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Uncovering freight curbside management effects on cities' sustainable development goals. A systematic literature review.

Juan Pablo Castrellon[a,b]*, Ivan Sanchez-Diaz[a]

[a]*Chalmers University of Technology, Vera Sandbergs Allé 8, Gothenburg 41296, Sweden*
[b]*Universidad Nacional de Colombia, Ciudad Universitaria, Bogota 111321, Colombia*

Abstract

Scarce urban space needs to be wisely managed to avoid cities' unsustainability. Overlooking freight activities in urban mobility policies leads to conflicting scenarios in public space use with negative consequences in congestion, pollution, crashes, and productivity losses. This paper aims at identifying the unsustainable effects of freight parking practices and the solutions reported in the literature to overcome them. A systematic literature review was conducted to collect quantitative evidence of curbside management impacts on sustainability. Key performance indicators from the 11th Sustainable Development Goal (SDG11) were linked to the 55 selected studies. Findings suggested positive impacts from four practices of freight curbside management and the need to include people-centred approaches in the design, implementation, and evaluation of public space policies.

Keywords: Curbside management; Sustainability; Sustainable development goals; Freight parking; Re-design of urban space for active mobility; Sustainable cities and communities.

1. Introduction

The increasing urbanisation, with over 80% of the European population residing in cities (Cherrett et al., 2012), and the decline of liveability—in terms of traffic and environmental conditions—in the last decades have augmented the pressure on public authorities, industry, civil society and, in general, citizens worldwide to define and implement practices that meet Sustainable Development Goals (SDG).

A critical urban challenge is the lack of space and how to use it to foster competitiveness for private transportation and goods movements without hampering environmental and social wellbeing. Urban planners designate areas along the curbside reserved explicitly for private cars parking, loading/unloading and/or service operations. This public space

* Corresponding author. Tel.: +46(0)-701-487-231
E-mail address: juanpabl@chalmers.se

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provision is the physical evidence of an urban dialogue that sometimes is ignored or disregarded, i.e., a back-and-forth conversation between inhabitants, businesses, and city planners (Smith, 2019). A recent approach aims at decreasing parking space for private cars in cities as a travel demand management strategy that reduces congestion, pollution, and fosters both active and mass transportation modes. For instance, Paris is removing up to half of its street parking by 2025. Amsterdam is removing 10.000 parking spots in the city centre. Stockholm is implementing a plan for dynamic curb parking spaces.

However, this approach cannot be implemented directly to freight and service vehicles as the demand and mode choice for these commercial vehicles have a completely different nature. This fact motivates the study of curbside policies, particularly for freight and private parking, and how a proper management and fluent dialogue among stakeholders can minimise adverse impacts on sustainability. Research on this topic is called to reflect on how to transform curbside conflicting conditions into more sustainable systems with innovative and creative solutions that make the most of the benefits of having dynamic, flexible-use, and self-adjusting spaces. This paper studies the different approaches documented in the literature for managing curbside for freight operations and summarizes their impacts on the SDG metrics. Specifically, this paper aims at understanding the link between the implementation of freight curbside management practices and the SDG metrics associated with urban sustainability, i.e., SDG11 – Sustainable cities and communities.

2. Background

In 1987, the Brundtland report launched one of the first definitions of sustainable development (SD) that remains relevant, stating that SD "(…) meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). This definition pointed out at three fundamental components to achieve SD: economic growth, social equality, and environmental protection. Aiming at addressing this definition in cities' contexts, several researchers and practitioners have called the attention to focus on the study and solutions for the challenges cities are facing nowadays regarding the quality of life, the local economy, transport and traffic management, environment, and interaction with government offices (Papachristou & Rosas-Casals, 2018; Węziak-Białowolska, 2016).

Unifying those challenges in a more strategic perspective, the United Nations included cities in the seventeen Sustainable Development Goals, focusing interventions on public space, mobility, health, energy, economic growth, infrastructure, and productivity (United Nations, 2017). For instance, the SDG11 – Sustainable cities and communities, promotes policies and actions that leverage universal access to safe, inclusive, and green public spaces.

SDG11 guides policymakers in coping with one of the most critical cities' sustainability issues, i.e., public space use. In essence, it measures the effectiveness of managing competing demands for public space for uses that deal with human needs of social interaction, mobility, access to supplies, activation, and a healthy environment. Aiming at linking public space management to SDG, Emanuel et al. (2020) have paraphrased the SD definition by inviting public space policies to move towards a fair allocation of urban space whereby "one person's mobility does not come at the expense of another's mobility in the present or future generations".

Cities worldwide are moving in that direction. Nowadays, mobility plans have a clear focus on more space for human interactions, promoting active and mass transportation modes, reducing congestion and pollution levels. However, they tend to overlook the distinct nature of demand and mode choice of freight deliveries compared to private cars (Malik et al., 2017). For example, commercial establishments are part of streets' activation strategies, but little attention has been paid to their demand for freight parking curbside space (Al-Turjman & Malekloo, 2019). Similarly, home deliveries are part of consumption trends that the pandemic has accelerated and that nowadays require special attention in terms of fair access (Sanchez-Diaz et al., 2021) and parking infrastructure to avoid curbside conflicts in neighbourhoods (Macário, 2021). Ignoring freight transport activities in policies and urban plans leads to improper conditions for people and businesses' provision of goods and services, resulting in congestion, pollution, and productivity loss issues. In the specific case of freight parking operations, limited space for parking and its misuse, e.g., double-parking or search for parking, is one of the main roots of cities' unsustainability (Mingardo et al., 2015).

2.1. Unsustainable impacts of freight parking

Freight transportation represents 20 to 30% of the total traffic in cities, yet it accounts for up to 60% of transport-related CO2 and PM emissions (Dablanc, 2007). The time a freight vehicle is parked represents more than 40% of the time it spends in a city (Sanchez-Diaz et al., 2020), and in some contexts, it is up to 80% (Fransoo et al., 2022). Cruising (search for parking) or double parking are the most common practices under scarcity scenarios of freight curbside allocation, with high negative impacts on urban sustainability. Besides environmental emissions, unsustainable effects of poor conditions for freight parking operations are also economic losses, congestion, noise, and intimidation of public space users due to vehicle size and safety risks. The authors summarized findings from several research publications that quantified the unsustainable effects of freight parking operations as follows:

- *Social impacts:* The lack of parking spaces conduces to cruising practices and sometimes the illegal use of the public space such as double parking or parking in banned zones. Both practices lead to traffic congestion, which negatively affects citizens' stress and, in general, city liveability. For instance, Kawamura et al. (2014) found that double parking is the third most important cause of nonrecurrent traffic congestion after construction projects and crashes. Shoup (2011) estimated that cruising for parking accounted for more than 30% of downtown traffic. Lopez et al. (2016) found that cruising for parking occurs in 70 – 80% of the last-mile deliveries in European cities. Seemingly, Roca-Riu et al. (2017) affirmed that illegal double parking occurred in up to 50% of the freight movements. The social implications of these impacts are evident in traffic delays and their associated consequences on citizens' health. In the case of the United States, illegal freight parking generates 476 million vehicle hours of delay each year (Wenneman et al., 2015). In Paris, the daily loss due to double parking accounted for 2.777 hours (Beziat, 2015). For the case of Athens (Greece), Kladeftiras & Antoniou (2013) concluded that eliminating double parking could reduce traffic delays by up to 33%. Besides delays, noise is another negative consequence of high traffic congestion. Kijewska et al. (2018) have documented the impacts of traffic noise on the quality of sleep, rest, and work.

- *Economic impacts:* Freight parking is part of the last-mile logistics operations, the last leg of supply chains aimed at meeting customers' demands. Cost estimations of this last leg differ from city to city and are conditioned by commodity type. The Council of Supply Chain Management Professionals estimated that last-mile deliveries represent 28% of the cost of the entire supply chain (Butrina et al., 2017). Gevaers et al. (2011) affirmed that last-mile deliveries can cost between 13% and 75% of the total logistics cost. Dablanc & Rodrigue (2017) concluded that due to the low levels of operational efficiency, last-mile operations are the weakest link of the supply chain, accounting for up to 50% of the total cost. Low payloads ratios –average load factor between 30-40%–, empty trips, deliveries fragmentation, congestion, searching for parking (cruising) are among the leading causes of these inefficiencies (de Marco et al., 2017).

For the specific case of freight parking operations, the economic consequences of cruising and illegal parking practices have been quantified in particular contexts. For instance, in New York (US), Holguín-Veras (2008) found that freight vehicles often are forced to park illegally with costly consequences due to parking fines, i.e., USD$500 to USD$1000 per truck per month. In the case of Toronto, freight vehicles incurred more than CAN$27 million in parking fines. (Wenneman et al., 2015).

Cruising for parking and double-parking add traffic volume to the city's congestion levels. According to researchers from the Harvard School of Public Health, congestion had an economic impact of USD$100 billion by 2020 (Fahim et al., 2021).

- *Environmental impacts:* Freight vehicles contribute to 15% of the GHG emissions in urban contexts (Hammami, 2020) and 50% of the particulate matter (PM) (de Marco et al., 2017). These impacts are directly related to the kilometres travelled, the technology of freight vehicles, and traffic conditions during urban logistics operations. High congestion levels and travel delays due to double parking and cruising for parking increase the negative impacts of freight parking operations on cities environment as shown by Iwan et al. (2018). The consequences of high levels of emissions are lethal for human life. The United Nations Environment Program (UNEP) estimates that around 7 million premature deaths are related to air pollution globally (Fahim et al., 2021).

Providing the proper conditions for freight vehicle parking can potentially reduce travel time, pollutant emissions as well as congestion levels (Comi et al., 2018). Given the relevance of freight parking impacts on urban sustainability, this paper studies how freight curbside management can make parking operations and delivery more efficient while lessening their unsustainable effects.

2.2. Freight curbside management

Freight parking operations are part of the microscopic level of the urban freight transport concept (Sanchez-Diaz & Castrellon, 2022). At this level, urban space is often provided for freight operations in the form of (un)loading zones, defined by Transport Departments as areas reserved for loading or unloading goods (Regal-Ludowieg et al., 2022). The set of decisions on these loading zones (LZ) is referred as freight curbside management.

The concept of freight curbside management has recently emerged in the academic literature (Olsson et al., 2019). It refers to strategic (long-term), tactical (mid-term), and operational (short-term) decisions that public and private actors make to enhance the efficiency and sustainability of freight parking operations at LZ (Castrellon & Sanchez-Diaz, 2022). Decisions about LZ can refer to the number, location, size, parking duration limits, monitoring technology, and enforcement, among others. (Castrellon et al., 2022) identified the following factors as determinants for successful freight curbside management: a) matching freight supply-demand of public space, b) knowledge and management of parking durations, c) enforcement capabilities, and d) data sharing strategies.

Several cities worldwide have implemented policies related to freight curbside management to improve traffic conditions and reduce the negative impacts of freight parking. Holguín-Veras et al. (2018) conducted a survey showing that 29.8% out of the 56 surveyed cities had implemented freight curbside management as part of their mobility plans. Practitioners, freight companies and society ranked high this infrastructure initiative as a solution for urban mobility issues. In de Marco et al. (2017), 35% of the 70 European cities considered in the study had implemented freight curbside management.

The effects of freight curbside management have been measured mainly via microsimulation and optimization tools, evaluating several performance measures. Butrina et al. (2017) proposed a set of performance measures according to the objectives of the curbside management decisions. This research adopted the curbside management factors presented in (Castrellon et al., 2022) and collected data about their impacts on the Butrina's performance measures referred to delivery time, cost, cruising for parking, occupancy levels, emissions, and parking violations. Hence, freight curbside management is linked to the SDG11 according to the extent it impacts the selected performance measures (Fig. 1).

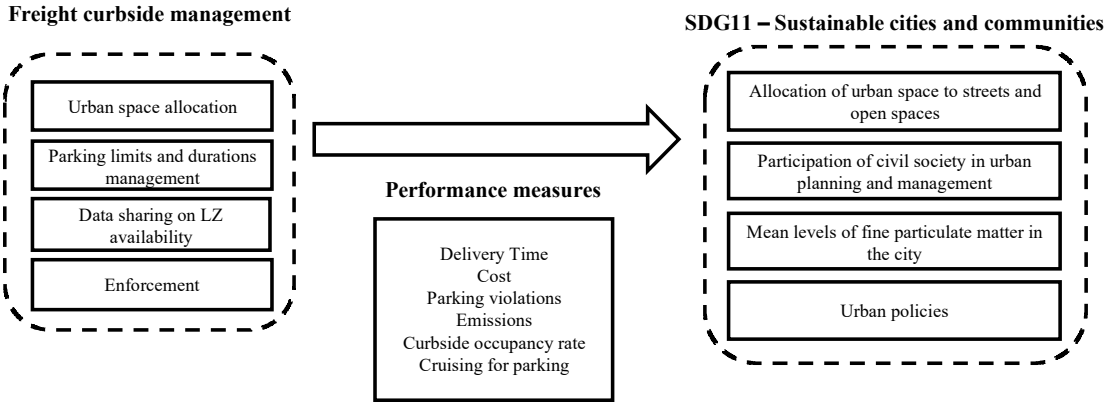

Fig. 1. Framework for assessing freight curbside management impacts on SDG11.

SDG11 metrics shown in Fig. 1 correspond to the United Nations framework that proposed four metrics for this goal, i.e., average global share of the urban area allocated to streets and open public spaces, participation of civil society in urban planning and management, mean levels of fine particulate matter, and development of urban public policies.

3. Method

Although several research publications have quantified the effects of curbside use on emissions, economic costs, and urban mobility, there is still a long path to understanding how freight curbside management contribute to the SDG.

Compilation of case-specific research findings can hint at the potential effect of freight curbside management, thus identifying future development fields for research and policy implementations. This research conducted a systematic literature review aimed at building a meta-analysis of reported curbside management effects on SDG11 metrics. The paper presents the first stage of a meta-analysis study by describing the systemic literature review and results from the data extraction process.

Meta-analysis is a technique for extracting quantitative data necessary to conduct a statistical combination of multiple studies (Xiao & Watson, 2017). The systematic literature review searched for a summary statistic, e.g., performance measures of freight curbside management, in each study to serve as the dependent variable. Since effect measures vary from one study to the other, authors followed the approach described by Ewing & Cervero (2010), who obtained studies statistics at comparable scales, e.g., elasticities or percentage of change, by either copying them from published studies if reported explicitly or calculating them from regression coefficients or performance evaluation tables. Then, data extraction considered the percentage of change in performance measures of freight curbside management factors and linked them to the SDG11 metrics. The research question that guided the study was: what are the effects of freight curbside management on sustainable development goals?

A systematic literature review was built upon a search query derived from the research question, i.e., (“freight parking” OR “loading zone” OR “loading bay”) AND ("curbside" OR "curb side" OR "kerbside" OR “street”) AND (“impact” OR “effect”) AND (“sustainability” OR "sustainable development" OR "environment") AND ("urban" OR "city"). To avoid sources of sample bias such as publication bias, authors used Google Scholar database for accessing grey literature, i.e., unpublished reports, thesis, preprints, and white papers. The first 980 results were available for being included in the sample out of the 2350 search results. Publications from Web of Science, ProQuest, and Scopus databases were also included. The search process was conducted in April 2022. Depuration of the first query results consisted of selecting studies based on information from the title and snippet. Only studies that contained the keywords connected coherently in aspects related to this research were selected.

The screening process deleted 138 duplicated results and filtered 357 records that fit the research interest. After applying the deletion and exclusion criteria shown in Fig 2., 55 records were included for data extraction. The list of references is available at https://dsw.chalmers.se/projects/d69106a2-6a4b-42d5-9a47-5185b9f7f621.

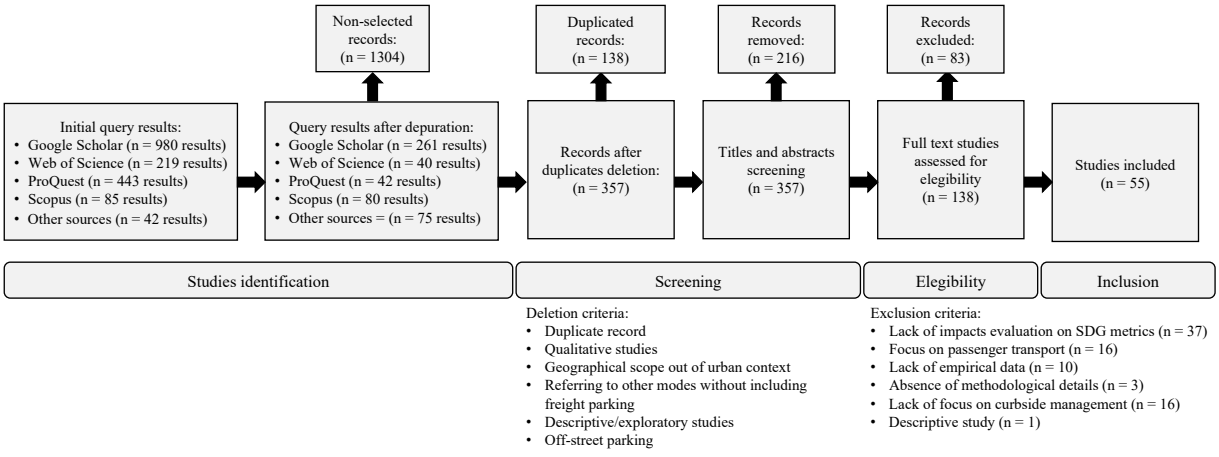

Fig. 2. Prisma diagram of the systematic literature review.

Papers selection was based on the possibility of accessing quantitative results of the performance measures shown in Fig. 1 when implementing freight curbside management. Besides the summary statistic, the authors collected information about the country, city and zone of study, data collection methods, and assessment tools, e.g., microsimulation and optimization. Performance measures were assigned to the corresponding SDG11 metrics based on each paper’s aim and practical implications.

4. Results and Discussions

Figure 3 presents a summary of the data extracted from 55 studies conducted in 158 cities from more than 60 countries worldwide since 2005. Results were grouped by freight curbside management factor and linked to the corresponding SDG11 metric based on the reported performance measures. The figure shows in parenthesis the number of studies that referred to the specified performance measure, SDG11 metric, and freight curbside management factor. For the cases when (N ≥ 2), figure 3 (left) shows the increasing (↑) or decreasing (↓) range of the performance measures change reported from the corresponding freight curbside management factor. Figure 3 (right) shows the number of studies linked to each SDG11 metric. Based on the evaluated performance measures and practical implications, one study could fall into more than one classification. Results discussions are grouped by SDG11 metric.

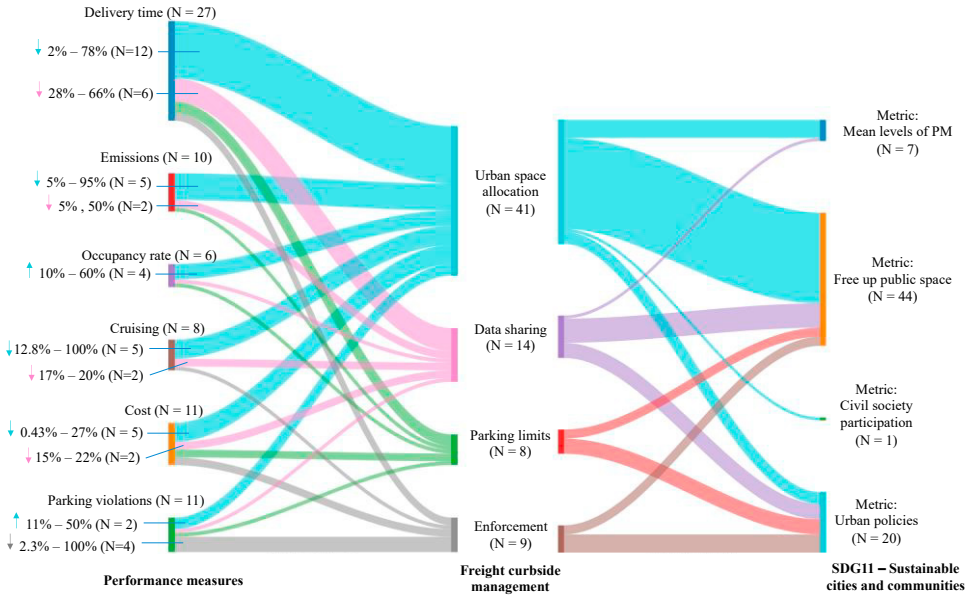

Fig. 3. Results from the data extraction process of the systematic literature review.

Mean levels of the particulate matter in the city: Seven studies quantified the impact of freight curbside management on emissions. This number is low compared to other SDG11 metrics, e.g., allocation of urban space, which makes evident the need for more research quantifying the environmental impacts of curbside initiatives. Reports found that urban space allocation and data sharing implementations generate pollutant reductions ranging from 5% to 95%. Research findings suggest that increasing public space for parking and information about its occupation levels would decrease GHG emissions and local emissions due to reduced traffic levels achieved with less cruising and double parking. Also, the promotion of modal shifts, e.g., cargo bikes, electric trucks, and increased transport and fuel efficiency, are expected outcomes of the enhanced management of parking and delivery practices.

Allocation of urban space to streets and open spaces: Most of the contributions, i.e., 80% of the sample, fell in this category due to the evident alignment between this SDG11 metric and the core function of city authorities of public space management. Findings showed how public authorities must face dilemmas among several options for curbside uses according to user demands, e.g., bike lanes, parking spaces for private vehicles, public transport stops, service times, and loading zones. Evaluations concluded that effective management of space for freight could free up space for other users (up to 70% in one of the studies) and most of the time, reduce cruising for parking (↓ 12.8% – 100%), and cost (up to 27%) through allocation of LZ, enforcement, data sharing, and parking limits initiatives.

The most popular performance evaluation was delivery time. Improvements ranged between 2% and 78%. Data sharing related to parking availability or pre-booking systems reported reductions between 28 and 66%. However, it was a common finding that equilibrium in the space allocation and enforcement are challenges in the management of parking spaces as they cannot improve the system further or negatively impact the system.

Urban policies: This metric was assessed based on the paper's aim of including public policies and regulations whereby urban system improvements could be achieved. 60% of the sample falling in this category reported policy evaluations regarding delivery time and cost. A generalized finding related to reductions in delivery times was evidenced by data sharing, enforcement, duration limits and urban space allocation policies. Research reports concurred that technology adoption improved public and private decision-making processes and reduced the last-mile distribution cost by preventing cruising for parking and illegal parking. Introducing data-driven policies for managing curbside space also opens the possibility of introducing dynamic curbside management. This means a wide array of opportunities for new business models and innovations, e.g., on-street lockers, charging stations for e-vehicles, parking for scooters and new dynamic commercial or recreational spaces. Few studies (N = 6) reported measures on occupancy rate, although its importance for public authorities. Data collection improvements in cruising for parking studies could revert this situation.

Participation of civil society in urban planning policies: Only one study matched civil society's involvement goal in the definition of parking policies by considering different stakeholders' perspectives. This finding represents an opportunity for future research whereby citizens' perceptions and interactions with freight parking activities can be considered in the formulation/evaluation of policies. By understanding users' needs for public space and assessing conflicting conditions, public policies could better suit stakeholders' interests, reallocate rights-of-way, and strive for fairer decisions under people-centred curbside solutions.

5. Conclusions and limitations

This research investigated the effects of freight curbside management initiatives on metrics of a sustainable development goal. Findings suggested that actions in data sharing, enforcement, parking limits and allocation of public space contributed to the goals of emissions reduction, congestion management, efficient delivery time, and equitable access. However, there are some trade-offs between the different initiatives.

The main contribution of this research is to pinpoint the contribution of freight curbside management to the UN Sustainability Development Goals of achieving universal access to safe, inclusive, and green public spaces, i.e., SDG11. Outputs from the systematic literature review can foster reflection of urban mobility stakeholders about policies and initiatives implementation that include freight operations while providing open public space for all the citizens, free of stress, noise, pollution, and traffic hazards. In essence, knowledge on enhanced management of the curbside space can help in designing actions that positively impact SDG11 metrics. Nonetheless, more research is needed on people-centred design, implementation, and evaluation of freight curbside management practices by understanding conflicting conditions, urban space demands and social equilibriums.

Future works could develop meta-analysis methods of the collected statistics and propose techniques for performance measures standardization given the multiple scales and metrics found.

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