Classification and Benchmark of City Logistics Measures: An Empirical Analysis

Urban freight distribution accounts for a significant share of pollution and congestion in urban areas. To reduce these negative impacts, municipalities have implemented several City Logistics (CL) measures. This paper presents the empirical analysis of a dataset of 70 European cities that have been piloting or rolling out a CL measure, to provide an updated indication of the status of CL initiatives and analyse the diffusion of CL internationally. The research objective is also to help understand the contextual factors might explain their introduction. To this end, a set of City Logistics Indices (CLI) is used as indicators of the breadth and number of CL measures implemented in a city. A statistical correlation of these CLIs with respect to a set of independent variables, namely the contextual factors, is also performed. Results reveal that the level of pollution, the diffusion of e-commerce and GDP are important drivers of CL deployment.

Keywords: City Logistics; Classification; Dataset; Factor analysis; Correlation analysis

Introduction

In recent years, both local governments and private organisations have been implementing measures to reduce the negative impact of last-mile freight distribution (Thompson, 2014). This trend originates from the importance of logistics in both urban environments and global supply chains. On the one hand, freight transport accounts for up to 20% of vehicle-kilometres travelled on urban roads (Gonzalez-Feliu et al., 2012) and logistics activities use from 3 to 5% of urban land (Dablanc, 2009). On the other hand, a significant proportion of supply chain activities and up to 40% of their cost are related to last-mile distribution (Schäffeler and Wichser, 2003; Roumboutsos et al., 2014). In this context, road traffic congestion in urban areas is often perceived as one of the most important factors affecting the costs and services in relation to freight transportation activities (Sankaran et al., 2005).

As a consequence, urban freight distribution systems are largely accountable for pollution, traffic congestion and other concerns in cities. For instance, a large French distributor estimates that their last-mile logistics activities in urban areas account for more than 60% of its CO_2 emissions (Bohne and Ruesch, 2013). Earlier surveys also report that the share of CO_2 emissions from freight vehicles in relation to total urban traffic is about 20 to 30%, while, for Particulate Matter (PM), this figure reaches around 50% (Schoemaker et al., 2006).

To try to reduce these negative impacts, several measures have been devised, tested and implemented in many cities around the world and especially in Europe. These measures are typically referred to as City Logistics (CL) initiatives. CL is defined as a comprehensive solution for "totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption" (Taniguchi et al., 2002). A CL system consists of a number of supply chains that start at the intercity transportation hubs, flow through logistic terminals and shopping centres, and end at the shoppers' home (Yang and Moodie, 2011).

However, most CL initiatives do not take into account all these aspects together, but are instead fragmented and mainly address just some of these elements individually. For example, some industry players have been using green vehicles or reshaping delivery time windows to increase their environmental efficiency and reduce the operational costs of urban delivery (Wygonik and Goodchild, 2011). Similarly, some municipalities have put in place, or are currently implementing, public policies to reduce the number of freight vehicles (Marcucci and Danielis, 2008; Crainic, 2008).

In this context, the interest of academia and institutions, such as the EU, has been directed towards sharing international best practices and developing roadmaps and guidelines to support the planning and implementation of effective public and private CL policies (Taniguchi et al., 1999; Ballantyine et al., 2013; Schliwa et al., 2014). In addition, emphasis has been placed 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 (European Commission, 1998; Quak and de Koster, 2007; Russo and Comi, 2011; Muñuzuri et al., 2013).

Therefore, the variety of stakeholders and approaches involved, in addition to commitment by multiple levels of government (local, national, supranational) make up the main characteristics of the almost two-decade long structuring process of the CL arena. These features are responsible for a mixed landscape of CL experiences across different regional contexts. To shed some light on the rationale for implementing certain CL initiatives, several classifications and overviews of CL measures and initiatives have been proposed in literature, together with some examples of real life applications and international best practices.

However, there is a shortage of studies that present an updated indication of the status of CL initiatives and analyse the diffusion of CL internationally to help understand which of the CL measures have been more widely introduced and the possible reasons for different ways of interpreting and implementing CL systems and measures in different cities internationally.

In an attempt to bridge this research gap, this paper presents an empirical analysis of a dataset of 70 European cities that have been piloting or rolling out a CL project. In order to understand the extent to which a city has implemented a CL initiative, the dataset classifies and lists the possible infrastructural, regulatory and technological CL measures that have been adopted by the sample European cities. Since existing classifications of CL measures are theoretical in scope, it is necessary to build an empirical classification. To do so, real life implementations of CL measures are integrated into a classification scheme that has been adapted from literature. The dataset also includes relevant urban, demographic and environmental factors, such as levels of pollution and population density, which might affect and help explain the reasons of local CL variants. This is pursued via the definition of a set of City Logistics Indices (CLI) used as indicators of the breadth and number of CL measures implemented in a city and analysis of their statistical correlation to the observed relevant external factors.

An Aggregated City Logistics Index (ACLI), referred to as a weighted summation of the set of CLIs, is also proposed as a parameter for the range 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: firstly, we present several classifications of CLs available in literature and, from these, we classify and define the relevant types of infrastructural, regulatory and technological measures of a CL system. Secondly, we explain the research methodology and provide an illustration of the dataset. Following this, we analyse the dataset and interpret the results. Finally, we discuss the main implications and draw our conclusion.

Classifications of CL Measures

Several classifications of sustainable urban freight distribution measures are available in literature.

For example, Rosini (2005) classifies measures of urban sustainable freight transportation into two axes, one related to elements subject to regulation (e.g. infrastructures, operating times, vehicles) and the other associated with the methods of regulation (e.g. the level of intervention by the public sector). This classification does not include the technological aspects of the CL and is limited to selected Italian cities.

Muñuzuri et al. (2005) classify measures in terms of their scope and stakeholders involved. Urban freight solutions are divided into five groups depending on their field of application, namely: Public Infrastructures, Land Use Management, Access Conditions, Traffic Management, Enforcement and Promotion Tools. This classification is an overview of the potential measures and solutions that can theoretically be put in place by a public administration for CL purposes. However, it lacks an empirical application to existing measures.

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). These categories represent some approaches that can be adopted for solving the issues arising from urban freight transportation systems.

A classification developed exclusively according to the analysis of existing case studies is that of Dasburg and Shoemaker (2007), who identify four categories of measures:

- Infrastructure, Technology and Equipment;
- Restrictions and Incentives;
- Logistics and Transport Organisation;
- Accompanying measures;

Russo and Comi (2011) study and classify CL measures in terms of their time horizon (i.e. strategic, tactical, and operative) and their expected outcomes, following a similar approach to that of Muñuzuri et al. (2005). This classification is made up of four categories: Material Infrastructure measures include linear or nodal infrastructures devoted to CL purposes; Intangible Infrastructure measures include ITS, which require a significant amount of investment in order to be implemented, as well as softer initiatives in the fields of research and training; Equipment measures include regulation of both loading unit standards and transportation units (i.e. vehicles). These measures aim to optimise handling and transportation performed with low-emission vehicles; finally, Governance measures consist of traffic regulations such as time-window access and low emission zones. The authors then provide a tentative framework for helping policy makers choose the most suitable measure in relation to the predetermined goal.

A fairly comprehensive and updated classification is also proposed by Thompson (2014), who categorises CL measures into four management types. However, the identified measures are not well balanced and not thoroughly explained and detailed.

For the current purpose of providing an empirical analysis based on the actual implementation of CL measures, all previously reviewed classifications fall short to some extent. In fact, some are too theoretical in scope (Muñuzuri et al., 2005; Van Duin and Quak, 2007), and others are not well structured or balanced between major categories, or fail to provide the reasons behind the creation of the categories (Dasburg and Shoemaker, 2007; Russo and Comi, 2011; Thompson, 2014) or even fail to include the basic technological aspects of CL (Rosini, 2005).

Finally, the foundation behind this work is demonstrated by the most recent classification proposed by Creazza et al. (2014). This classification is founded 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 use of urban spaces by freight vehicles;
- Technology, based on the use of innovative Intelligent Transportation Systems (ITS) and low emission vehicles;
- Regulation measures, which include public measures aimed at promoting the improved and optimised use of infrastructures and freight vehicles (e.g. off-hour deliveries and multi-use lanes);

It is assumed here that the classification by Creazza et al. (2014) provides a suitable framework for the quantitative analysis of the diffusion of CL measures, as it is both non-redundant and mostly practical in nature.

CL Measures

This classification allows the identification of eleven measures that have been implemented as part of a CL system. These measures are listed in Table 1 according to a breakdown adapted from Creazza et al. (2014). However, some modifications have to be made to take into account some potential flaws that might hinder its ability to represent effectively a CL system. In particular, Restrictive and Regulation measures both cover public policies regulating urban freight transport and thus have been condensed into one category.

Table 1 divides the CL measures into three domains, namely Infrastructure, Regulation and Technology, and gives a literature source for each measure. An explanation of these categories and associated measures is provided in the following paragraphs.

Table 1. Review of CL measures

Infrastructure

This category comprises CL initiatives that require either the planning or building of new logistics infrastructure or the use and improvement of existing infrastructure, including the allocation of public spaces for freight transportation purposes. The use of shuttle trains or trams on existing railway or underground systems has not been included in the classification (Munuzuri et al., 2005; Russo and Comi, 2011; Thompson, 2014) insofar as it has not yet proved to be feasible (Arvidsson and Browne, 2013).

A consistent number of works has focused on the development of urban consolidation centres (UCC) in the outskirts of the city as a means of consolidating goods and reducing the number of vehicles moving in the inner city. Browne et al. (2005a) provide a comprehensive review of UCCs. UCCs have different characteristics, in terms of spatial coverage, range and type of products handled, ownership and operation (for example, they might be public or private, and operated by a single operator or a joint venture). Moreover, UCCs can provide some potential benefits, both from an operative point of view (e.g. better inventory control) and in terms of economic and social benefits. However, the implementation of UCCs sometimes struggles with high set-up costs or limited attractiveness to logistics companies, given that freight flows are already consolidated at an intra-company level and the UCCs are not able to handle a wide range of goods.

Today most cities have dedicated roadside lay-by areas to avoid the problem of double-parking by trucks that will eventually use roadside 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 et al., 2012). However, some scholars point out the fact that public administrators should design the location of loading and unloading areas more carefully, in order to minimise the cost and time of delivery (Aiura and Taniguchi, 2005). Moreover, they should set strict rules regarding their usage time in order to guarantee a fair through-flow for the benefit of all carriers. Sometimes, lay-by areas can be used only in combination with time windows, as is the case in Paris (Crotti, 2006). 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. In this case, freight vehicles can use those areas depending on their occupying space: if this is less than 29 $m^{2,}$ vehicles can load and unload between 10am and 5pm; for vehicles over 29 m^2, logistics operations can be carried out at night-time only.

Micro-consolidation centres (MCC) are small warehouses located within the city centre, in which goods are transhipped from heavy commercial vehicles to electric distribution vehicles for the last mile of the delivery process. Janjevic et al. (2013) provided a review of micro-consolidation schemes, arguing that they might be more profitable than UCCs, although for smaller goods (e.g. packages, mails, office supplies). Overnight deliveries to micro-consolidation centres may further increase the productivity of operations (Browne et al., 2011; Verlinde et al., 2012).

The use of bus lanes or the allocation of dedicated goods delivery routes can reduce congestion levels, optimise existing road networks and increase carrier efficiency (Russo and Comi, 2011). In fact, planning commercial routes within the existing road networks provides methods of diverting commercial traffic from congested roads to more suitable and efficient routes. This measure requires dynamic road signalling (e.g. variable message signs) and may be supported by a navigation and communication tool that indicates the planned routes to the drivers. Multi-use lanes have been implemented in Barcelona (Hayes et al., 2006): variable message signs show the actual access rights per user group in real time. In fact, roads can be used by private vehicles and public transportation between 8am and 10am and 5pm and 9pm, while commercial vehicles only can use the selected lanes between 10am and 5pm.

Regulation

Regulation measures include three classes of public policies: restriction or limitation of the access of delivery vehicles to the city centre, imposition of monetary disincentives for certain types of vehicles, and incentives to encourage more sustainable transportation companies (e.g. third-party delivery).

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 improves the pedestrian safety and increases the attractiveness of urban areas during store opening hours.

Historically, scholars have focused a lot of attention on restriction measures, such as low emission zones (Carslaw and Beevers, 2002; Anderson et al., 2005; Browne et al., 2005b; Lindholm, 2010; Arvidsson, 2013), time windows (Quak and de Koster, 2007; Van Duin et al., 2012) and restrictions on vehicle weight and volume (Behrends et al., 2008; Awasthi and Chahuan, 2012). A load factor control might also be a suitable regulation measure to encouage greater loads and, in turn, fewer freight vehicles (Taniguchi and Van der Heijden, 2000; Comi et al., 2008) but it has been adopted by very few cities (Teo et al., 2014). Such restrictive policies prevent or limit access of commercial vehicles based on their size (weight, space occupancy) and/or emission levels to certain areas of the city (typically historic centres). Despite their widespread use and potential for successfully reducing negative impacts, restrictive policies have to be carefully calibrated or they could significantly hinder freight operations (Ballantyne et al., 2013).

Night deliveries can resolve issues generated by freight transportation, by shifting deliveries to during less congested time periods. This can also increase the efficiency of delivery operations, with lower and more reliable journey times. Public administrators could also implement this solution to foster the attractiveness of third-party delivery to retailers. In fact, delivering outside of office hours demands the deployment of more resources, therefore it is profitable only with high volume deliveries (Holguín-Veras et al., 2014). However, implementing this solution might be unfeasible; Holguín-Veras et al. (2014) argue that both the consignee and the carrier must understand the benefits of the solution and therefore enter into a contract agreement. Moreover, from a public administration perspective, this solution is only feasible when low emission and noiseless vehicles are used.

Technology

Technology measures involve the introduction of technology-based infrastructures to the urban freight transportation system. These include, for instance, ICT platforms connecting 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).

Intelligent Transportation Systems (ITS) focus on improving carrier operations (e.g. route and trip planning), as well as providing value-added services for carriers and their customers (e.g. reliable estimated time of arrival). They can be divided into two main categories (Allen et al., 2007): freight transport management systems (e.g. fleet management systems) and traffic management systems (TMS).

Electronic access control and road pricing systems or access charges simplify the interaction between freight carriers and public administration. TMSs of this sort must work via an integrated IT platform that can be accessed by different players (municipality, private citizens, operators, banks, etc.) via different online and mobile methods. A possible example of a policy that requires significant TMS investment is road pricing or congestion charges. The congestion charge is paid for using urban roads and the rate depends on either the access time (i.e. higher charge during peak hours) or the emission level of the vehicle. According to Quak and Van Duin (2010), this policy promotes a more balanced use of the existing infrastructure and the adjustable charge forms an effective tool to achieve this goal. As stated by McKinnon (2006), it is expected that, by being forced to pay a congestion charge, carriers will be encouraged to optimise use of their vehicles or reduce the negative polluting impact of their fleet. Therefore, this policy acts as a disincentive to inefficient or polluting freight transportation.

TMSs also deliver value-added services, such as real-time information about traffic and occupancy of lay-bys. Monitoring the usage of lay-bys and providing real-time occupancy information on their can increase the rotation in the use of urban infrastructure, while potentially reducing the number of vehicle-km travelled. In fact, carriers can change their routes according to the availability of the nearby areas, and therefore reduce idle time looking for a free roadside parking spot. Monitoring lay-bys has the second advantage of being a more effective, real-time method of preventing illegal parking. In the long term, the improved monitoring b of lay-by areas may be a successful deterrent against the illegal use of these areas, leading to the improved correct use of the road network. This issue is particularly significant in most cities; by most accounts, only a small percentage of carriers occupy lay-bys for deliveries (Comi et al., 2011). Monitoring the occupancy of lay-bys is often included as part of the electronic booking service, which enables a specific area to be booked in advance. It is certainly the case that, in the case of electronic booking, the strong enforcement of occupancy regulations is required to secure the booking and make the service feasible. Moreover, the traditional operational methods of carriers forms a potential barrier to the introduction of online booking of loading bay areas, as they are often not able to plan their stops in advance (Alho and Abreu e Silva, 2015) (e.g. they need to be flexible for last-minute pick-up and delivery jobs). The effectiveness of a monitoring and booking system can be significantly enhanced by dynamic or static routing algorithms that compute optimal delivery routes. This measure provides a technological solution to increase the efficiency levels of carriers and reduce negative impacts (Russo and Comi, 2011). Such tools exploit existing algorithms developed for solving the typical Vehicle Routing and Scheduling problem (VRP), which are studied particularly in literature with regard to time window constraints (VRPTW) (Braysy and Gendreau, 2005a, 2005b; Fuellerer et al., 2009; Crainic et al., 2010).

Finally, technology does not just concern ICT platforms, but also 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 et al., 2014; Trip and Konings, 2014; Cagliano et al., 2015) or small electric distribution vehicles (Browne et al., 2011; Nesterova et al., 2013; Melo et al., 2014). 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.

Research Methodology

This research paper is developed according to the following three steps:

First, we define and classify the spectrum of possible CL measures based on the adapted classification from Creazza et al. (2014), which is modified to adapt to the CL context, as previously discussed.

Second, we select and study a sample of 70 European cities that have been developing initiatives in one or more of the three CL domains measures, namely: infrastructure, regulation and technology. The selection and study of these cities is carried out in reference to project documentation, national reports (Ambrosino et al., 2005; Crotti, 2006), European (Dablanc, 2009, Bohne and Ruesch, 2013, Posthumus et al., 2014) and regional reports (Roche-Cerasi, 2012; Campbell et al., 2010), scholarly papers (Morganti and Gonzalez-Feliu, 2015), conference proceedings (Van Rooijen and Quak, 2010; Pulawska and Starowicz, 2014) and websites that gather data on the measures set up by municipalities (http://sootfreecities.eu/city). The decision to consider European cities only as part of the survey is based on the demand expressed by European urban areas for projects aimed at enhancing CL operations. A number of initiatives have been launched to promote CL projects, such as the "Interregional Co-operation Programme" or the Horizon 2020 framework programme. The European Commission has also focused heavily on the logistics sector, developing a freight transport logistics action plan. This plan highlights the importance of logistics to European society, since it is associated with many current problems, such as pollution, congestion and oil dependence (CityLog, 2010).

In the sample group, there are both small towns such as Burgdorf in Switzerland (15,584 inhabitants) and big cities like London, UK. The sample cities are distributed according to geographical area. 32 out of the 70 cities are located in the South (Italy, Spain, Monaco), 13 in the North (Denmark, Norway, UK, Sweden), 12 in the Central Western Europe (Belgium, France, the Netherlands), and 13 in the Central Eastern Europe (Germany, Austria, Estonia, Latvia, Poland and Romania).

A score of 1 or 0 is given to each CL measure depending on whether a city has carried out a CL project or introduced a measure in that specific field or not. Following the factor analysis to determine the relative importance of each measure with respect to the three domains, a CLI is computed for each single domain as a weighted sum total of the measure scores. The same task is repeated to compute the upper-level Aggregated City Logistics Index (ACLI), which is calculated as a weighted sum total of the three single domain 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 a summary expression of the ability of a city to create a comprehensive and large-span CL system with a wide spectrum of measures to tackle the different aspects of CL vertical domains. This is assumed to be the indicator of an effective CL system. In fact, Marchau et al. (2008) argue that an integrated view of the different policy options is necessary for urban transport policy making. According to Browne (2013), combining solutions and reinforcing different networks is beneficial to the effectiveness of CL initiatives and systems. Few European cities have assimilated these notions and have written CL strategies that include several measures at once. The most notable example is the Sustainable City Logistics Charter signed in 2013 in Paris, which includes 16 projects including electric vehicles, modernisation of delivery zones, night deliveries and parking space reservation, among others (Levivfe, 2016).

According to the ACLI, a rank of the cities is proposed in the Appendix.

Third, assuming the set of CLIs to be the dependent variables, correlation analyses with relevant urban, demographic and environmental factors are conducted using a statistical software tool to understand the influence that the various external independent variables may have in shaping the local CL system. The unit of measure, the statistics and database source of the chosen relevant external variables are presented in Table 2.

Table 2: Relevant urban, demographic and environmental factors

Relevant independent variables are selected based on literature evidence. Typically, higher levels of complexity for an urban area call for more CL initiatives. The complexity of the urban environment is here measured via the population, the city area and the population density. In particular, it is expected that highly populated cities are called upon to implement multiple CL initiatives due to an increased demand for goods and consequent further pressure on urban logistics (Behrends, 2016). Similarly, the spatial expansion of a city in terms of squared kilometres is related to an increased interest in the problem of urban logistics and this has a positive impact on CL initiative development (Jedlinski, 2014). Also, big cities are usually more capable of implementing such projects due to greater available financial resources. Therefore, large and populated cities are expected to be willing to run projects to enhance logistics activities.

The concentration of air pollution is also taken into account, since logistics have a significant impact on the environment (Awasthi et al., 2016): the higher the level of particulate matter in the air, the higher the number of CL projects that are likely to be carried out to reduce the negative effects of pollution.

Also, the increasing success of e-commerce has caused a shift in the operations of logistics companies from Business to Business (B2B) to Business to Customer (B2C). In this context, the possibility of achieving efficiencies from load consolidation is reduced. Thus, the higher the level of e-commerce, defined as the computer-to-computer processing of a transaction for the purchasing of a service of product (Ng, 2009), in both absolute and market share, the greater the impact on a CL system (Teo et al., 2012) and the lower the initiatives in the CL arena that can obstruct its success.

The level of GDP is related to the financial availability for developing projects. Also, it is expected that, by 2020, 85% of European GDP will be produced within urban areas (European

Commission, 2013); therefore, the higher the rate of GDP per capita, the greater the opportunities for CL initiatives. In line with the above, the higher the rate of growth of GDP, the greater the willingness to implement new CL projects.

Finally, based on the fact that the oldest cities have more fragile and narrow streets, the Age of the cities has been included in the analysis. This variable expresses the age of a city from its year of foundation. It is here assumed that the older a city the lower the level of robustness of its road infrastructure and, in turn, the higher the need for enacting CL initiatives.

Results

Diffusion of CL initiatives

Figure 1: City Logistics Index according to sub-domain

Fig. 1 is an illustration of the diffusion of CL initiatives. In particular, three types of measures are implemented in more than 50% of the panel of European cities, namely: Low Impact Vehicles, UCCs 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.

Factor analysis

The objective of this analysis is to identify the significant contextual variables that are likely to influence the CLIs and the ACLI. To this end, CLIs are calculated as the weighted total sum of their subdomain scores. Weights are consistent with the loadings computed using factor analysis as per Nicoletti et al. (1999). The results of this factor analysis are given in Table 3. This shows that the three identified domains can be related mainly to load consolidation practices and to stakeholder coordination initiatives. In fact, one of the key goals of a CL system is to blend these two factors (Bektas et al., 2015). Therefore, the factor analysis enables the computation of the weights for every CLI.

Table 3: The identification of loadings in factor analysis

Correlation analysis

Correlation analyses are carried out in order to understand the impact of the contextual variables on the set of CLIs. The level of dependence between two quantities is expressed by the Pearson coefficient that ranges from -1 to +1. It is equal to +1 in the case of total positive linear correlation, -1 in the case of total negative linear correlation, and 0 in the case of no linear correlation (Rodgers and Nicewander, 1988). The reliability of the relationship is represented by the p-value, which ranges from 0 to 1 and represents the probability of rejecting the null hypothesis given below.

H0: there is no significant relationship between the variable and the CLI

H1: There is significant relationship between the variable and the CLI

The significance level, which is typically equal to 0.05, represents a constant critical value. If the p-value is smaller than the given critical value, the null hypothesis is rejected and it can be concluded that the relationship is significant. On the contrary, if the p-value is greater than the critical value, the test fails to reject the null hypothesis and it can be concluded that there is not enough evidence to prove a significant relationship (Bhattacharaya and De Sale, 2002).

In particular, their effects have been considered at two different levels: by taking into account the coverage of all the domains identified and then via exploring the coverage of each single domain (see Table 4).

Table 4: Result of the correlation analyses

The results given in Table 4 show that the city size in terms of number of people, extension and population density is not correlated to the implementation of CL initiatives in each domain; moreover, at the aggregated level, the City Area variable appears to be correlated with the ACLI.

GDP per capita has proven to drive adoption of CL measures in urban logistics, in the infrastructure and regulations domains.

Pollution positively impacts on carrying out initiatives in the infrastructure domain. This is likely due to the fact that polluted cities are dealing with environmental challenges via implementing initiatives to improve air quality. This result reaffirms the importance of the environmental benefit as a primary goal associated with CL projects.

Another consideration is that the rate of growth of GDP negatively influences CLIs, especially in the infrastructure domain. This result may be associated with the need expressed by cities experiencing important economic growth rates to focus on other aspects of urban life not necessary related to CL.

Both the e-commerce to GDP ratio and the proportion of e-commerce as a fraction of total sales show a negative influence on the CLIs in both infrastructure and regulation domains. These relationships mainly depend on the fact that e-commerce activities do not allow for efficient load consolidation due to fragmented deliveries and, in turn, efficient trip routings. Thus, cities enjoying widespread growth in e-commerce are unlikely to implement projects that may jeopardize its success. In other words, the higher the number of CL initiatives, the higher the number of obstacles and constraints related to collection and delivery and, in turn, the lower the diffusion of e-commerce. As well as the above, the Age of the City also has an impact on the CLIs, particularly in the Infrastructure domain. This result shows that oldest cities call for new CL projects in the light of the weakness of their road infrastructure that was not designed for modern vehicles. On the contrary, the technology domain does not depend on any contextual variable.

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.

Figure 2: Results of the one-way ANOVA: CLI versus Geographical Area

For instance, Southern European cities appear to be more active in implementing CL initiatives than cities in Central Western, Central Eastern and Northern Europe.

Moreover, Southern European cities belong to countries where lower e-commerce purchase penetration is recorded and this could confirm the negative relationship between the diffusion of e-commerce and CLIs.

Discussion of Results

To deal with the challenges of increasing traffic congestion, pollution and noise, urban areas are called upon to invest in CL initiatives that can improve the environmental sustainability of last mile freight distribution and, in turn, enhance the quality of life of citizens. To sustain this growing interest, public policy makers still require support in the implementation of CL projects, to better understand their effects and to identify potential improvements and opportunities.

In this context, this paper attempts to provide a more structured understanding of the notion of CL and an empirical evaluation of current trends at a European level. To this regard, several considerations and discussions can be made.

From a geographical point of view, Southern European cities show higher CLIs. This is likely due to the fact that Southern European cities have undertaken fewer measures to reduce traffic congestion and pollution in the past compared to other regions and are now trying to bridge the gap. Nevertheless, some cities in other regions, such as Graz, Bath, Bremen among others, show relatively low ACLI even though they have invested in infrastructure projects (e.g. UCCs). On the one hand, it can be argued that they have probably focused on selected projects rather than on a wide range of activities and, hence, the analysis should include this aspect in the calculation of the ACLI. On the other hand, the financial sustainability of CL projects and availability of financial resources could also be considered as an important factor (i.e. independent variable) to explain why some cities are lagging behind schedule in the deployment of CL initiatives. This is an intrinsic flaw of the study, caused by the fact that, due to missing data, it was not possible to include the implementation costs of CL initiatives in the study.

Population and density do not seem to be correlated with the breadth of integrated CL measures. This could be due to the fact that the level of congestion is arguably a more important factor, when it comes to optimising urban freight distribution, than the size of a city. Traffic congestion is usually higher in the city centres, where streets are narrower. As older cities are more likely to feature narrow streets and congested city centres, this is measured by means of the Age of the City. The Age of a city is thus associated with the strength and capacity of the road infrastructure, and it significantly affects the propensity to implement CL initiatives. This result demonstrates that the need for new CL projects is particularly high in old cities where the efficiency of the last mile distribution process is lower. Narrow streets and congested city centres are also more likely to be present in smaller cities and not just in older cities. This is one of the considerations explaining the negative correlation between the ACLI and the City Area.

The Infrastructure domain is correlated with the level of pollution. This demonstrates that pollution is an important driver of the development of CL projects. Polluted cities have created consolidation centres for more efficient collection and delivery, set up lay-by areas and dynamic routing algorithms to optimise vehicle stops, promoted the introduction of micro consolidation centres and low emission vehicles for more sustainable freight deliveries and dedicated lanes within the road network for faster freight vehicle travel.

In addition, the negative relationship with GDP growth demonstrates that those areas that are affected by intense economic growth are still not focused on enhancing CL projects. On the contrary, low growth rates are associated with more CL initiatives, based on the demand for increased efficiency and to create cheaper methods of urban logistics organisation. In particular, the effect of the growth in GDP is significant for infrastructural measures, showing that local administration may be interested in infrastructural investment to counteract the economic trends and stimulate growth at a local level. This is confirmed by the negative correlation between Infrastructure measures and GDP per capita.

Another important result is associated with the negative impact of e-commerce practices. Areas where e-commerce has large market shares are less oriented towards CL measures. A possible explanation for this counterintuitive result could lie in the peculiarity of the B2C delivery market. In fact, the delivery of e-commerce goods is characterised by smaller, fragmented and more frequent deliveries. Most of B2C deliveries are made by a few global Logistics Service Providers (LSP) that need to invest large amounts of money in warehousing and vehicle fleet capacity to compete for their market shares. Therefore, as far as infrastructural measures are concerned, it would be complicated for these companies to proactively participate in CL initiatives, whose objective is to consolidate goods coming from other LSPs. As for regulatory measures, it can be argued that in countries with a larger penetration of e-commerce, the bargaining power of these major global LSPs is strong enough to restrain the implementation of restrictive measures implemented by local administration. Finally, the technology domain does not appear to be related to any contextual variables. This could be explained by the fact that the implementation of technology in CL does not depend on the local urban structure of the city, but rather on its maturity and on the willingness of some private players to make IT investments. A typical example is the diffusion of electric vehicle for collection and delivery in urban areas, where the involvement of private companies is crucial.

In addition, some considerations can be drawn based on the relationship between load consolidation and stakeholder coordination. Projects aimed at consolidating loads are influenced by certain contextual factors, such as the level of pollution and e-commerce diffusion. On the contrary, stakeholder coordination projects do not appear to be related to these factors. This result might be due to the fact that the coordination of various CL actors is becoming a common objective for every public authority, independently of the progress and the level of success of the CL projects that they have been undertaking.

Implications, Limitations and Future Research

The present study gives rise to both theoretical and practical implications.

From a theoretical point of view, this work can be considered as a precursor to a stream of research on the classification of CL projects and their relationships with urban contexts. In particular, this work provides for a comprehensive definition of the CL notion, classification of CL measures, and identification of current European trends. It illustrates how the notion of CL has been interpreted and applied in different European geographical areas, laying the foundations for exploring the socio-cultural implications of various CL implementations in the European regions.

Also, the methodology proposed for computing the set of CLIs can enhance existing qualitative works such as that presented by Russo and Comi (2016), can be considered as a basis for the CL integrated metrics for diffusion analysis of CL projects, and can provide more robust results to garner insights regarding the status of CL initiatives across Europe.

From a practical point of view, this paper could assist the managers of public bodies to measure the magnitude of their CL initiatives and set their future objectives. 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 (Michelucci et al., 2016). Also, the identification of significant contextual variables shows the crucial aspects that should be taken into account by policy makers and managers of public bodies in defining CL programmes and CL measures that can be included towards the expansion of the breadth and range of intervention.

As mentioned above, a major limitation of the analysis proposed in this paper lies in the lack of detailed financial variables indicating the capacity of a city council or private company to fund the implementation of a CL project, alongside more aggregate factors such as GDP per capita and growth of GDP.

This work is limited to a sample of European cities and does not provide a worldwide analysis. CL appears to be a typically European practice and few municipalities are actively involved in CL projects in other international regions. This may be due to the fact that European cities have been facing traffic congestion and pollution problems for longer than cities in emerging and fast-growing countries. Furthermore, the present CLIs do not take into account the success or impact of CL initiatives that have been implemented in the sample cities.

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. Such further research will help analyse and possibly confirm the preliminary results of this study by engaging in a more quantitative assessment of the impact of single CL initiatives via the principal environmental, social and economic performance indicators, in such a way that the breadth of a CL programme will be also combined with its effectiveness to create a more sustainable city.

Conclusion

This work is a preliminary, challenging, informative, empirical analysis that helps classify and understand current trends of CL development in Europe.

To this end, three main domains (Infrastructure, Regulation, and Technology) and their related sub-domains of CL deployment were identified and a set of CLIs were computed as the proportion of domains covered by a city's CL initiatives as a ratio of the total potential domains and sub-domains.

Then, a list of contextual variables was created and correlation analyses were performed so as to identify their relationship with the dependent CLIs. Results reveal that the level of pollution, the diffusion of e-commerce and GDP are important drivers of CL deployment.

This work is intended to stimulate the adoption of CL systems that would embrace multiple measures in all infrastructure, regulatory, and technological domains of a CL system and that would contribute to the current debate on the present and future trends of CL. Furthermore, this work may assist public authorities in understanding these factors and shaping proper strategies and plans for the future of their cities.

Acknowledgements

The authors are grateful to Ms. Silvia Moroni for her active involvement and contribution to this research as a Master student in the M.Sc. Program in Engineering & Management at the Politecnico di Torino.

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Appendix: City Logistics Index for cities of the sample group

State	**City**	**City Logistics Index**
Italy	Brescia	71.85
Italy	Parma	61.34
Italy	Padua	56.69
Italy	Vicenza	54.07
Italy	Milan	51.35
Italy	Cremona	50.14
Italy	Ferrara	48.94
France	Lyon	48.81
France	La Rochelle	48.22
The Netherlands	Amsterdam	48.22
Italy	Bologna	47.98
Poland	Cracow	46.85
Italy	Lucca	46.66
The Netherlands	Utrecht	46.01
Denmark	Copenhagen	43.25
Germany	Berlin	41.44
Italy	Bergamo	41.32
Monaco	Monaco	40.81
Italy	Turin	40.6
Italy	Reggio Emilia	39.31
Spain	Vitoria	37.46
Italy	Pisa	35.26
Italy	Rome	35.26
Sweden	Goteborg	34.7
Sweden	Stockholm	34.7
UK	Bath	34.63
Italy	Lecco	34.05
France	Besancon	32.54
Austria	Graz	32.26
UK	London	32.21
Spain	Barcelona	29.68
Italy	Florence	28.92
France	Paris	28.57
Spain	Burgos	28.57
Italy	Modena	28.08
Italy	Venice	28.08
Spain	San Sebastian	27.43
UK	Bristol	27.43
Italy	Ravenna	26.76

Spain	Cordova	26.51
Germany	Strasbourg	26.36
Romania	Ploiesti	24.91
France	Bordeaux	21.9
Spain	Bilbao	21.22
Belgium	Brussels	20.58
Italy	Piacenza	20.58
Sweden	Borlänge	20.08
France	Nancy	20.02
Germany	Dresden	20.02
Germany	Regensburg	20.02
Germany	Bremen	20.02
The Netherlands	Nijmegen	20.02
Spain	Seville	20.02
Denmark	Aalborg	18.58
The Netherlands	Groningen	17.44
France	Poitiers	14.73
UK	Durham	14.68
Latvia	Riga	14.61
Italy	Siena	14.24
Italy	Treviso	14.24
Italy	Verona	14.24
Estonia	Tallinn	12.67
Germany	Stuttgart	12.52
Norway	Stavanger	12.52
Romania	Bucharest	12.52
Sweden	Malmo	12.52
Switzerland	Bergdorf	12.52
UK	Cambridge	12.52
Germany	Kassel	7.5
UK	Sheffield	7.5

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 area 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 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 transportation	Rosini (2005); Van Duin and Quak (2007); Thompson (2014); Creazza et al. (2014);

Table 2: Relevant urban, demographic and environmental factors

Context variable	Unit	Mean	St Dev	Min	Max	Source
Population	# inhabitants	680,091	1,448,260	15,584	8,308,369	Census, 2010 [3]; Eurostat [4]
City area	Km^2	248.9	336.4	2.0	1,572.1	Census, 2010 [3]; Eurostat [4]
Demographic Density	# inhabitants/ km^2	3,439	3,925	81	21,347	Census, 2010 [3]; Eurostat [4]
Pollution – Pm 10	µg/mc	28.96	12.63	0.1	59	World Health Organization; www. aqicn.org
E-commerce/GDP	%	2.066	0.0147	0.77	5.74	www.ecommerce-europe.eu
E-commerce share	%	5.34	0.0422	1.9	20.00	www.ecommerce-europe.eu
GDP per capita	$/inhabitant	35,553	8,001	17,218	71,977	www.indexmundi.com
Country GDP growth	%	-0.0113	0.1505	-1.698	4.226	www.indexmundi.com
Dependent variable	Unit	Mean	StDev	Min	Max	
City Logistics Index	%	29.98	14.42	7.50	71.85	

Table 3: The identification of loadings in factor analysis

Factor	**Domains**	**Loadings**	
		1	**2**
Load Consolidation	Infrastructure	0.8880	0.0550
	Regulation	0.6780	-0.3780
Stakeholder Coordination	Technology	-0.0810	0.9580

Table 4: Result of correlation analysis

Total domains			**Infrastructure**		
Variable	Pearson Coefficient	p-value	Variable	Pearson Coefficient	p-value
Population	-0.127	0.294	Population	-0.131	0.279
City Area	-0.198	**0.000**	City Area	-0.123	0.310
Demographic Density	-0.088	0.471	Demographic Density	-0.079	0.516
Pollution - pm10	0.196	0.107	Pollution - pm10	0.247	**0.041**
e-commerce/GDP	-0.276	**0.021**	e-commerce/GDP	-0.447	**0.000**
e-commerce share	-0.246	**0.046**	e-commerce share	-0.434	**0.000**
GDP per capita	-0.078	0.876	GDP per capita	-0.247	**0.039**
GDP Growth	-0.421	**0.000**	GDP Growth	-0.328	**0.006**
Age of the City	0.311	**0.009**	Age of the City	0.276	**0.021**
Regulation			**Technology**		
Variable	Pearson Coefficient	p-value	Variable	Pearson Coefficient	p-value
Population	-0.071	0.561	Population	0.136	0.180
City Area	-0.171	0.157	City Area	0.145	0.231
Demographic Density	0.027	0.823	Demographic Density	0.043	0.723
Pollution - pm10	0.226	0.061	Pollution - pm10	0.147	0.228
e-commerce/GDP	-0.424	**0.000**	e-commerce/GDP	-0.052	0.670
e-commerce share	-0.370	**0.020**	e-commerce share	-0.050	0.683
GDP per capita	-0.237	**0.048**	GDP per capita	0.019	0.874
GDP Growth	-0.100	0.410	GDP Growth	-0.013	0.913
Age of the City	0.166	0.170	Age of the City	-0.051	0.677

Figure 1: City Logistics Index by sub-domain

Figure 2: Results of the one-way ANOVA: CLI versus Geographical Area