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A New Taxonomy of Smart City Projects

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Abstract

City logistics proposes an integrated vision of freight transportation systems within urban area and it aims at the optimization of them as a whole in terms of efficiency, security, safety, viability and environmental sustainability. Recently, this perspective has been extended by the Smart City concept in order to include other aspects of city management: building, energy, environment, government, living, mobility, education, health and so on. At the best of our knowledge, a classification of Smart City Projects has not been created yet. This paper introduces such a classification, highlighting success factors and analyzing new trends in Smart City.

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Keywords: Smart City; Smart City Projects; Taxonomy; Classification; Business Models

1. Introduction

City logistics proposes an integrated vision of freight transportation systems within urban area and it aims at the optimization of them as a whole in terms of efficiency, security, safety, viability and environmental sustainability. Recently, this perspective has been extended by the Smart City concept in order to include other aspects of city management: building, energy, environment, government, living, mobility, education, health and so on. Thus, Smart City proposes a holistic vision of future communities where new intelligent technological tools, services and applications are integrated in a unique platform, providing interoperability and coordination between these several

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sectors. Furthermore, Smart City also involves the definition of new governance instruments as well as new public and private funding methods. These new requirements of innovations for cities lead to contemplate and undertake new initiatives. For this reason, last years have seen a significant number of Smart City Projects (SCPs) in all over the world. In fact, the Seventh Framework Programme (FP7) of the European Commission gave the opportunity to private and public actors, as well as to the researchers, to decline the Smart City idea in several technological frameworks and case studies. Despite some pioneering works by Giffinger et al., 2007 and Giffinger et al., 2009 under the Smart Cities FP7 Research EU Programme, only a few works have been done in order to categorize Smart Cities initiatives. In particular, Giffinger et al., 2007 gave a first operational definition of Smart Cities, grouping 74 indicators in six categories. Unfortunately, the classification of SCPs indicators have some drawbacks, including the presence of a large number of indicators (about the 35%) that cannot be defined at the urban level (Giffinger, R., & Haindlmaier G., 2010).

A more social inclusion driven approach, , is due to Kanter & Litow (2009), while an information sharing definition is not universally recognized, bringing to different forms of communication and participation, including net cities (Castells, 2004), open cities (Partridge, 2004), sentient cities Shepard, 2011), wiki cities (Calabrese et al., 2009), cities 2.0 (Chadwick, 2009), etc.

A first taxonomy is due to Benjelloun et al., 2010. The authors focus only on City Logistics projects, without considering the other aspects of SCPs, including Social Inclusion, Business and Governance models, human and social relations.

Thus, at the best of our knowledge, a taxonomic classification of SCPs in the literature providing a systemic and complete overview of these issues has not been created yet. The importance to have this classification is the possibility to understand the success factors of past SCPs and to extract and analyze new trends. This paper aims at giving a first answer to this issue, providing both a methodology to classify the existing SCPs and a key to read the fragmented map of existing and new projects.

The paper is organized as follows. Section 2 presents the methodology for building the initial projects database. Section 3 gives a detailed description of the taxonomy axes and their sub-categories, while Section 4 provides the detailed analysis of the SCPs and a discussion of strength and weakness of the projects presently under development.

2. Methodology

Our aim is to define a taxonomy able to compare two or more projects and this can be useful for several reasons. First, it allows extracting success factors for SCPs. Second, it should be an easy tool for developing a trend analysis able to underline potential gaps. Third, government and stakeholders should be able to use it to define more appropriate business models and policies for smart cities considering projects innovation. Following these guidelines, we chose the sources of information in order to populate our SCPs database. In particular, we used public available information only, including projects and city websites, published papers and presentations, as well as governmental communications.

The taxonomy present a trend analysis based on Italian and European projects studied in building the taxonomy. We select projects looking at their status. We only consider projects that are already funded by National or European calls, still active in 2013 or just implemented. Due to coexistence of several project at different maturity level in some large cities, we considered them as different projects. The sample is composed of 28 projects for a total of 24 participating countries (see Fig. 3).

According to their geographical target, the number of habitants potentially involved can vary from a few thousand to hundreds of millions (see Fig. 2). These data immediately give an idea of the potential impact of each project. Besides, the most active nations seem to be Spain, Italy and France.

3. Taxonomy dimensions

As highlighted in the Introduction, the complexity in categorizing SCPs led to several attempts to group SCPs logically. In the following, we describe the criteria we use to catch the different aspects of SCPs. Criteria are grouped into categories and each category is assigned to an axis. We identify three main axes. In this way, our

taxonomy enables efficient and quick analysis of projects by creating different multidimensional aggregations. An analysis could focus on one criterion, or on a set of related criteria, and then investigate all projects, which are characterized by this criterion (or by a subset of criteria).

Fig. 1 describes the structure of our taxonomy. The three axes are: *Description*, *Business model* and *Purpose*. *Description* identifies the project context and it is composed of four categories: *Objectives*, *Tools*, *Project initiator* and *Stakeholders*. Business model analyzes project management and finance through three categories: *Management*, *Infrastructure financing* and *Financial resources*. Finally, the third axis, *Purpose*, specifies customers, type of products and geographical target of each project and it contains three categories: *Client*, *Product* and *Geographical target*.

The subsections 3.1, 3.2 and 3.3 offer an insight to *Description*, *Business model*, and *Purpose* axis, respectively.

Description

Objectives	Tools	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		

Purpose

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

Fig. 1. Dimensions and categories of our taxonomy.

3.1. Description

It aims at describing the project main features that allow to immediately identifying the project context and components. It is composed of four categories: *Objectives*, *Tools*, *Project initiator* and *Stakeholders*.

3.1.1. Objectives

While the major objective of City Logistics is to mitigate the negative impacts of urban freight transportation through sustainable freight-transport systems significantly, “Smart city” term can refer to several fields, where the use of information and communication technologies (ICTs) can be applied to support more efficient and integrated systems in everyday urban life. Thus, there are several fields of activity in relation to the term “Smart City”. We have identified eight major fields:

- *Water*: Due to the population growth, cities of both emerging and developed economies need new water management, harvesting and distribution systems. Some SCPs are developing new practices, services and tools in order to reduce water consumption and water contamination, increase pathways for water circulation and enable the effective utilization of water resources.

- *E-Governance*: Several SCPs aim at developing ICTs to enhance the efficiency, effectiveness, transparency and accountability of communications and transactions between government and public administration, and citizens and businesses.
- *Buildings*: Increasing attention is paid on developing "smart buildings", which improve building automation, life safety and telecommunications, while, at the same time, they reduce energy consumption, optimize how space is used and minimize their environmental impact.
- *CO_2 emissions*: Urban areas account for 80% of CO_2 emissions. By applying ICTs as well as Optimization methods, cities are trying to cut down on CO_2 and other greenhouse gas emissions, save resources, and provide the base for new economic activities. Even though this objective involves several sectors, the largest part of CO_2 emissions is generated by transportation in urban area. Better urban planning and changes in individual behaviors, induced and supported by new technologies, are viewed as possible answers to this issue.
- *Energy*: Sustainable development is the first aspect of a smart city and it requires new, efficient, and user-friendly technologies and services, in particular in the areas of energy. Concerning energy, cities efforts principally aim at reducing its consumption and carbon footprint, developing alternative fuels and mobile energy sources, creating a single and smart electricity grid.
- *Security*: The security of citizens should be a cross-cutting issue of all SCPs. It concerns the definition and implementation of new technologies and systems to improve safety and security within urban areas;
- *Social Innovation*: Several SCPs aim at developing innovative activities and services to meet social needs and to increase standards of life within urban areas.
- *Transportation*: Even if it causes many problems within urban areas such as emissions of greenhouse gases, air polluting compounds, noise and congestion; urban mobility of citizens and goods is vital for the functioning of cities. To overcome these issues, there are currently some projects focusing on multimodality, new technological approaches for booking and ticketing processes, new organization of city logistics as well as on the implementation of cooperative intelligent transport systems and services (ITS).

However, because of the strong interconnectivity and integration between these fields within urban areas, several SCPs cover more than one objective. We refer to them as *multi-objective projects*.

3.1.2. Tools

A Smart City is a city where new technologies are intelligently implemented to provide more efficient, secure, safe and sustainable everyday activities and services. We have identified eight classes of technologies, which are the most widely used tools for achieving SCPs objectives:

- *Cloud Computing*: Cloud computing offers several computing services that are accessible over the Internet and that ensure high reliability, increased security, high availability at low total cost of ownership. There are different kinds of cloud computing services depending on the type of resources delivered via them, such as Infrastructure as a service (IaaS), Platform as a service (PaaS), Software as a service (SaaS), Network as a Service (NaaS), Storage as a service (STaaS), Sensor as a Service (SSaaS) and others.
- *Database*: The use of databases allows containing, structuring and sharing data between several actors of a system. Thanks to a Database Management System (DBMS), it is possible to efficiently and effectively manage a large set of structured data, and run operations on the data requested by numerous users. Their usage become more and more effective when paired to networks of sensors. Due to the huge amount of data to manage, Big Data applications often arises in this context.
- *DSS*: Decision Support Systems (DSS) are interactive software-based systems that help decision makers to identify and solve problems and make decisions. They are based on computer-based optimization and simulation models which are properly designed to support decision making process of an organization or of a complex system and that can lead to significant improvements in the management of smart cities by enabling value-driven, data-intensive and participative governance models.
- *ICT*: The Information and Communications Technologies (ICTs) play an important role for the design of smarter cities and, for this reason, a significant part of city investments is addressed to the development of new ICTs. They can enable a better use of energy in buildings, transport, street lighting etc. They can also facilitate the

integration of locally generated renewable energy into the electricity grid, as well as enable new production, distribution and governance processes.

- *Innovative Sensors*: They are transducers that are in direct contact with the system to be measured and applied for an innovative purpose and using new technology. In the specific context of the Smart City projects, they may be used to measure humidity, temperature, CO_2 emissions, the flow of people and cars and so on.
- *Portable Smart Devices*: Portable devices allow users to be connect wherever they are. They can be used to have data access or to exchange information. Smartphones, tablets and laptops are included in this category.
- *Smart Grids*: A smart grid is an electrical grid that uses ICT to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. Smart grids can help cities to ensure resilient delivery of energy, improve energy conservation and efficiencies as well as enable coordination between urban infrastructure operators and users.
- *Other new technologies*: New technological solutions that are implemented to perform a particular task and that cannot be categorized in the above list.

3.1.3. Project initiator

Both government and private sector businesses are promoting SCPs to find sustainable solutions to the growing issues. The public sector is offering incentives to support Smart City initiatives to enhance city sustainability and security, while SMEs are interested in improving their efficiency and acquiring a competitive advantage on competitors.

- *Private sector*: One or a group of enterprises;
- *Public sector*: City councils or a government entities;
- *Mixed*: Mixed management between private and public entities;

3.1.4. Stakeholders

Various parties may be involved in SCPs, each covering a different role and with its own objectives. We identify five key stakeholders:

- *City*: In SCPs, cities or a portion of them are always an active member.
- *Government*: The public sector may be involved in problem analysis and promoting the implementation of promising solutions.
- *SMEs*: Enterprises are usually involved in the SCPs and sustained by the public sector.
- *Universities*: Researchers play an important role in SCPs, developing and creating innovative tools and ideas.
- *Consumers / Citizens*: they can be involved in the project directly in the test procedures or indirectly as end-users of the project product or service.

3.2. Business model

The introduction of new solutions of SCPs requires the definition of new business models and governance mechanisms in order to create a virtuous system. In fact, the adoption of these new services and technologies strongly relies on the definition of business models, that make them financially sustainable, and on the presence of a set of shared rules and policy mechanisms.

The first critical issue of a SCP project is related to the definition of the funding scheme, its feasibility and its profitability. This axis provides information on how the project was imagined, identifying by whom it is managed (*Management*), who provides necessary infrastructures and equipment needed for developing the project (*Infrastructure and equipment financing*) and who financially supports the SCP.

3.2.1. Management

The implementation of SCP requires the collaboration within two or more entities. They can be SMEs and companies cooperating for the realization of a shared project, public entities or a mix of them.

3.2.2. Infrastructure and equipment financing

Necessary infrastructures, facilities, equipment, vehicles and devices can be provided by both private and public entities. In addition, also in this case a sharing of public and private ownership is possible.

3.2.3. Financial resources

For realization, projects need financial resources that can be given by private or public entities.

3.3. Purpose

This axis classifies SCPs according to their final goal. It identifies who will benefit and use the product developed by the project, the type of product and the geographic target.

3.3.1. Client

The outcome of the SCPs can be addressed to citizens, private firms, public companies or public administration. We group them into two categories:

- *Private*: Citizens, SMEs or private firms;
- *Public*: Public entities.

3.3.2. Product

Some SCPs aim at developing and implementing a clear and specific product or service, but, at the beginning, several SCPs have not identified yet what could be the final product because they still have to research and develop the product.

- *Specific:* If at the beginning of the SCP, the product or service is already defined;
- *Nonspecific*: If the product or service is still to be defined.

3.3.3. Geographical Target

The SCPs might concern the city area or their area of interest can be expanded at the national and international levels.

- *City*: The SCP concerns a specific city;
- *National*: The geographical coverage involves more cities within a country;
- *International*: The SCP concerns more cities, located in an international area;

4. Using the taxonomy: an analysis of existing SLPs

As can be seen in Fig. 2, projects that focus on individual cities affect from 20 thousand inhabitants, as the case of Isernia Project, until more than 15 million inhabitants such as POI, which interests on considerably larger conglomerates.

On national scale, the number of inhabitants potentially affected goes up rapidly and it reaches the peak of 273 millions with the project called Grid4EU. Fig. 4 shows the number of potential citizens involved for each project at national level considered in our analysis.

In the following, we present our analysis presenting the result we get from each axis and each categories.

Considering the Description axis, it splits projects by sector. We notice a remarkable propensity to the axes of energy, 64%, and transport, 32%. While improving energy consumption within urban area is relatively a recent topic, since 90s City Logistics initiatives have focused on improving efficiency, security, safety, viability and environmental sustainability of urban transportation systems. Even if several projects have been realized with this purpose, transportation is still considered an important sector that still need to be improved. Furthermore, projects having multiple goal are 43% of the total and Table 1 shows that between them, 75% includes energy. Thus, energy is confirmed to be the most crucial sector to invest on. Another interesting fact to consider is that projects including

the building sector or water management aim at improving the energy efficiency.

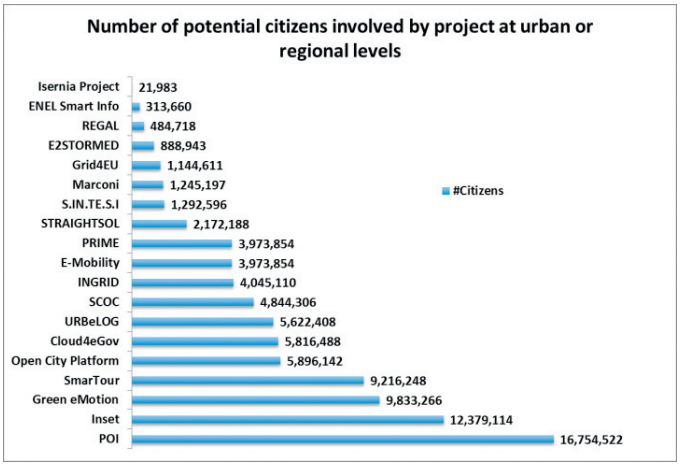


Fig. 2. Number of potential citizens involved by project.

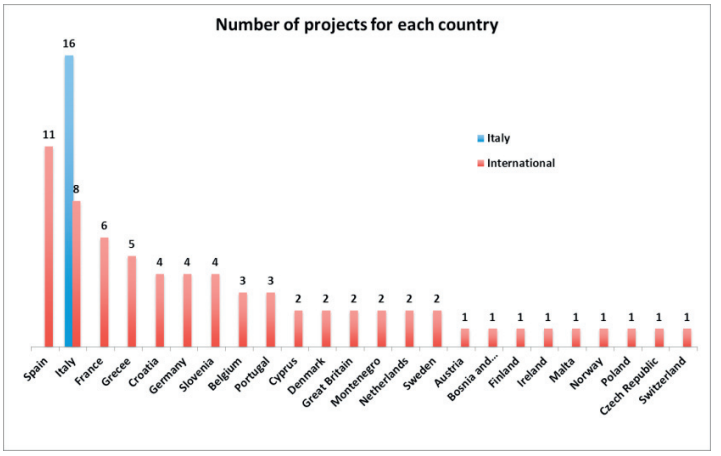


Fig. 3. Number of projects for each country.

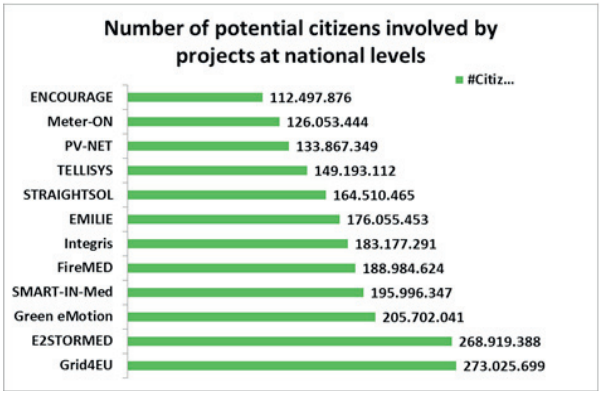


Fig. 4. Number of potential citizens by project at national level.

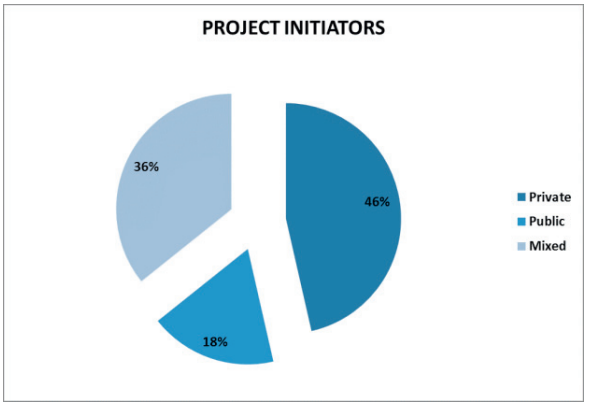


Fig. 5. Percentages of project initiators.

Considering the Tool attribute, innovative technologies, ICTs are the most popular because they allow maximum integration and convergence between different areas and sectors. ICT is present in 86% of SCPs and they are always associated with Smart Grids and for 80 % of cases, even with Innovative Sensors. 5 analyses the role of public and private entities. It arises the importance of public aid to Smart City projects. Public entities participate as project initiator initiators for 56% of the total, but for the majority of cases within partnerships where the private sector is involved as well. This trend is also confirmed by the results we obtain from the *Business model* axis.

Looking at the *Management*, the public sector assumes even a more important role. In fact, 82% of Smart City projects are managed by government programs or through partnerships with private firms. With regard to financial resources, the trend is the same. For 86% of projects, financial resources are public or mixed, while, for 72% of projects, public entities provide infrastructures and equipment. The participation of the public sector to SCPs through partnerships, where the private sector is involved as well, confirms a trend highlighted Crainic et Al. (2010) while analyzing the financing of City Logistics projects.

The third axis analyses projects in terms of their output. In most cases, 57%, they are pilot or experimental projects to define the specific characteristics of their products. This trend justifies the great support of the institutions.

In 86 % of the projects, they are directed to "customers" public or mixed. Finally, the majority of SCPs aims at sharing solutions with several European cities.

Table 1. Multi-objective projects.

Project Type	Number of projects	%
Multi-objective projects	12	
Energy	9	
Energy + Transportation	3	33%
Energy + Buildings	5	56%
Energy + Water	1	11%

We now discuss some problems and general trends we discovered by means of our analysis of the taxonomy results.

First, we faced several critical issues in data retrieval and information. There are no formally recognize entities that store and organize the development of Smart City projects, the results obtained from each project. Furthermore, no entity aims at monitoring and benchmarking SCP initiatives. This lack can be found both at the national level, where the Ministry of Education should be the point of reference, and within Europe. Furthermore, the dispersion of information and the absence of SCPs monitoring lead to the definition of similar projects. It is hard to identify the best practices already in place in other cities and to exploit the know-how already acquired from similar projects. For this reason, the creation of a centralized governance is essential for the management of SCPs to increase the coherence and effectiveness of these projects.

Table 2. Description axis: SCPs objectives. The sum of the percentage is more than 100% due to multi-objectives projects.

	Energy	Transportation	Buildings	CO2 emissions	Water	Security	E-Governance	Social Innovation
#Proj.	18	9	5	3	2	2	2	2
%	64%	32%	18%	11%	7%	7%	7%	7%

At the national level, the main goal should be the creation of a shared identity and strategy of SCPs. If all projects move in the same direction, they will create a new way of living the urban areas, which can be integrated into the national culture more easily. Hence, on one hand SCPs would benefit of a strong social commitment, on the other hand people would be more properly informed, trained and motivated.

Second, the analysis underlines that SCPs do not look at obtaining results in the short term. To get results in a short time horizon, it is essential to overachieve the social skepticism. This requires the communication of a clear and effective message able to support cities innovations. Besides, positive results in the short term will guarantee the sustainability of projects in the long term.

However, when promoters of SCPs are private companies, the situation is opposite. According to the analysis, private companies aim at returning on investments as soon as possible. In addition, a second goal of private

stakeholders is to obtain great social media return, in terms of image. Thus, they focus more on sensationalism rather than concrete activities.

The third critical point is given by a technology driven approach to SCPs. This lead to a plethora of methods (the mostly part derived from the ICT field), which are somehow introduced without explicitly considering the governance and the underlying business models. This lead to a loss of effectiveness of the developed methods and tools. Thus, even if SLPs are mature from the technology point of view, there is still need to research on the definition and the integration of the business models, their effects on the governance model and the overall synergy of stakeholders, logistics service providers, manufacturers, and city inhabitants.

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