities Council websites, containing several deliverables and information about the projects without any categorization, making difficult the monitoring of the outcomes.

Finally, the analysis of the different business models of SCPs highlighted a limitation, which is the business perspective. The majority of the projects focus on the technology perspective, omitting the business development phase and giving insufficient exploitation support. Such product/service rarely survives to the end of the pilots and usually is not tested in a real market environment, or a clear customer discovery phase is performed [39]. Hence, all the projects require the adoption of Innovation and Business Development methodologies and, as project outputs, a clear exploitation plan.

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