Sustainability in Urban Logistics – a Literature Review

Purpose:

The importance of urban logistics is on the rise. On the one hand, the population in cities is growing due to urbanization processes. On the other hand, there is a significant increase in the flow of goods (e.g., a boost in online purchases). Such changes are leading cities to face social, economic, and environmental issues, which urge to be addressed. Based on these premises, this study aims to identify, classify and provide an overview of the environmentally sustainable logistics solutions for urban contexts.

Methodology:

This study performs a systematic literature review. First, it provides a quantitative description of the results, highlighting eventual trends; second, it displays a narrative description of the papers considered to map the current solution and of the related methodology.

Findings:

The study highlights the maturity and interest in adopting more sustainable delivery options in urban logistics. The selection of suitable transport means, the engagement of stakeholders, as well as the definition of norms and regulations, emerge as the most discussed and promising solutions.

Originality:

This study is a first attempt to classify the existing body of knowledge related to urban logistics, analyzing contributions based on different axes of classification and highlighting cutting-edge solutions to propose possible research directions.

1 Introduction

Urban Logistics in the last years is on the rise. The main topic under investigation concerns the process of "optimizing logistics and transport activities accounting of environment, safety and energy savings within the framework of a market economy" (Taniguchi et al., 2002). The rising trend of e-commerce, (+ 20% in 2021, with respect to 2020 in Italy) is expected to endure and become a relevant sales channel, creating new challenges for logisticians in the urban context. Parcel delivery, due to order fragmentation, extensive handling operations, missing deliveries and high stop frequencies are identified as the less efficient and most expensive "leg" (around 50% of the total cost) of the logistics operations (Koning et al., 2016). The European Commission quantified, in 2015, the environmental impact of urban freight operations, which accounts for up to 25 % of GHG emissions (EC, 2015), value that given the latest trends is expected to grow.

The increasing attention from both logistics operators and public administration led to the identification of initiatives aimed to reduce the impact of logistics in the city context. On one side, legislation (Fossheim and Andersen, 2017) promotes sustainable initiatives (e.g., delivery time windows, tolls for old diesel and petrol vehicles) on the other logistics operators that introduce changes into their delivery operations considering market economies objectives (Sanz et al., 2018). In particular, the portfolio of solutions adopted so far by logistics operators is wide and full of different alternatives

So far urban distribution problem seems to represent a widely discussed topic, with rising attention to the sustainability aspects (social, economic and environmental ones) due to the increasing interest of practicians and policy makers. Some attempts to classify the extant study exists. More in detail, previous literature reviews on city logistics (synonym of urban logistics) were conducted. For example, de Oliveira et al., (2017), identified city logistics as a highly evolving environment in terms of transport methods (e.g., drones, crowdsourcing vehicles). Consequently, a literature review was performed to assess the new configuration of operations and technologies in last–mile delivery in city logistics, that effectively addresses sustainability. Despite highlighting how freight transport is moving towards smaller size vehicle, the review focus on the implication of

cargo bikes (legislations, weight limitation and health issues) and electric powered vehicle. The authors themselves identified as too narrow their research scope, suggesting focusing future researches on a broader context that considers different vehicles. Lagorio et al. (2016), performed a review from a logistics and managerial perspective identifying the main area of discussion, research methodology and instrumental papers (i.e, “core line of the development of the discipline”). The results showed how the discussion of city logistics is extremely fragmented and how research focuses mainly on technical aspects (definition/improving solutions) rather than others.

2 Objectives and methodologies

2.1 objectives

Coherently with the above discussion, the present paper aims to enlarge the research horizon on city logistics (CL), overcoming the limitations of the previous reviews and categorizing the existing body of literature in the context of city logistics and sustainability. This focus is driven by the rising attention of policy makers towards sustainability (EC 2020), the increasing commercial activities requiring logistics services in cities (e-commerce) and the variety of possible solutions in a CL context as previously highlighted by de Oliveira et al., (2017) and Lagorio et al. (2016). The objective of the research is twofold: (i) classify the extant knowledge and provides a comprehensive view of sustainable CL for academic and practitioners and (ii) identify possible gaps of research.

2.2 Methodologies

A systematic literature review was conducted to reach these objectives, in line with the existing reviews (de Oliveira et al., 2017; Lagorio et al., 2016). Four stages were performed in line with Srivastava (2007) and Mangiaracina et al. (2015): literature search – papers were classified and collected; paper classification - highlights of main characteristics of papers; literature analysis – review of the selected study; identification of the potential area of investigation.

2.2.1 Literature search

The paper classification process includes the following steps, summarized in figure 1:

- Classification context: classification context to categorize the material identified (i.e. city logistics and sustainability)
- Definition of the unit of analysis: single scientific paper, taken from black and grey literature (e.g., conference proceedings) with the objective to collect all the updated publications.
- Collection of the publications: Likewise to Mangiaracina et al. (2015) the identification of relevant publications begins using library databases (i.e., Scopus, Web of Science). Then, the research was performed using keywords, (i.e., "city logistics", "urban freight", "urban distribution", "last-mile delivery", "sustainab*", "electric*", "green", "intermodal", "innovative") and their combination, used at least in title, abstract or keywords.
- Delimitation of the field: from all the publications collected, selection of the most relevant ones for in-depth investigation. A first discrimination was performed according to the language (only English), then a restriction on the subject area (See Figure 1) to exclude non-logistic subject areas. Finally, only publications from 2000 onwards were selected, period when city logistics started to become a relevant topic. This first step led to the identification of 668 papers. These papers were then reduced to 341 by evaluating title and keywords and by including the ones where the scope of the paper was on city logistics and sustainability. A further screening phase was performed by reading first the abstract and then the full paper, leading to an identification of 64 eligible papers. The papers were discarded if sustainability was not a central aspect of the discussion.

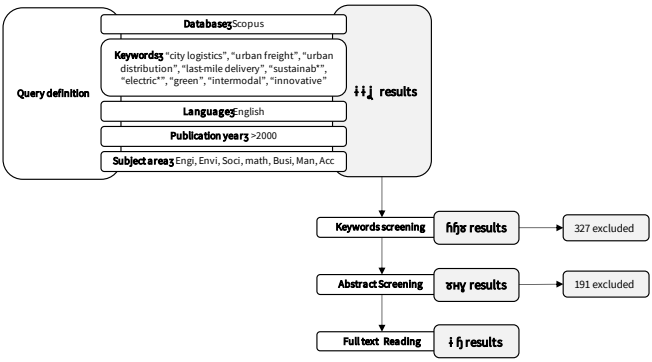

Figure 1. Literature search process (Prisma diagram)

2.2.2 Paper classification

In phase 2 the paper selected were first classified according to their main characteristics and content (Mangiaracina et al. 2015). Then the contents were analysed and categorized to identify possible patterns that eventually could highlight interesting themes or gaps.

Most of the papers (see figure 2), despite the constrain during the search phase to the year 2000, were mostly published after the year 2008 with a growing interest from 2015 onward. This can be explained as follow. The increasing attention to last-mile deliveries in those years, accelerated by e-commerce growth, increased the interest also on sustainability related aspects.

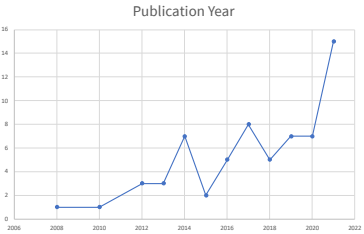

Figure 2. Publication year of the papers selected

The 64 papers under review were published in 37 different journals, addressing different publication areas, namely Logistics and Supply Chain (51 %), Business Management and Social Sciences (20 %), Sustainability (17 %), Technology (6 %) and Mathematics (4 %).

A second classification was performed based on the research methodology adopted. Following Mangiaracina et al., (2015), papers were divided into seven categories, i.e., analytical models (32%), case study (21%), simulations (16%), survey (10%), conceptual framework (7%), literature review (3%) and others (11%).

Papers were also analysed according to their nationality (see figure 3). It emerges how European countries were the most productive followed by North America and Asia, countries with high heterogeneity in city logistics solutions due to the different features of cities and policy (Negabadhi et al., 2019). This breakdown also reflects the engagements of countries in sustainability practices.

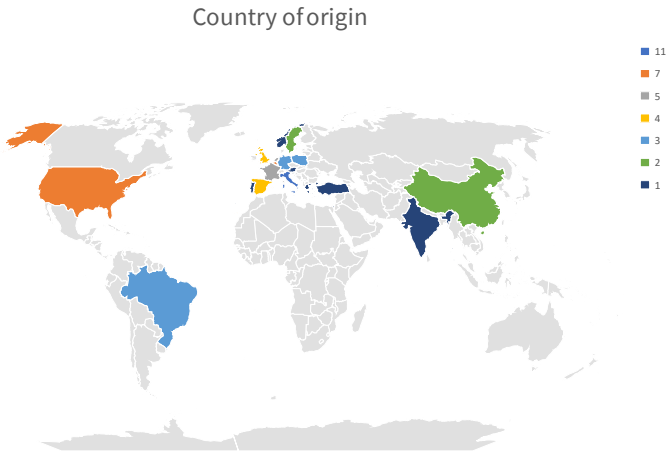

Figure 3. Country of origin of the papers considered. Colours represents number of publication

3 Literature analysis – discussion of findings

The papers were reviewed according to the contents and solutions proposed. To provide a clear reading of the results to foster a focus on the discussion, a bi dimensional classification of the content was performed. The papers were considered according to two axes: solutions proposed to improve the sustainability of city logistics operations (i.e., "Leverages for sustainable city logistics") and methodology used to assess city logistics sustainability (i.e., "Impacts").

3.1 Leverages for sustainable city logistics

Based on the papers examined, three main enablers of sustainable city logistics emerged, namely transportation means, regulations and stakeholders. In this first part, a focus on the existing solution concerning the use of different vehicles is proposed, showing the characteristics and limitations of each technology. Attention is given to the sustainability aspects were possible.

1. Transportation means

Most of the papers evaluated, proposed the use of alternative vehicles with respect to traditional vans (i.e., internal combustion engines, ICE), going in a descending order of interest starting from Cargo-Bicycles, Alternative-Fueled Vehicles, Non-Road Transportation and finishing with Autonomous Vehicles.

Cargo bikes (human and electric powered) represent a green solution for city logistics thanks to their huge benefits and reduced investments (de Mello Bandeira et al., 2019; de Oliveira et al., 2017). Given the nature and the reduced capacity of a cargo bike with respect to a van, these vehicles require urban depots, from where parcels are sorted, loaded (Schliwa et al., 2015) and dispatched (Naumov et al., 2021). These hubs are supplied by vans, which can be traditional (Enthoven et al., 2020; Rosenberg et al., 2021) or electric/hybrid (Leonardi et al., 2021). However, while comparing cargo bikes and traditional delivery, researchers put emphasis mostly on the cargo-bikes path rather than considering the overall one (Fraselle et al., 2021; Lee et al., 2019; Navarro et al., 2016). In other cases, instead, cargo-bike activities follow non-road transportation, like railways or waterways (Divieso et al., 2021). Other authors evaluate cargo bicycles as a

standalone method for last-mile delivery (Conwey et al., 2017; Melo and Baptista, 2017) while others consider a contemporary use of cargo bikes and vans, where larger parcels or the furthest are delivered from the latter (Fraselle et al., 2021; Leonardi et al., 2012; Llorca et al., 2021). Finally, vans can be used as mobile depots for the cargo-bikes on top of their traditional usage (Anderluh et al., 2017; Verlinde et al., 2014).

On the one side, the benefits identified by the adoption of cargo-bike are several (e.g., zero emissions, urban space occupation) (de Mello Bandeira et al., 2019). On the other hand, cargo bicycles are lower-performing than traditional vans in two points: maximum speed and maximum loading capacity (de Oliveira et al., 2017; Llorca et al., 2021). These two limits are partially overshadowed by the low saturation of delivery vans and city congestion (Allen et al., 2018). Other factors limiting cargo bike adoption emerged (Schliwa et al., 2015): city geography (e.g., accessibility to the city centre) and local authorities (e.g., road regulations).

Electric and hybrid vehicles becomes more operationally and economically attractive than before (Lebeau et al., 2015; Lin and Zhou, 2020). Alternative-fuelled vehicles show high potential for adoption as they can exploit the positive characteristics of vans, while minimizing the operational and organizational effort in reconfiguration. Fully electric (EV) and hybrid vehicles (HEV) were successfully implemented due to their environmental advantages (Li et al., 2019; Lin and Zhou, 2020; Nocera and Cavallaro, 2017; Siragusa et al., 2020). To overcome some of the EVs barriers (e.g., battery capacity), they tend to be used in combination with traditional vans or depots to perform specific task of the delivery process: supply activity for urban depots (Leonardi, 2012; Fraselle et al., 2021; van Duin et al., 2013) or last-mile delivery after other vehicles supply an urban/semi-urban hub (Arvidsson and Browne, 2013; Gonzalez-Feliu, 2014; Moore, 2019). Companies' sustainability objectives, redesign of the network (e.g., recharging point, consolidation centre) and local authorities' support (i.e, financial and regulation) represent some of the barriers to the adoption of EV in a city logistics context (Quak and Nesterova, 2014).

Non-road transportation is usually coupled with road transportation to achieve a high level of synergies, enhancing features of each transport mode. High capillarity of the road network for parcel delivery to reach every destination and high efficiency (costs and

emissions) of non-road transportation for freight transport (Alessandrini et al., 2012; Singh et al., 2020). In a city logistics context, the path between depots and the inner city could be performed with public transportation, by exploiting their spare capacity (Masson et al., 2017; van Duin et al., 2019) or by adding dedicated space (Pietrzak et al, 2021; Pietrzak and Pietrzak, 2021) while the remaining part by another type of transports. The main vehicles and infrastructures available are railways, with trains (Guo et al., 2021; Villa et al., 2021) and trams (Browne, 2013; Pietrzak and Pietrzak, 2021) and waterways (Bruzzone, 2021; Divieso et al., 2021; Diziain et al., 2014). Different infrastructure composes the resulted network, requiring higher coordination effort between providers and municipalities (Behrends, 2012).

Autonomous vehicles (e.g., robots and drones) were the less discussed solution. These vehicles are capable of autonomously delivering parcels to customers. Different solutions were studied and compared using an estimative model, mostly in terms of costs (Ostermeier et al., 2021) or an increase in service time (Boyesen et al., 2018; Murry and Ritwik., 2020; Simoni et al., 2020; Swanson et al., 2019). Autonomous vehicle regulation showed a lack of clear direction and many implementation barriers (e.g., acceptance, viability) limits their adoption (Bucchiarone et al., 2021).

2. Regulations

Policies and regulation definition represents an incentive for companies and people to foster long-term benefits for city liveability and well-being. Historically, regulators' attention was given to the definition of documents that prompt action focused on public and private mobility. However, the rising flow of goods in the city context urges integer freight planning as well, to further improve environmental and social conditions (Fossheim and Andersen, 2017). Different papers present real cases of regulations implementation (Koning and Conway, 2016; Quak and de Koster, 2008; Fossheim and Andersen, 2017; Menga et al., 2013) or else present different possible regulations and their potential effects (Morfulaki et al., 2016; Patier and Browne, 2010; Sanz et al., 2018). The main policies identified are related to Limited Traffic Zones, time window operating areas, limitations on the number of vans, tolls for entering the city, benefits for electric vehicle purchase and/or usage, carbon taxes and others.

3. Stakeholders

Last-mile delivery operations are affected by low effectiveness and efficiency (Seghezzi and Mangiaracina, 2021), due to several factors (i.e., low saturation of vans, order fragmentation, missing deliveries). However, the collaboration between logistics providers and other stakeholders (e.g., citizens and municipalities) plays an important role in reducing the above-mentioned problems.

Thanks to the collaboration between companies more couriers can share infrastructures and/or vehicles, integrating their flows and exploiting the efficiency benefits coming from the resulting network (e.g., Bucchiarone et al, 2021; Li et al, 2019; Leonardi et al., 2012; Nocera and Cavallaro, 2012; Rosenberg et al., 2021). A vital role is performed by urban consolidation centres (UCC) and vehicles that affect cost, emission and social health. Integration needed at both operational and IT level between the systems of the different couriers represents the main barrier to the adoption.

Costumers and citizens may participate in two main different ways in the delivery process. In a first case, by retrieving the parcel through the usage of parcel lockers or collection points instead of home deliveries. To optimize these “facilities”, their location plays a relevant role. Results agreed that collection points have higher performances in a highly densely populated area (Cardenas and Beckers, 2018; Mommens et al., 2021). Parcel lockers may have a dual utility: in one case they can be used as a delivery point (e.g., Cardenas et al., 2017; Brown and Giuffrida, 2014; Vural and Aktepe, 2021) while in another they can be used as micro depot like in Enthoven et al. (2020), in which collection-delivery points were used in combination with cargo-bicycles.

The second option considering people involvement is crowdsourcing: a system in which mainly citizens, during a commuting or non-commuting trip in the urban area, deliver parcels to other people (Giret et al., 2018; Seghezzi and Mangiaracina, 2021; Simoni et al., 2019). Studies in this field focus on understanding the assignment of riders to parcels and customers, evaluating the effect of different transportation means used by riders and on the possibilities of bundling deliveries to decrease the number of riders needed. However, implementation complexities and variabilities (e.g transport mode used, demand and offer match, detours, delivery size) limit the systematic adoption of this solution (Seghezzi and Mangiaracina 2020, Seghezzi et al., 2021, Simoni 2019). It is worth

mentioning, however, that some companies already perform this type of service (Amazon flex).

3.2 Sustainability evaluations

The second line of classification was identified according to the objective of the research in terms of social, economic or environmental sustainability. The following classification was based on the three classical categories of sustainability.

The classification identified some aspects:

- different study methodologies to assess the same impact (i.e., quantitative vs qualitative)
- more than one impact is considered at the same time (e.g., Siragusa et al, 2020 assessed both economic and environmental aspects) due to their possible interaction.

The main impact under investigation is the economic one as different technology, and configurations of the system can provide not only environmental benefits but also an economic one. Several methods were adopted, mostly quantitative, where life-cycle assessments (Fraselle et al., 2021; Nocera and Cavallaro, 2017; Siragusa et al., 2020), vehicle routing problem (Enthoven et al., 2020 Lee et al., 2019; Li et al., 2019) and TPS problem (Naumov et al., 2021) emerged as the most applied. Of particular interest is the study of Gevaers et al. (2014) which attempts to simulate the total cost of last mile deliveries according to specific last mile characteristics (e.g., transportation means, network) used as independent variables.

The model used differs according to the (i) research objectives (e.g., comparison with the existing solution, distance travelled, failure rate), and (ii) costs considered (e.g monetary or non- monetary). Monetary cost concerns investments and running cost while non-monetary evaluates the corresponding cost of the emission (€/tonCO2, congestion costs).

Complementary to the economic aspects, most of the papers discuss, employing analytical model or case study, the effective impact of the green solutions from the environmental viewpoint. The studies vary accordingly to the micro-pollutants considered (CO2, CH4, NO2, NOx and PM10) and methodology used. Concerning the

latter two main methods were the most used: (i) Well-To-Wheel (Alessandrini et al., 2012; Nocera et Cavallaro, 2017; Singh et al., 2020) that considered both the emissions produced during the usage of the vehicle and the one used for producing the energy and (ii) Life-Cycle Assessment that considers emissions related to the entire lifecycle of the product, process or activity (Siragusa et al., 2020, Melo and Baptista 2017; Fraselle et al., 2021).

Finally, the last pillar of sustainability, social sustainability, is considered. It emerges that this is the less assessed aspect as it is difficult to assess the objectivity of the results (Navarro et al, 2019; Sanz et al., 2018), mainly performed using surveys and qualitative methodologies (i.e., case study). The main aspect considered are traffic reduction, road safety and accident, noise and quality of life improvements (Pietrzak et al., 2021; Navarro et al., 2016; Villa et al., 2021). In most cases, the social aspect is evaluated from the citizen's viewpoint, but some papers attempt to evaluate the same from a logistics worker's perspective (de Mello et al., 2019).

An explicative framework, to graphically summarize the relationship between the leverages and evaluation methods is proposed. The following relationship emerged:

- Economic evaluations were mostly assessed when transportation means and stakeholders were considered
- All the leverages identified were assessed by means of environmental evaluations
- Lastly, social assessments were limited and performed when regulations and stakeholders were involved.

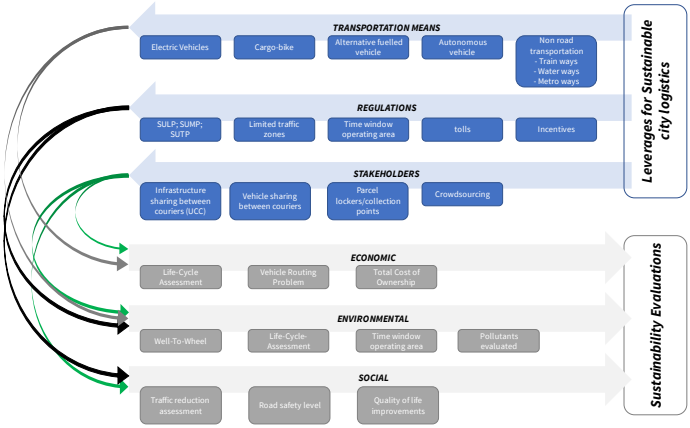

Figure 4. Graphical representation of the classification axes

4 Conclusion

Given the growing attention to sustainability in city logistics operations, a subject increasingly discussed due to the trends of e-commerce, sprawling cities and climate initiatives, this study aimed to yield an up-to-date review of the literature on these topics. The analysis focused on 64 selected papers, published between 2008 to 2021 in 37 different journals. Previous reviews were identified, however, they presented limitations in the time frame (i.e., the latest identified is from 2017), focus (i.e., attention only to operational aspects) or content (i.e., discussion on specific typologies of sustainable solutions). This review aims to overcome the previous limitations, providing a more extended knowledge of sustainable city logistics and implications.

Concerning the content, several areas of interest, all dealing with sustainability, were identified. Three main enablers for sustainable logistics were identified, namely transportation means, regulations and stakeholders. Sustainability was then classified according to the scholar and the main methodologies and theories to assess it was identified. More than 70 percent of the paper proposed combined methodologies where

economic and environmental sustainability were considered together using quantitative methodologies. Limited attention is given to social sustainability due to the complexity of collecting and evaluating the results (Navarro et al., 2019).

This paper has implications for both academics and practicians. From an academic perspective, the existing study aims to provide knowledge and a clearer classification of the existing solutions to develop sustainable city logistics. It is expected that this paper, due to the rising attention to sustainability from both academics and governments, can provide valuable knowledge on these topics.

Implications for practicians are proposed as well, with a clear view of the actual solution proposed and tested, the potential benefits as well as the interaction with stakeholders and regulations.

Despite the extant literature providing relevant material on city logistics subject, some themes are still not adequately addressed or considered. This is both a limitation for academics and practicians that can negatively affect the implementation of these solutions.

First, the extant literature focuses mainly on two specific solutions and a wide combination of them in various networks: electric vehicles and cargo bikes (de Mello Bandeira et al., 2019; Lin and Zhou, 2020; Nocera and Cavallaro, 2017). Other solution, such as shared use of public transportation, robots or drones, shows limited attention despite the great potentiality and the innovative aspects they carry (Alessandrini et al., 2012; Giret et al., 2018; Singh et al., 2020; Seghezzi and Mangiaracina, 2020). However, several factors (e.g., regulations, costs, coordination, operational complexity) limit the application of these solutions. Between the options previously proposed, the use of public transport, due to the already existing infrastructure, seems to be the most promising solution for a fast green transition, thanks to a reduced effort required for the implementation.

Second, actual regulations struggle to keep pace with the evolution of city logistics, leading to a mismatch between practicians and citizen needs (Fossheim and Andersen, 2017). A more inclusive regulatory plan, considering more logistics needs would lead to a more integrated and effective mobility plan.

Third, most of the actual research focuses on the economic and environmental assessment (Gervares et al., 2014; Patier and Browne, 2010), with little attention to social assessment that would consider some external factors. With integration with traditional evaluation, a more complete picture of the sustainability objective of a specific solution would be provided.

Finally, a possible limitation of this study should be identified. Despite the research methods being as much inclusive as possible, some studies may have been unintentionally omitted, thus excluding additional city logistics solutions. Despite that, the present review is able to provide a clear representation of the actual body of research on sustainability and city logistics.

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