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Sustainable Last Mile in E-commerce: A Literature Review

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Abstract. The interest in last mile, considered the most important factor in e-commerce, has grown as online sales have increased. This interest has been reflected in the literature. However, there is not an overview of this whole research field. The purpose of this article is to provide a complete view of the topics in the field of sustainable last mile in e-commerce. To achieve this, a literature review was carried out in which 58 articles were identified. Afterwards, these papers were classified according to their topic and research method, providing a complete vision of the field of analysis. As a result, 11 topics were identified, the most studied being the *Quantification of the effect on sustainability of the last mile in e-commerce*. In addition, four future lines for research were established.

Keywords: Last mile, sustainability, e-commerce, literature review.

1 Objectives and Methodology

E-commerce is undergoing exponential growth, which means the last mile (transporting online orders from the last point of contact with the retailers to the point where they are consumed) has become the most important factor in online sales [1]. This importance stems from it being the only point of contact between the e-retailer and the final customer. However, it is also important because of its disproportionate impact on online logistics costs and the environmental and social damage caused by transportation [2].

This importance has been reflected in the literature, where research into sustainable design in this operation has started to proliferate, including the appearance of literature reviews on this subject. However, these works have focused on analyzing a specific problem (e.g, electric vehicles), without differentiating the methodologies employed to tackle it, or they have compiled the issues dealt within the last mile from a specific perspective (e.g., stakeholders). There is not, therefore, an overview of this whole research field.

Thus, this paper aims to provide a literature review on the sustainable last mile in e-commerce. By classifying publications according to the research method adopted, it will in turn provide a clear view of the topics dealt with in the articles published to date and the research lines for the future.

In order to carry out this study, the authors opted, due to its capacity to identify the topics covered in the articles, for a systematic review of the literature based on three stages (planning, implementation, and presentation of results), a method followed by Mangiaracina et al. [3]. In the first stage, the scope of the research was defined as being sustainable management of the last mile in e-commerce. On the basis of this scope, Scopus and Web of Science were searched using the following concepts: "last-mile", "e-commerce" and "sustainability". A total of 576 papers were identified. After examining their titles and abstracts, a refined list of 58 articles was generated. The full list is available on request from the authors¹. Once the articles were selected, they were analyzed and the results presented. To do so, the general characteristics of the collected articles were identified and the publications were classified according to their content and the research method used.

2 Results

Regarding the general characteristics of the papers under review, it is important to point out that the first article on the sustainable last mile in e-commerce was published in 2014 although no further papers were published on the topic until 2017. Four publications were identified between 2017 and 2018 (7% of the total). However, interest in the subject grew from 2019, by which time a total of 11 studies had appeared (pushing the total thus far to 19%). A total of 42 papers were published between 2020 and 2022—72% of the total—with 2021 having the greatest tally at 26 articles, or 45% of the total.

The 58 papers considered in this literature review were published in 29 journals. Over half of the papers studied came from just six publications (i.e., *Sustainability*, *International Journal of Logistics Research and Applications*, *Sustainable Cities and Society*, *Transportation Research Part D: Transport and Environment*, *Journal of Cleaner Production*, and *International Journal of Sustainable Transportation*).

The selected articles were classified based on their decision-making and sustainability approach. First, 23 papers belong to the strategic level, 18 publications analyze the sustainable last mile from a tactical level, and the remaining 17 articles used an operational focus. Second, 30 publications analyzed the environmental pillar of sustainability, 18 papers focused on the economic pillar, 3 articles on the social pillar, and 7 publications jointly analyzed the three pillars of sustainability.

¹ Due to page limits, it is not possible to include the full list in this paper.

For the study of the topics, the papers were classified according to their research method. The methods were grouped into the following: quantitative models (analytical models and simulations), conceptual models (frameworks and general classifications), and empirical models (case studies, interviews, and surveys) [3].

Twenty-five papers were identified that were based on quantitative models. In this sense, 13 articles focused on quantifying the effect on sustainability of the last mile in e-commerce and the different design alternatives. Thus, de Mello Bandeira et al. [4] created a model that allowed calculation of the effect on the three pillars of sustainability (economic, environmental, and social) of three different delivery strategies (traditional intermodal distribution, alternative intermodal distributions, and distribution by electric tricycle). Another example is by Wang et al. [5], whose study analyzed the sustainable deployment of different last-mile strategies in e-commerce on the basis of different criteria. The work determined that the criteria with the most impact are delivery time, order fulfillment, decarbonization, convenience of payment, and real-time tracking systems. Finally, Siragusa et al. [6] compared the effect on the economic and environmental pillars of sustainability's of electric vans and traditionally fueled vans, concluding the superiority of the former both economically (after the eighth year) and environmentally.

At the same time, ten of the papers in this study are based on the analysis of models or simulations for alternatives aimed at improving last-mile sustainability. Thus, Leyerer et al. [7] developed a model to optimize a network of refrigerated lockers, where packages are deposited to be collected by customers or delivered to homes by electric bicycles. Another example is the paper by Simoni et al. [8], in which a delivery service based on crowdsourcing is simulated, identifying the crucial operational aspects for the sustainability of this strategy (length of detours, parking behavior, and daily traffic variations).

The final two articles analyzed the response of customers to price changes in sustainable deliveries and explored specific factors that influence the sustainability of last-mile deliveries in rural areas. In the latter, Jiang et al. [9] highlighted four basic factors (convenience of returning goods, integrity of goods, advance reservation of goods pickup, and delivery costs).

A total of 14 articles were selected on the basis of conceptual models. Several papers are worthy of note. First Olsson et al. [10], with a study that provided a classifying framework for the last mile, comprising five components (logistics, distribution, fulfillment, transport, and delivery). At the same time, Guo et al. [11] analyzed the effectiveness of crowdsourced delivery when mitigating last-mile sustainability issues. To do this they created a framework based on five basic principles (small-scale pilot, community-based approach, low added network complexity, low additional investment level, and co-functionality). Another example is by Halldorsson and Wehner [12]. Their study created a framework that establishes the basic parameters (distribution structure, transportation execution, and household logistics capability) that should be taken into account when it comes to creating energy-efficient last-mile strategies in e-commerce.

Nineteen articles with empirical models were identified. First, research that focuses on determining how the sustainable last mile ought to be structured should be highlighted. In this regard, Mkansi and Nsakanda [13] opted to study the benefits of using an offline logistics strategy (mainly stores) as the starting point for the creation of sustainable last-mile strategies for e-commerce.

Ten of the papers analyzed consumer behavior towards different sustainable last-mile strategies. In this regard, Rai et al. [2] analyzed changes in consumer behavior in choosing delivery type, according to the information on sustainability received. By offering free deliveries and returns, consumers were willing to collect their orders themselves or wait longer for them to arrive. For their part, Caspersen and Navrud [14] analyzed the consumer response to five sustainable design factors for the last mile (delivery time, delays, information, CO2 emissions, and particulate matter).

At the same time, four of the articles under study analyzed the benefits for last-mile sustainability of the use of different novel strategies (electric vehicles, drones, cargo bikes, mobile depot, or crowd logistics). An example is the study by Serrano-Hernandez et al. [15], which analyzed the state of the last mile in cities, highlighting the preference for the use of drones or bicycles for city-center deliveries in order to reduce social and environmental problems.

Finally, two of the selected articles focus on analyzing the role of two main stakeholders: delivery drivers and institutions. In this regard, de Kervenoael et al. [16] studied the importance of the delivery drivers as a key factor in attaining a sustainable last mile, concluding that collaboration with independent workers can increase the sustainability of this operation.

Table 1 gives a summary of the topics identified in the articles published within the scope of the sustainable last mile in e-commerce.

Table 1. Summary of topics covered within the scope of the sustainable last mile in e-commerce.

Research Method	Topic	Articles mentioned	Total number of articles	%
<i>Quantitative model</i>	1. Quantification of the effect on sustainability of the last mile in e-commerce	[4], [5], [6]	13	22
	2. Modeling or simulation of different sustainable alternatives for the last mile in e-commerce	[7], [8]	10	17
	3. Customer response to price changes in sustainable deliveries		1	2
	4. Study of the relationship of factors influencing the sustainability of last-mile deliveries in rural areas	[9]	1	2
<i>Conceptual model</i>	5. Classification framework for the sustainable last mile in e-commerce	[10]	6	10
	6. Framework allowing analysis of the effectiveness of different strategies to mitigate sustainability problems in the last mile	[11]	3	5
	7. Framework that serves as a design tool for sustainable last-mile strategies	[12]	5	9
<i>Empirical model</i>	8. Determination of how the sustainable last mile should be structured	[13]	3	5
	9. Analysis of consumer behavior in the face of different sustainable strategies for e-commerce deliveries	[2], [14], [17]	10	17
	10. Study of the benefits to last-mile sustainability of using different novel strategies	[15]	4	7
	11. Analysis of the role of stakeholders in the sustainable last mile	[16]	2	3

3 Conclusions and Future Lines for Research

This systematic literature review on sustainable management of the last mile in e-commerce reveals an area of research that is limited but in which there has been

growing interest over recent years. After analysis of the contents of the 58 articles, 11 predominating topics have been identified (see Table 1).

An increased concern for the high impact of last mile on sustainability [2] prompted research on three specific topics (from Table 1, number 1, followed by number 6 and 4). Researchers began the study of these topics by analyzing the total cost of deliveries, as well as the emissions of pollutant gases (e.g., [6]). Over the years, other implications have begun to be analyzed, such as level of service, congestion, fuel consumption or safety and accidents (e.g., [4]). However, the analysis of cost and emissions continues to be the predominant approach in this research, with the analysis of the rest of the impacts being minimal in comparison. In this sense, there is a lack of a global vision of the impact of the last mile in e-commerce on the three pillars of sustainability, mainly from the social point of view.

When defining and structuring the last mile (topics number 5 and 8), research has focused on determining which elements must be taken into account, in addition to defining possible structures to be used when designing a sustainable last mile in e-commerce (e.g., [13, 10]). However, this research again lacks the integration of the three pillars of sustainability in last-mile strategies.

Regarding the topics that study new sustainable alternatives (number 2, 7 and 10), articles discussed crowdsourcing, collection and delivery points, drones, city hubs, cargo bikes or AGVs, among others, studying their applicability and benefits, mostly through geographically limited case studies (e.g., [8, 15]). The lack of analysis on the possibility of large-scale implementation (different geographical circumstances and characteristics) of some of these alternatives (for example, AGVs, drones and crowdsourcing), as well as their implications on security and legislation, is preventing their mass implementation in last-mile deliveries.

Finally, the role of stakeholders in sustainable last mile (topics number 3, 9 and 11) is unevenly analyzed. On the one hand, multiple authors have extensively studied the role of customers, determining, among others, the willingness of consumers to use sustainable alternatives such as AGVs (e.g., [17]). However, there is a lack of analysis on the factors that can change this behavior towards these alternatives (e.g., [2]). On the other hand, regarding the rest of stakeholders (local governments, residents, transport companies) only two articles have addressed this issue, analyzing the need for collaboration between them (e.g., [16]). Thus, this limitation is reflected in the lack of research on the challenges and benefits of establishing collaborative relationships between all stakeholders.

In relation to the above and with regard to future lines for research, although many topics have been studied concerning the sustainable last mile in e-commerce, there are still some aspects that should be examined in more detail, particularly from the empirical and conceptual standpoint. Primarily, the three pillars of sustainability should be included in order to investigate any effects on them and to take any necessary steps. On the basis of the findings, there is also a need to offer a holistic view on sustainable last-mile design and structure all the design factors taken into account when it comes to creating sustainable strategies. There is also a need, through the creation of a system of metrics, to evaluate the current level of sustainability of last-

mile strategies employed by e-retailers, taking into account the three pillars of sustainability. Finally, future studies should focus on establishing which sustainable last-mile design is the most suitable, depending on the features of each online retailer, the preferences of its customers and the relationship with its stakeholders.

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