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Abstract: Last mile urban freight distribution systems generate negative externalities such as pollution, traffic congestion and other nuisances. To minimize such negative impacts, City Logistics (CL) projects are being implemented in many cities around Europe. CL aims at optimizing the logistics and transport activities by private companies in urban areas while considering traffic congestion and energy consumption. However, most CL initiatives do not consider all these aspects together, but they address them separately. In this context, there is a lack of studies on the state of the art and international diffusion of CL systems. In order to bridge the research gap, this paper proposes an exploratory study of a sample made of 70 European cities that have been piloting CL projects and a set of City Logistics Indices (CLI) is defined and used as indicators of the breath and number of CL measures implemented in a city. In particular, three different domains of application have been defined, namely Infrastructure, Regulation and Technology, together with and Aggregated City Logistics Index (ACLI) encompassing all of them. Results highlight that Southern European cities show higher CLIs. This is due to the fact that these cities have been undertaking fewer measures to reduce traffic congestion and pollution in the past compared to other regions and are now trying to filling the gap. This work illustrates how the CL issue has been applied in different European geographical areas so that it lays foundations for exploring the socio-cultural implications of various CL implementations.

Keywords: City Logistics, Classification, Factor Analysis,

1. Introduction

Several city councils and private entities have been developing City Logistics (CL) initiatives to mitigate the negative impacts of freight last-mile distribution in urban environments (Thompson, 2014). In fact, some distributors estimate that more than 60% of CO_2 emissions are accounted for their logistics activities in urban areas (Bohne and Ruesch, 2013). Earlier studies show that the share of CO_2 emissions from freight vehicles compared to total urban traffic ranges from 20 to 30%, whereas it reaches up to around 50% for Particulate Matter (PM) (Schoemaker *et al.*, 2006).

Urban logistics systems often comprise complex configuration of transport infrastructures, situated in different geographical layers. In fact, these systems are made up of multiple supply chains that start at the intercity transportation nodes, flow through logistic terminals and shopping centers and end at the shoppers' home (Yang and Moodie, 2011). CL therefore surged as a comprehensive solution aiming at "totally optimizing the logistics and transport activities by private companies in the urban areas while considering the traffic environment, the traffic congestion and energy consumption" (Taniguchi and Thompson, 2002). However, most CL initiatives are rather fragmented in scope and mainly address just some of these components separately. For example, some industry players have been using green vehicles or reshaping delivery time windows to increase their environmental efficiency and reduce operational cost of urban delivery (Wygonik and Goodchild, 2011). In parallel, some municipalities have been experiencing or are currently enacting public policies that aim at reducing the number of freight vehicles (Crainic, 2008; Marcucci and Danielis, 2008). In this context, interest from CL scholars and practitioners has been directed towards sharing international best practices and developing roadmaps and guidelines for supporting the development of effective CL public and private policies (Taniguchi *et al.*, 1999; Ballantyne, Lindholm and Whiteing, 2013; Schliwa *et al.*, 2015). In addition, more attention has been posed on the impact that a specific public or private CL measure has on a particular stakeholder in terms of its economic, environmental and social impact (Quak and de Koster, 2007; Russo and Comi, 2011; Muñuzuri *et al.*, 2013). However, there is still a lack of research focusing on the diffusion patterns and factors of CL across different international contexts so to facilitate the understanding of the most widely adopted CL measures. In order to bridge this research gap, an empirical analysis on a dataset of 70 European cities that are carrying out a CL project is here presented. Also, the dataset groups the possible infrastructural, regulatory and technological CL measures that have been adopted in each city. This objective is pursued through the definition of a set of City Logistics Indices (CLI) that are used as indicators of the breadth of CL measures, per each set of measure, implemented in a city. An Aggregated City Logistics Index (ACLI), referred to as a weighted summation of the set of CLIs, is also proposed as a parameter of the span of the CL initiative and as a useful benchmark metric to compare and rank the various CL initiatives in Europe. The paper is structured as follows. First, several classifications of CL available in the literature are presented. Accordingly, the relevant types of infrastructural, regulatory and technological measures of a CL system are defined. Second, the research methodology and dataset are described. Then, the dataset is analysed and results are interpreted. Finally, the implications are drawn together with the conclusions.

2. Classification of CL measures

Several classifications of CL measures in urban areas are available in the literature. For example, Rosini (2005) classifies measures into two axes, one related to what is regulated (e.g., infrastructures, operating times, vehicles) and the other associated to how to regulate (e.g.: the level of intervention by the public sector). Muñuzuri *et al.* (2005) groups measures based on their scope and the stakeholders involved. Urban freight solutions are grouped into five classes according to their field of application, namely: Public infrastructures, Land use management, Access conditions, Traffic management, Enforcement and promotion tools. However, this classification is only a theoretical overview of the potential measures and solutions that can be put in place by a public administration for CL purposes. Van Duin and Quak (2007) classify CL measures according to three main areas of interest, namely: flow improvements (e.g., consolidation centres), hardware (e.g. infrastructures) and policy (e.g. licensing and regulation). Then, a classification exclusively developed upon analysis of existing case studies is the one by Dasburg and Schoemaker (2007) who identify four categories of measures: infrastructure, technology and equipment, restrictions and incentives, logistics and transport organization, and finally accompanying measures. Russo and Comi (2011) analyze CL measures in terms of their time horizon (i.e.: strategic, tactical, and operative) and their expected outcomes. The classification proposed by Thompson (2014) coaches on four *management types*. They provide a comprehensive overview of the application of CL measures worldwide, but lack to define the measures in detail. Finally, a foundation to this work is the most recent classification proposed by Creazza, Curi and Dallari (2014). This classification is based on four pillars, namely: Restrictive measures (e.g. low emission zones, time windows); Infrastructure, which comprises the development of new CL facilities as well as the utilization of urban spaces by freight vehicles; Technology, based on the use of innovative ITS and low emission vehicles; and finally Regulation measures, which comprise public measures aiming at promoting a better and optimized use of infrastructures and freight vehicles (e.g. off-hour deliveries and multi-use lanes).

2.1 A new classification of CL Measures

The above classifications allows to identify eleven measures that have been implemented as part of a CL system. These measures are listed in Table 1. In particular, Table 1 subsumes the CL measures into three domains, namely infrastructure, regulation and technology. A literature references is also provided for each measure. An explanation of these categories and associated measures is given in the following sections.

Table 1: Review of CL measures

Category	Measure	Reference
Infrastructure	Urban consolidation centres (UCC)	Rosini (2005); Munuzuri et al. (2005); Van Duin and Quak (2007); Dasburg and Schoemaker (2007); Russo and Comi (2011); Thompson (2014); Creazza et al. (2014);
	Lay-by areas	Rosini (2005); Munuzuri et al. (2005); Van Duin and Quak (2007); Russo and Comi (2011); Thompson (2014); Creazza et al. (2014);
	Micro consolidation centres	Munuzuri et al. (2005); Russo and Comi (2011); Thompson (2014); Creazza et al. (2014);
	Multi-use lanes (mainly bus lanes) and dedicated/preferential freight vehicles lanes	Rosini (2005); Munuzuri et al. (2005); Dasburg and Schoemaker (2007); Russo and Comi (2011); Creazza et al. (2014);
Regulation	Low emission zones	Rosini (2005); Munuzuri et al. (2005); Van Duin and Quak (2007); Dasburg and Schoemaker (2007); Russo and Comi (2011); Thompson (2014); Creazza et al. (2014);
	Time windows	Rosini (2005); Munuzuri et al. (2005); Van Duin and Quak (2007); Dasburg and Schoemaker (2007); Russo and Comi (2011); Thompson (2014); Creazza et al. (2014);
	Restrictions on vehicle weight and volume	Rosini (2005); Munuzuri et al. (2005); Van Duin and Quak (2007); Dasburg and Schoemaker (2007); Russo and Comi (2011); Thompson (2014); Creazza et al. (2014);
	Night deliveries	Munuzuri et al. (2005); Van Duin and Quak (2007); Thompson (2014); Creazza et al. (2014);
Technology	Dynamic routing and lay-by areas monitoring and booking	Munuzuri et al. (2005); Van Duin and Quak (2007); Dasburg and Schoemaker (2007); Thompson (2014); Creazza et al. (2014);
	Electronic control and charging for the access to the city centre	Rosini (2005); Munuzuri et al. (2005); Van Duin and Quak (2007); Russo and Comi (2011); Creazza et al. (2014);
	Adoption of low emission vehicles and alternative transportations	Rosini (2005); Van Duin and Quak (2007); Thompson (2014); Creazza et al. (2014);

2.2. Infrastructure

This category encompasses CL initiatives that require planning and building new logistics infrastructure, using and improving existing ones, including the allocation of public spaces to freight transportation purposes. The use of shuttle trains or trams on existing railway or underground systems has been not included in the classification (Munuzuri et al., 2005; Russo and Comi, 2011; Thompson, 2014) since it has not yet proved to be feasible (Arvidsson and Browne, 2013). A considerable amount of studies has focused on the development of urban consolidation centres (UCC) in the outskirts of the city as a mean to consolidate goods from different shippers and thus reduce the number of vehicles moving in the inner city. Most cities have nowadays dedicated curb side lay-by areas in order to avoid the problem of double-parking by trucks that will eventually double-park or use space reserved for other purposes (Dablanc, 2009). Double-parking not only generates congestion but also puts significant strain on enforcement costs. The lack of lay-by areas is also seen as one of the major issues that carriers have to face in urban environments (Stathopoulos, Valeri and Marcucci, 2012). However, some scholars point out that public administrators should carefully design the location of loading and unloading areas to minimize the cost and time of delivery (Aiura and Taniguchi., 2005). Moreover, they should set strict rules about their usage time in order to guarantee a correct turnover for the benefit of all carriers. Sometimes, lay-by areas are used only in combination with time windows, as in the case of Paris (Crotti, 2006). In Paris, two types of areas are devoted to logistics purposes: one where loading and unloading is permitted during daytime only, and one permanently dedicated to loading and unloading activities. Then, freight vehicles can use those areas depending on their space occupancy: if this figure is less than 29 m^2 vehicles can load and unload between 10pm and 5pm; on the contrary, they can fulfil logistics operations only at night-time. Another urban logistics infrastructure type is represented by Micro-consolidation centres (MCC). MCC are small warehouses located within the city centre where goods are transhipped from heavy commercial vehicles to electric distribution vehicles for the last mile of delivery process. (Janjevic, Kaminsky and Ndiaye, 2013) provide a review of micro-consolidation schemes, stating that they might be more profitable than UCCs, although for smaller deliveries (e.g. packages, mails, office supplies). Overnight deliveries to micro-consolidation centres may further increase the productivity of operations (Browne, Allen and Leonardi, 2011). The use of bus lanes or the allocation of dedicated routes to deliver goods can reduce the congestion level, optimize existing road network and increase carriers' efficiency (Russo and Comi, 2011). In fact, planning commercial routes within the existing road network may provide for a measure to divert commercial traffic from congested roads to more suitable and efficient routes.

2.3. Regulation

Regulation measures refer to three types of public policies: restriction or limitation to the access of delivery vehicles to the city centre, imposition of monetary disincentives on certain types of vehicles, and incentives to more sustainable transportation companies (e.g. third-party account). The main objective of regulation measures is to reduce the level of noise, pollution and congestion in urban areas, to improve the quality of life and to protect the environment and architectural structure of city centres. Regulating the access of commercial vehicles to city centres also aims at improving the safety of pedestrians and increasing the attractiveness of urban areas during store opening hours. Scholars have traditionally focused on low emission zones (Anderson, Allen and Browne, 2005; Lindholm, 2010; Arvidsson, 2013), time windows (Quak and de Koster, 2007; van Duin *et al.*, 2012), and restrictions on vehicle weight and volume (Behrends, Lindholm and Woxenius, 2008; Awasthi and Chauhan, 2012). A load factor control might also represent a suitable regulation measure to foster greater loads and in turn less freight vehicles (Taniguchi and Heijden, 2000; Comi *et al.*, 2008) but it has been adopted by very few cities (Teo, Taniguchi and Qureshi, 2014). Road pricing or congestion charge could discourage the use of inefficient or polluting freight vehicles. In particular, the amount of a congestion charge might depend either on the access time (i.e. higher charge during peak hours) or on the emission level of the vehicle. According to Quak and Van Duin (2010), this policy aims at using the existing infrastructure in a more balanced way, and price can be leveraged as an effective tool to achieve this goal. Night deliveries can relieve the nuisances generated by freight transportation, by shifting deliveries to less congested hours. This would also increase the efficiency of the delivery process, due to lower and more reliable journey times. Public administrators could also implement this solution to foster the attractiveness of third-party account to retailers. In fact, delivering outside of office hours demands more resources to be deployed, hence turning profitable only with high volumes (Holguín-Veras *et al.*, 2014).

2.4. Technology

Technology measures encapsulate the introduction of technology-based infrastructures in the urban freight transportation system (Cagliano *et al.*, 2017). In the field of urban transportation, Intelligent Transportation Systems (ITS) focus on improving carrier's operations (e.g. route and trip planning), as well as providing value-added services to carriers and their customers (e.g. reliable estimated time of arrival). In particular, traffic management systems (TMS), such as the electronic access control, make the interaction between freight carriers and the public administration easier. Road pricing is a further example of a policy that requires significant investment in TMSs. Moreover, private and public actors are developing and implementing ICT platforms able to collect data from a system of sensors and other hardware deployed in the city to monitor and control the occupancy level of a particular area (e.g. parking sensors) or the access to the city centre (e.g.: cameras) (URBeLOG, 2016). Monitoring the usage of lay-by areas and giving information on their real-time occupancy level can increase the rotation in the use of urban infrastructure, while potentially reducing travelled vehicle-km. In fact, carriers can adapt their routes according to the availability of the nearby areas, and therefore lose less time looking for a free curb side parking spot. Finally, technological innovation also include vehicle innovation. Different types of low-emission vehicles have been experimented for city logistics purposes, namely electric, hybrid or fuel cell vans (Nesterova *et al.*, 2013; Pelletier, Jabali and Laporte, 2014; Trip and Konings, 2014; Cagliano *et al.*, 2017) or small electric distribution vehicles (Browne, Allen and Leonardi, 2011; Nesterova *et al.*, 2013; Melo, Baptista and Costa, 2014). In particular, the diffusion dynamics of electric and hybrid commercial vans and its enabling factors in CL contexts has been also investigated (Cagliano et al., 2017).The investment required for a large uptake of low-emission vehicles is very high, and sometimes the benefits may be not enough to cover all initial expenses.

3. Research Methodology

The present research is developed according to the following steps. First, the spectrum of CL measures is defined according to the new classification proposed in the previous section. Second, a sample of 70 European cities that have been developing initiatives in one or more of the three CL domains measures (Infrastructure, Regulation and Technology) is constructed. The inclusion in the sample is carried out referring to different sources, such as project reports at national (Ambrosino *et al.*, 2005; Crotti, 2006), european (Dablanc, 2009; Bohne and Ruesch, 2013) and regional level (Campbell, MacPhail and Cornelis, 2010; Roche-Cerasi, 2014), scholarly papers and conference proceedings (Van Rooijen and Quak, 2010; Morganti and Gonzalez-Feliu, 2015), and web sites that collect the measures set up by municipalities (http://sootfreecities.eu/city). A score of 1 or 0 is assigned to a city that has carried out a CL project or introduced a measure in that specific field or not. Then, a factor analysis is performed to extract the relative importance of each measure with respect to the three domains, and a City Logistics Index (CLI) is computed for each single domain as a weighted summation of the measures' scores. Similarly, an upper-level ACLI is computed as a weighted summation of the three single CLIs. The ACLI expresses the number of domains that are covered by CL measures implemented by a city. Thus, the proposed index can be considered as a summary expression of the ability of a city to create a comprehensive and broad CL system with a wide spectrum of measures. This is assumed to be an indicator of an effective CL system. Finally, an Analysis of Variance (ANOVA) has been carried out in order to capture significant differences among the different regional areas about the willingness of implementing CL projects.

4. Results

4.1. Diffusion of CL initiatives

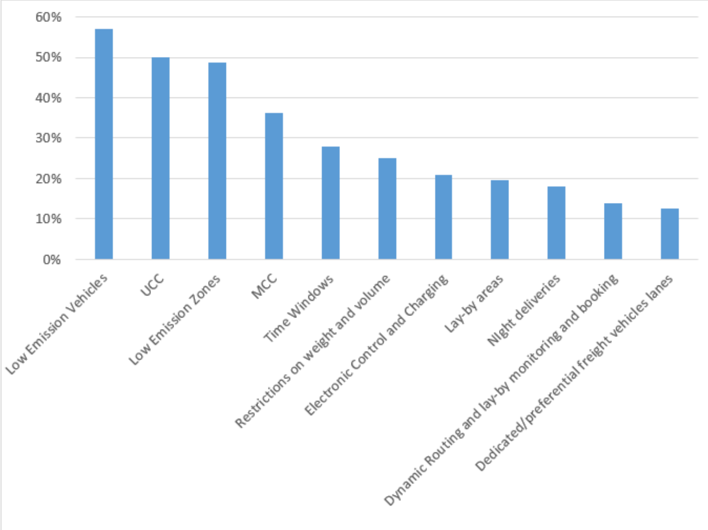

Figure 1: CLI by sub-domains

Figure. 1 shows the diffusion of CL initiatives among the cities of the sample under study. In particular, three types of measures are implemented in more than 50% of the cities, namely: Low Impact Vehicle, UCC and Low Emission zones. Moreover, each type is part of one of the three identified sub-domains. This confirms that a wide array of CL practices has been already put in place across Europe.

4.2. Factor Analysis

CLIs are obtained as a weighted summation of their subdomain scores. Weights are consistent with the loadings computed using a factor analysis as per Nicoletti, Scarpetta and Boyland (1999). The results of this factor analysis are given in Table 3. The analysis shows that the three identified domains can be related to two factors: load consolidation practices and coordination of stakeholders. In fact, one of the key goals of a CL system is to blend these two factors (Bektas, Crainic and van Woensel, 2015). Therefore, the factor analysis allows to compute the weights for every CLI.

Table 2: Identification of the loadings in the factor analysis

Factor	Domains	Loadings	
		1	2
Load Consolidation	Infrastructures	0,8880	0,0550
	Regulation	0,6780	-0,3780
Stakeholder Coordination	Technology	-0,0810	0,9580

Another important observation can be made based on the Analysis of Variance (ANOVA) presented in Figure 2, which shows the geographical differences in developing CL initiatives across Europe, taking also into account the different domains.

Table 2. Significance level in the ANOVA

Index	p-value
ACLI	**0.01**
Infrastructure	**0.003**
Regulation	**0.008**
Technology	0.676

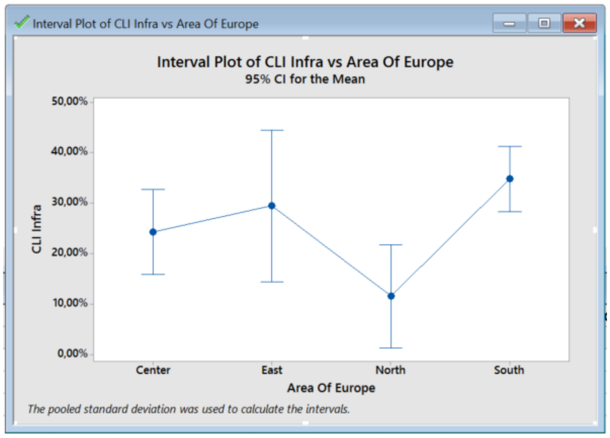

Figure 2: Interval Plot for the ANOVA- Infrastructure domain

From the ANOVA, it can be remarked that there are significant differences among the different areas of the European Continent. In particular, the ACLI, the Infrastructure and the Regulation domains assume different values among the areas, as shown in Figure 2.Southern European cities present higher values of the ACLI with respect to cities situated in other macro regions. On the contrary, the domain associated with the Technology adopted for implementing CL project does not present significant differences. This means that Europe is pretty much aligned in the use of technology for CL initiatives.

5. Implications and Conclusions

To face the challenges of increasing traffic congestion, pollution and noise, urban areas are called to invest in CL initiatives that can enhance the environmental sustainability of last mile freight distribution and, in turn, enhance the quality of life of citizens. In order to achieve this objective, public policy makers and private operators still need to better understand their long-term effects, and figure out potential improvements and opportunities based on the specific context they operate in (Zenezini and De Marco, 2016). In this context, this paper is a first attempt to give a more structured comprehension of the notion of CL and an empirical evaluation of the current trends at the European level. With this regard, several considerations and discussions can be made. From a theoretical point of view, this work can be considered as a funding reference for practical classification of CL projects identifying their relationships with urban environments. Also, the methodology proposed to compute the set of CLIs can enhance existing qualitative works such as the one presented by (Russo and Comi, 2016) and can provide more robust results to get insights regarding the status of CL initiatives across Europe. From a practical point of view, this paper might assist public authorities in measuring the magnitude of their CL initiatives and set their future objectives (Michelucci and De Marco, 2017). In fact, the proposed definitions of CLIs and ACLI offer a systemic and structured definition of CL initiatives to drive policy makers' strategic and planning efforts. Furthermore, different implications can be drawn from the analysis of the results. First, the factor analysis confirms that CL measures aim at consolidating goods and coordinating stakeholders. Moreover, in terms of geographical perspective, Southern European cities show higher CLIs. This is likely due to the fact that Southern European cities have been undertaking fewer measures to reduce traffic congestion and pollution in the past compared to other regions and are now trying to fill the gap. The adoption of technological solution does not appear to be significantly different among the continent, since the different European areas can be considered at the same level in the exploitation of the available technology.Finally this work suffers from some limitations. As a matter of fact, it is limited to a sample of European cities and does not provide for a worldwide analysis. CL appears to be a typical European practice and few municipalities are actively involved in CL projects in other international regions. Future research will be directed towards overcoming these limitations by collecting extended international samples and developing key performance indicators that would support the evaluation of the effects and impact of CL projects on local urban contexts.

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