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Transportation for Smart Cities: A Systematic Review

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Abstract. The Smart City concept is experiencing a huge transformation with innovations to support the sustainable development of urban areas. In this direction, City Logistics has a key role in enhancing sustainable transportation and livability of smart cities. This paper provides the most extensive analysis of smart cities presented in the literature. Indeed, through the adoption of a scalable and replicable taxonomy, we analyze a set of 199 outstanding smart city projects highlighting key success and failure factors of these initiatives, with emphasis on the link with a smart city and the freight transportation and City logistics field.

Keywords: Smart city, taxonomy, urban freight transportation, city logistics.

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INTRODUCTION

In recent years, the rate of urbanization is accelerating, challenging local administrations, firms and communities to sustainable development. According to UNPD (2014), the urban population of the world is expected to increase by more than two thirds by 2050 and the most urbanized regions include Northern America (82% living in urban areas in 2014), Latin America and the Caribbean (80%), and Europe (73%). These projections highlight an important and huge challenge for local administrations, firms, and communities to build sustainable development.

In this context, the interest of countries in Smart Cities is still increasing. For example, by the 2013, 193 pilot Smart Cities projects (SCPs) were approved in China, under a strategy of accelerating the industrialization, ICT services penetration, urbanization and agricultural modernization (Li et al., 2015).

Although the literature inherent the concept of what is a smart city and which is the mean of smartness is vast (Benevolo et al., 2016; Benjelloun et al., 2010; Bibri & Krogstie, 2017) a broad view of the smart city field based on systematic data on the trends and patterns of SCPs and that integrates business, technological and operative aspects, is still missing.

For example, Benjelloun et al. (2010) proposed the first attempt of taxonomy focusing on City Logistics projects, but without considering the other aspects of SCPs, including social inclusion, business and governance models, human and social relations.

This paper aims to fill this gap applying the taxonomy proposed by (Perboli et al., 2014) to a set of 199 outstanding SCPs in the world, to provide some relevant insights on the key success and failure factors of projects in the transportation industry. Indeed, it emerged as the most predominant sector the city managers are looking for sustainable development, reflecting the close link between City Logistics and Smart City. To our knowledge, this study provides the most extensive analysis on SCPs presented in the literature.

The paper is organized as follows. Section “Literature review” investigates the literature concerning the concept of Smart Cities and its link with City Logistics.

Section “Methodology” presents the methodology and taxonomy adopted to analyse the set of SCPs, whose results are discussed in Section “Trends of the transportation industry in SCPs”. Finally, some relevant conclusions are presented in section “Conclusions”.

LITERATURE REVIEW

Smart cities have received increasing attention in recent years. One part of the literature addresses the concept of smart cities by elaborating the definitions, applications and main characteristics. For example, Albino et al. (2015) provide an in-depth analysis of the literature and identify the main definitions of smart cities. Su et al. (2011) identify the relevant content of the construction of smart city applications including the wireless city, smart home, smart transportation, smart public service and social management, smart urban management and green city. Caragliu et al. (2011) summarize the common characteristics of smart cities from different perspectives which concern the smart economy, mobility, environment, living, and governance. Moreover, Zanella et al. (2014) elaborate the smart city concept and services including the structural health of buildings, waste management, noise monitoring, traffic congestion, city energy consumption, smart parking, and lighting.

Although the concept of smart cities lacks universality due to the different vision and priorities, the improvement of people mobility and freight transportation in urban areas through the adoption of ICT solutions represents one of the main pillars to achieve a smart city, according to a consistent part of the literature.

For example, Xiong et al. (2012) provide a review of intelligent transportation systems for smart cities and illustrate the outlook of urban intelligent transportation in China. The intelligent transport planning is introduced in the 12^{th} Five-Year Plan, and the “Internet of Things” and “Smart City” major special projects.

Mohanty et al. (2016) identify the different components of a smart city, such as smart infrastructure, smart transportation, smart energy, smart healthcare, and smart technology. The ICT, especially two emerging technology frameworks Internet of Things (IoT) and Big Data (BD), are enabling keys for improving the smart cities. In particular, Nowicka (2014) presents smart city logistics on the cloud computing model for the sustainable city. The internet technologies promoting cloud-based services, IoT, use of smartphones and smart meters and RFIDs allow meeting the citizens’ demand-driven requirements in city logistics. Moreover, Awasthi et al. (2011) apply a fuzzy TOPSIS method to evaluate sustainable transportation systems for smart cities. It provides a multi-criteria decision-making approach for decision makers to evaluate the associated environmental costs including air pollution, noise, etc. which is regarded as the quality of life in modern cities.

Malindretos et al. (2018) introduce the link between City Logistics and Smart Cities reviewing the City Logistics models that have been implemented in Europe for the sustainability and the growth of the smart cities. The models that the authors investigate concern the application of City Logistics measures as the Urban Freight Consolidation Centres.

Although this paper recognizes the importance of City Logistics to foster the development of smart cities, we identify a lack of a global vision of the main trends and patterns as well as the key success and failure factors of these initiatives.

METHODOLOGY

This paper aims to overcome the gap in the literature concerning smart cities, by proposing a cluster analysis of SCPs, based on a taxonomy with polythetic classes (Bailey, 2005). The taxonomy used is illustrated in Fig. 1. Due to length restrictions, the interested reader could refer to the original work of (Perboli et al., 2014) for an in-depth description.

From a methodological point of view, we built it following a three-steps method described by (Bailey, 2005). First, we began with an empirical analysis the SCPs ended, ongoing or at least already funded in 2018, retrieving information about projects from refereed journals and conference proceedings as the source of Smart City literature, deliverables of the projects, governmental and consulting reports. This first phase yielded to a selection of about 199 outstanding SCPs (25 in Europe, 55 in Canada, 25 in the USA, 20 in Brazil, 26 in Australia and 48 in Asia) making our analysis, even if not exhaustive, the most extensive screening of SCPs in the selected areas.

According to the lean business methodology GUEST (2017), we added to the taxonomy a further level of analysis based on a managerial perspective, which could help researchers and practitioners to define more appropriate business models in future projects. With this purpose, for each SCP, we analysed the value proposition and the business model. The aim is to highlight the needs, gains, and pains of the main stakeholders involved in the project, and all the components needed to make the project works, including the costs and revenues structures.

This further analysis represents a value added for the future real case studies and research projects. In fact, considering these results, government and project initiators should be able to dene more appropriate business models and policies for Smart Cities applications, anticipating the stakeholders' requirements in the early stage of the project, with benefits regarding the success of the projects and financial sustainability in the long run.

The taxonomy (Fig. 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 following subsection, we briefly describe the taxonomy, while the interested reader could refer for a detailed discussion of each axis, and category to the original work of (Perboli et al., 2014).

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*

Figure 1. Taxonomy

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 (Key Enabling Technologies), the nature of the project initiator (Project initiator), and the key actors involved in an SCP (Stakeholders). In the following, we describe the categories contained in the *Description* axis.

- *Objectives*. As stated in the introduction, the term “Smart City” refers to several fields related to the city management.
- *Key Enabling Technologies*. As discussed above, the concept of “Smart City” is often related to the concept of ICT. For example, Toppeta (2010) defines a city combining ICT and Web 2.0 technology with other organizational, design and planning efforts to dematerialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, to improve sustainability and liveability. Thus, it is clear that Smart City initiatives are intensively using technology (Chourabi et al., 2012).
  All the Key Enabling Technologies are well-known technologies. Notice that we grouped in the items ICT and Other new technologies all the information technologies and the innovative ones (not included in the other items) useful to guarantee the value propositions of capturing and sharing data and information promptly.
- *Project initiator*. The initiator of an SCP, as in any other project, is the entity who begins the project. Both private and public sector are interested in promoting SCPs, with

different purposes. The public sector aims to enhance the sustainability and liveability of cities while reducing the emissions and negative externalities. The private sector aims to improve efficiency, both in economic and operative standpoints, gaining competitive advantage. In several cases, public and private entities cooperate to find sustainable solutions to the growing issues.

- *Stakeholders*. An SCP is a multi-actor initiative, involving different parties, each of them with own interests, objectives, and roles (i.e., city, citizens/consumers, administrations, enterprises, and universities).

Business model. The increasing Smart City interest leads to the need for redefining new business models and governance mechanisms. Thus, this axis addresses the aspects related to the project management and, the business and governance models. In particular, it investigates the nature of the project manager (Management) and the providers of infrastructures, equipment and financial resources (Infrastructure financing and Financial Resources). In the following, we describe the categories contained in the *Business model* axis.

- *Management*. The implementation of SCPs requires the collaboration within two or more entities that can be public, private or mixed in the form of Private Public Partnership (PPP). In fact, the city (Government) grants for a given number of years, the right to use public facilities to a private company. This grant is given according to fixed objectives and the perspective in reaching these objectives conditioning the renewal of the contract.
- *Infrastructure financing and Financial Resources*. An important building block of a Business Model is those concerning the key resources (Ostewalder et al., 2010). In SCPs they are mainly represented by physical assets as infrastructures, equipment, vehicles, and devices, or by financial resources essential for the project realization. These resources can be provided by private entities, public or mixed. According to the World Economic Forum(2016), the private sector has a pivotal role, with support the planning of the needed infrastructure and help to address capacity issues across state governments and urban local bodies.

Purpose. This axis classifies the SCPs according to their final goal. It identifies the user that will adopt and benefit from the solution developed by the project (Client), the type of product (Product) and the geographical target (Geographical target). In the following, we describe the categories contained in the *Purpose* axis.

- Client. The outcome of the SCP can be addressed to different actors: public, private or mixed.
- Product. Not all the SCPs have a specific goal, or better not all the projects during the beginning phases have already identified the final result that they want to reach.
- Geographical target. The SCPs might regard a city area or a portion of that. Instead, there are some cases in which the project can be expanded at the national level. Especially in Europe, it used to adopt a pilot project. The idea is to test the conceptual project in one city to deeply understand the problem and its related issues. Once the implementation of the solution is done, the project can be scaled in other cities, gaining in term of time and cost. So, the project could even become transnational, thus involving different cities from different counties. We consider three main levels of the geographical target.

TRENDS OF THE TRANSPORTATION INDUSTRY IN SCPS

In this section, we present the results obtained from the application of the taxonomy to the sample of SCPs in different continents.

Concerning the Description axis, the results reported in Table 1 highlight that transportation is one of the most frequent objectives in SCPs, particularly in the United States (60%), Europe (52%), Asia (75%) and Brazil (60%). Moreover, usually, Transportation is combined with Building, Energy and CO2 Emissions objectives, due to the high correlation of these sectors and mutual benefits. These results are more evident in Europe and Asia, and they are connected with the encouragement of the European Commission to zero-emission transport with the Horizon 2020 program, and the increasing attention of Asian countries on the City Logistics topic.

Due to the strict correlation between these industries, the SCPs that deal with the transportation objective commonly involve key enabling technologies (Fig. 2) as information and communication technologies (ICTs), new technologies (e.g., RFID and GIS), smart grids and innovative sensors. The results highlight the higher propensity of European, Asian and Canadian countries to adopt innovative technologies rather than the USA, where Cloud Computing and Database tools are the most present in projects focused on transportation and logistics. This finding reflects the increasing diffusion of the IoT paradigm for Smart Mobility and City Logistics issues. In fact, according to Zanella et al. (2014), urban IoTs are designed to support the Smart City vision, which aims at exploiting the most advanced communication technologies to support added-value services for the administration of the city and for the citizens.

In particular, many city managers are adopting smart transport solutions within the framework of the City Logistics to meet the biggest challenges that smart cities are facing today (e.g., traffic and congestion). An example is the URBeLOG project co-funded by the Italian Ministry of Education, Universities and Research under the Program “Smart Cities and Communities and Social Innovation” (De Marco et al, 2017). This initiative aims to develop an innovative open, dynamic and cooperative telematics platform combined with the adoption of infrastructure City Logistics measures as the mobile depot, providing services and applications for the last mile logistics in urban areas. Moreover, URBeLOG integrates main functions allowing the development of processes, services and applications for City Logistics of the future (e.g., possibility to book loading/unloading zones, road pricing and traffic restrictions).

Table 1. Different objectives of smart city projects for different countries. Notice that the sum of the percentages of the Objectives category is more than 100%, due to the great relevance of the multi-objective projects.

Objectives	USA	Canada	Europe	Australia	Asia	Brazil
Transportation	60%	44%	52%	46%	75%	60%
Energy	44%	45%	68%	50%	65%	95%
Buildings	20%	24%	56%	27%	48%	25%
CO2 Emissions	52%	33%	68%	46%	44%	100%
Water	24%	22%	8%	23%	39%	5%
Security	40%	33%	12%	12%	63%	20%
E-Governance	24%	25%	24%	15%	48%	35%
Social Innovation	40%	47%	32%	58%	63%	25%
Multi-Objectives	72%	69%	92%	69%	92%	100%

On the other hand, the governments aware of the need of more efficient and effective management of cities, due to the rapid urbanization, started to foster investment on ICT tools for improve the infrastructures and overcome socio-economic problems. In the majority of the projects, the ICT infrastructure is coupled with operations management and Operations Research tools to optimize the operations. Less pervasive is the use of such methods to incorporate user behaviors and integrate the business models. This trend confirms a more general trend in Operations Management, relegating the Operations Research methods to the operational and, sometimes, the tactical level and somehow losing the grip with the managerial and business model and development phases.

Moreover, on the contrary of what emerged in the study by Russo and Comi (2010), Smart Cities initiatives lead promoters to adopt measures to improve the freight transport and logistics within urban and metropolitan areas that can be attributed to social sustainability. These initiatives usually combine objectives as Transportation and Security, aiming to improve urban road safety.

Looking at the managerial aspects which represent the novelty of our approach, regarding the categories Project Initiator, Stakeholders, Management, Infrastructure Financing, Financial Resources and Client, it emerges a massive engagement of the public sector in the SCPs focused on the transportation industry, due to the huge amount of investment required by the infrastructures and the solutions for freight transport and smart mobility.

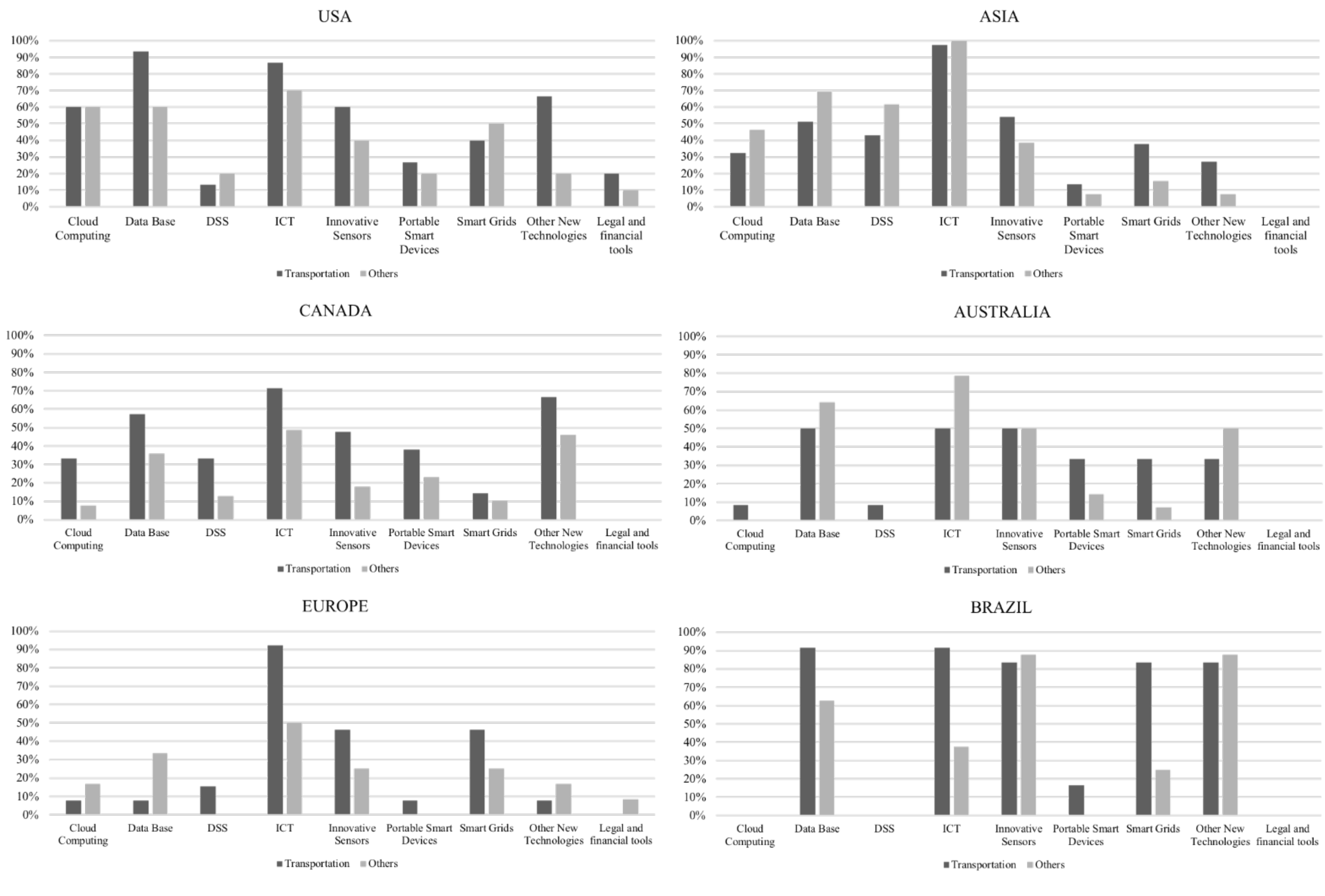

Figure 2. Key enabling technologies to deal with transportation in Smart Cities.

For example, according to Li et al. (2015), the rapid development of Smart Cities, particularly in China, is largely attributed to the cooperation between IT companies and the government. This aspect highlights a general policy of the Chinese government to accelerate high-tech and strategic startups by putting them in SCPs with larger funds. Another important outcome is that in North America, being a country more shaped by pro-business influences, the private sector assumes a valuable function as project initiator, provider of financial resources, and client, compared to the other countries as Europe that historically has been more welfare-oriented.

Some success factors including the partnerships and business model are also investigated. The current trends of partnership, infrastructure financing and financial resources for SCPs are mixed, which means to combine the advantages for both private companies and public institutions. The Fig. 3 shows the partnership in SCPs is mixed for all the countries. The same results can be found for the infrastructure financing and financial resources. According to Chen et al. (2016), cities can obtain the benefits from smart mobility investments by involving all the public and private actors in a collaborative and transparent manner. Another interesting outcome is that the geographical target of SCPs mainly focuses on the urban area, expecting for Europe and Brazil. This can be explained by the emerging need for demand-driven related ICT solutions, such as the car and bike sharing system, on-demand delivery as well as parking schedules. While considering Europe and Brazil, the more targets focus on the layer of international cooperation.

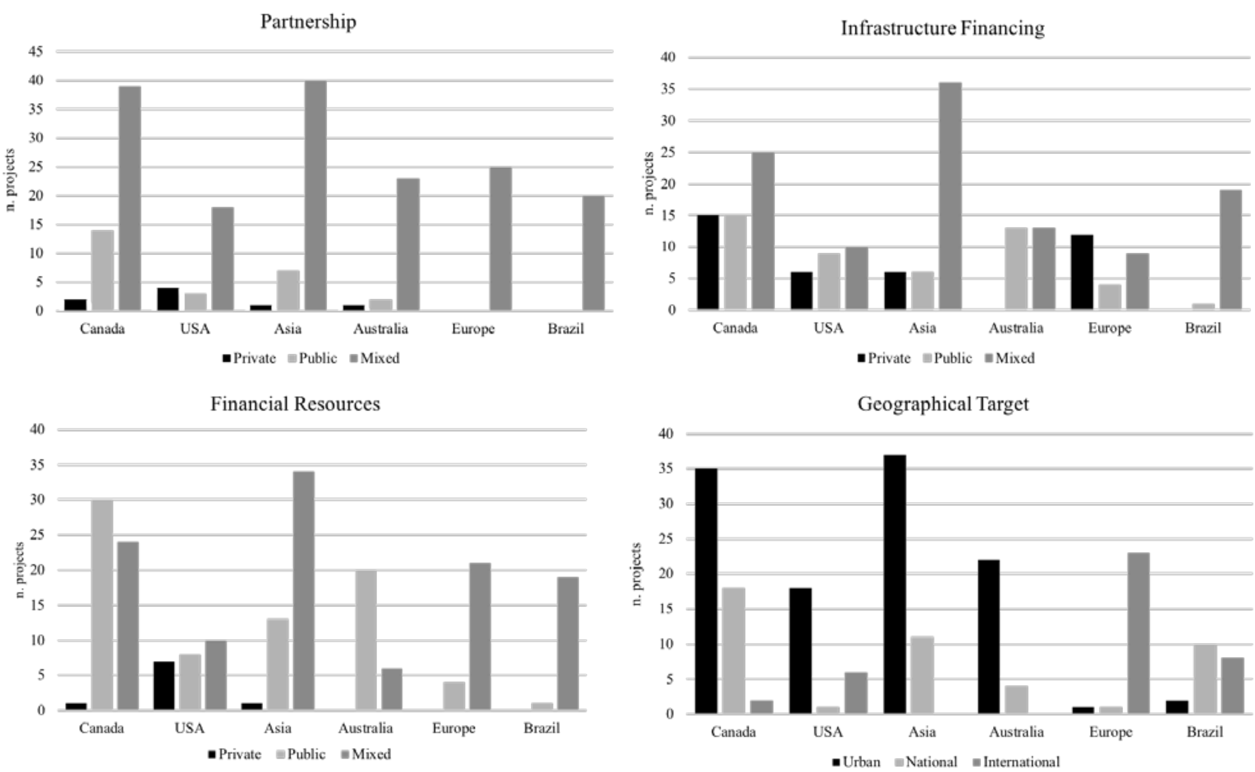

Figure 3. Business model and geographical target in SCPs.

The efficiency of City Logistics is strongly affected by conflicting personal preferences and multi-attribute decision makers. From the perspective of stakeholders, this paper analyses the perceptions of five different stakeholders including City, Citizens, Administration, SMEs, and Universities for all of the investigated countries. According to the results in Table 2, the main part of stakeholders for all of the countries are City, Citizens, Administration, and SMEs since almost all the perceptions are larger than 70%, with some 100% perceptions. On the contrary, University is less involved actors for four countries, with only 40% for the USA, 33% for Canada and 27% for both Australia and Asia. This result can be explained by the different commitment to local universities and the different level of cooperation between government and universities. For Europe and Brazil, all the five stakeholders play the main role of the SCPs since all of the perceptions are larger than 80%. Note that these two counties also pay more attention to international cooperation according to Fig 3. Citizens are one of the most significant stakeholders since all the perceptions are larger than 87%. Considering that transportation is the most frequent objective in SCPs, efficient urban mobility requires to improve the participation of Citizens.

Table 2. Different Stakeholders of smart city projects for different countries.

Stakeholders	USA	Canada	Europe	Australia	Asia	Brazil
City	76%	95%	80%	100%	100%	100%
Citizens	100%	87%	96%	100%	100%	100%
Administration	80%	76%	80%	62%	98%	100%
SMEs	88%	80%	100%	73%	83%	100%
Universities	40%	33%	88%	27%	27%	85%

CONCLUSIONS

Smart cities are urban environments where the efficient management of the passengers and freight flows becomes one of the key pillars for their sustainable growth.

This paper investigated the current state-of-the-art of SCPs, with focus on urban transportation to obtain the success and failure factors of smart cities. It applied a replicable and scalable taxonomy to a sample of 199 projects in different continents: America, Europe, Asia and Australia. This analysis examined the smart city logistics by the considering environmental aspects (e.g., energy saving, CO_2 emission), technic (e.g., IoT, ICT, RFID) and managerial concerns (e.g., operational management and integration of business models).

The aim of this paper was to support the understanding of the role of City Logistics for the sustainable development of Smart Cities. Indeed, the results highlighted how the transportation is one of the most frequent objectives in SCPs, particularly in the United States (60%), Europe (52%), Asia (75%) and Brazil (60%). Many projects adopt the ICT infrastructure and widespread sensor technology coupled with operations management and Operations Research tools to monitor and optimize the flow of traffic and operations, in particular areas that become “sustainable districts”. In these areas projects also strongly leverage the existing and new physical infrastructure as the urban distribution centers.

Moreover, we are assisting to a transition in the Smart City Logistics with growing interest in social innovation aspects as the road safety of people and freight.

The current trend of partnership, infrastructure financing and financial resources for SCPs is mixed, which can achieve the benefits by involving and encourage all the public and private actors to collaborative business models.

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