Chapter 096

The last-mile delivery process from a life cycle perspective

**Abstract.** More consumers shop online through their favorite channels and e-commerce sales are growing rapidly. Most of the Italian digital shoppers make, on average, at least one online purchase per month. Companies are called to face new challenges, one of these is the greater complexity of logistics activities, considering delivery option one of the most important aspects of online shopping. Pick up points, drop off mode, parcel lockers and door-to-door delivery mode will become the most important last-mile delivery solutions to serve the final customers. However, this phenomenon also generates environmental burdens related to emissions, traffic congestion and air quality.

The objective of this study is to explore what solutions can reduce the impacts associated with the last-mile delivery process from a life cycle perspective. This study presents a review based on 20 articles. A descriptive analysis is carried out to evaluate the main features of the articles; then the articles are classified considering the solutions analyzed.

This study highlights that the last-mile process is still underexplored from a life cycle perspective and presents the factors that can help directing towards its decarbonization.

**Keywords.** Last-mile; delivery; life cycle

**N.1 Introduction**

The years 2020 and 2021 have been exceptional due to the COVID-19 pandemic and health and safety measures boosted online shopping across Europe (Lone et al., 2021). This phenomenon is witnessed worldwide. According to Eurostat[[1]](#footnote-1), the share of e-shoppers among internet users is growing, with the highest proportions found in the youngest age group 16-24, closely followed by the age group 25-54. As revealed by a survey carried out in March 2021[[2]](#footnote-2), most Italian digital shoppers make, on average, at least one online purchase per month. The advantages of online shopping include lower prices, convenience of home delivery, free/low-cost shipping, price comparison, fast shipping, discounts, more products options and also safety[[3]](#footnote-3). One of its main characteristics is the territorial dispersion of customers: the customers usually order small quantities of goods, but they do it relatively often and in many cases remain outside of their homes. A parcel delivery to a recipient’s address generates costs of customer service and greater environmental pollution (Moroz and Polkowski 2016). The debate concerning the environmental impacts of online shopping, compared with traditional one is also growing (Ha et al., 2022). Even if e-commerce companies often claim the benefits of their online operations, these benefits are difficult to assess because of the great complexity of this phenomenon (Rizet et al., 2016). Innovative and viable last-mile delivery solutions include parcel lockers, crowdsourcing logistics, mapping the consumer presence at home and dynamic pricing policies (Mangiaracina et al., 2019). However, little is known about consumers’ preferences for environmentally friendly last-mile deliveries, although freight operators are noticing an increased consumer interest in sustainable deliveries (Caspersen et al., 2021). Despite its importance, the knowledge about the environmental burdens of last-mile delivery is still limited and the academic community is starting to perceive the need to extend the knowledge from a sustainability perspective (Ha et al., 2022). The feasibility of strategies in environmental terms is key to ensuring a sustainable performance. The life cycle thinking can help go beyond the traditional focus to include environmental, social and economic impacts of a product over its entire life cycle. Life Cycle Assessment (LCA) and Carbon Footprint (CF) are the main operative tools of the life cycle thinking and they are recognized by the practitioners and researchers worldwide (Petit-Boix et al., 2017). In this context, the aim of this paper is to provide a review of the literature on the application of life cycle tools to last-mile deliveries to explore what solutions can reduce the impacts associated with the last-mile delivery process from a life cycle perspective.

**N.2 Materials and methods**

In line with the objective, this work addresses the following two questions:

* RQ1: What are the aspects of the last-mile process explored with a life cycle perspective?
* RQ2: What solutions may reduce the environmental impacts associated with the last-mile process from a life cycle perspective?

To answer the above questions, a systematic literature review is conducted to synthesize and compare the empirical evidences, in line with Snyder (2019). The research is performed adapting the framework proposed by Ha et al. (2022) which address the sustainability aspect in the last-mile delivery literature and following the steps suggested by Durach et al. (2017).

***N.2.1 Literature search***

The unit of analysis is defined as a single scientific paper published in journals, books or conference proceedings. The literature search is developed as follows.

*Papers collection.* A search by keywords is performed in ISI Web of Knowledge with a time horizon from 1985 to 2022. The keywords are selected and combined to investigate the papers whose contents deal with the focus of our study. The resulting combination of keywords is ("last mile" OR "last-mile") + (("LCA" OR "Life Cycle Assessment" OR "Life Cycle Analysis") OR "Carbon Footprint"). Only articles written in English are considered.

*Papers selection.* From the previous step, 28 papers are collected which are then filtered. Only papers including consideration of last-mile process and referring or applying environmental life cycle evaluations are included. Finally, 20 papers are selected for an in-depth examination.

***N.2.2 Literature analysis***

A descriptive analysis of the selected papers is performed to evaluate the papers' main characteristics, namely year of publication, name of journal or conference, affiliation of the first author, and country of focus. The analysis of the content is based on the research questions and the framework proposed by Ha et al. (2022), the following contents are addressed.

* Aspects of last-mile process explored (RQ1): last-mile dimension, namely delivery, transportation, distributions and logistics; themes, namely operational optimization, emerging trends and technologies, performance management, supply chain structures and policy; last-mile solution; last-mile actor, namely delivery service or consumers.
* Solutions that may reduce the environmental impact (RQ2): environmental challenges addressed, such as cold storage, fuel consumption, air pollution, noise, greenhouse gases (GHG) emissions and life cycle application.

**N.3 Results and discussions**

The results are presented based on the main characteristics of the articles and on the analyzed content.

***N.3.1 Main characteristics of the articles***

According to the analysis of the characteristics of the papers, the following results are obtained. With reference to the time horizon, the first two contributions date back to 2014; 7 papers were published in 2021, showing that the interest has been quite limited for more than a decade but is growing. The journal with the main contributions is the Journal of Cleaner Production, followed by Sustainability. The country with the most contribution is the USA (7) followed by Germany (5).

***N.3.2 Review based on contents***

*Review of the aspects of last-mile process explored (RQ1)*. The literature analysis highlighted that the last-mile process is investigated from different points of view (Table 1). With reference to the themes, all of the studies explore the performance management of the last-mile process from an environmental point of view and 4 studies also investigate economic performance. Another theme often addressed is operational optimization, especially with reference to transport planning. The last-mile dimension more investigated is the last-mile transport, with 16 papers concentrating on moving goods from an hub to the final destination through different transportation modes, followed by last-mile distribution, with 3 papers concentrating on moving goods through different channels. 3 papers explore innovative solutions, concentrating on drones, robots and pick-up points. The main solutions explored are traditional transportation modes with diesel vehicles (11 papers) and electric vehicles (9 papers) which are often compared. The majority of the papers analyzed (15) explore the last-mile process performed by the delivery service, while 7 explore the case in which the last-mile is performed by the consumer. 2 papers analyzed the last-mile in relation to public transportation, thus with different scope.

Table 1. Aspects of “last-mile” process explored

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Themes | N. articles | Dimension | N. articles | Solutions | N. articles |
| Operational optimization | 8 | Delivery | 1 | Innovative solutions | 3 |
| Emerging trends and technologies | 2 | Transport | 16 | Electric vehicles | 9 |
| Performance management | 20 | Distribution | 3 | Traditional vehicles | 11 |
| Supply chain structures | 2 | Logistics | 2 | Cargo-bikes | 2 |
| Policy | 2 |  |  | Walking (on foot) | 3 |
|  |  |  |  | Public transport | 2 |

*Review of solutions that may reduce the environmental impact (RQ2)*. The main environmental challenge assessed is the GHG emissions, followed by air pollution and by analyzing other environmental categories such as acidification. Cold storage and fuel depletion are investigated just by 1 paper, respectively. Among the analyzed papers, CF calculations are performed by 7 papers and a calculation of CO2 emission is presented by 1 paper. LCA is adopted by 9 papers assessing the environmental impact of last-mile on other aspects beyond climate change. 3 papers highlight the importance of life cycle perspective, without quantitative applications.

***N.3.3 Solutions and challenges***

The solutions and the challenges revealed through this analysis can be distinguished as follows.

*Transport mode.* Compared to traditional vehicles, the adoption of electric vehicles is associated with an environmental impact reduction for global warming, photochemical smog formation and acidification. However, the use of electric vehicles increases the particulate matter emissions compared to diesel vehicles due to the carbon intensity of the national power system, showing that their environmental performance in closely related to the sources of the energy mix (Croci et al., 2021). Light electric vehicles facilitate a reduction in global warming potential and other environmental impacts related to specific transport performance due to their lightweight construction. Innovative technological solutions, as drones and automated vehicles, can help reduce the environmental impact.

*Distribution*. Siting urban points and route planning can help reduce the environmental impact; however, conflicting results can be obtained in combination with different transportation modes also considering the cases of cold transportation. Supporting neighborhood stores could limit the impacts.

*Logistics*. The type and routing of van deliveries, the packaging used, the energy efficiency of shop and center operations are significant aspects to consider. Service delivery can help reduce the environmental impact compared to consumer shopping trips, but it is dependent on the number of items, the drop density, the width of delivery windows, the failed deliveries and the nature of the return operation. Encouraging consumers to reduce complementary shopping trips and maximize the number of items per delivery can help reduce the environmental impact. The nature of the consumer's behavior in terms of travel, choice of e-fulfilment method and basket size can affect the environmental sustainability of last-mile process. The influence of consumer choices is considerable and mapping consumer behavior can help developing sustainability strategies.

**N.4 Conclusions and future perspectives**

In this study 20 papers, including studies published in scientific literature and conference papers, were analyzed. They were categorized based on their characteristics, such as year of publication, source and geographical scope, and based on their content. First, the aspects related to the last-mile process were explored, namely themes, dimensions, solutions and actors; secondly, the solutions that may reduce the environmental impacts were analyzed, highlighting the environmental challenges addressed and the life cycle perspective used. These solutions are electric vehicles, the optimization of siting points and route planning, the optimization of the packaging used, the energy efficiency of center operations and finally encouraging consumers to reduce shopping trips and maximize the number of items. This literature review revealed many aspects of the last-mile process but some elements should be further analyzed. Innovative solutions are still under-explored and even if different studies highlight the central role of the consumer (i.e. Castillo et al., 2022; Merkert et al., 2022, Seghezzi et al., 2022), there is a limited interest in mapping and using real data about consumer behavior in life cycle applications.

# References and Citations

Caspersen, E., Navrud, S., Bengtsson, J., 2021. Act locally? Are female online shoppers willing to pay to reduce the carbon footprint of last mile deliveries? International Journal of Sustainable Transportation 1–15.

Castillo, V. E., Bell, J. E., Mollenkopf, D. A., Stank, T. P., 2022. Hybrid last mile delivery fleets with crowdsourcing: A systems view of managing the cost‐service trade‐off. Journal of Business Logistics, 43, 36-61.

Croci, E., Donelli, M., Colelli, F., 2021. An LCA comparison of last-mile distribution logistics scenarios in Milan and Turin municipalities. Case Studies on Transport Policy 9, 181–190.

Durach, C.F., Kembro, J., Wieland, A., 2017. A new paradigm for systematic literature reviews in supply chain management. Journal of Supply Chain Management, 53, 67–85.

Ha, N.T., Akbari, M., Au, B., 2022. Last mile delivery in logistics and supply chain management: a bibliometric analysis and future directions.

Lone, S., Harboul, N. & Weltevreden, J.W.J., 2021. 2021 European E-commerce Report. Amsterdam/Brussels: Amsterdam University of Applied Sciences & Ecommerce Europe.

Mangiaracina, R., Perego, A., Seghezzi, A., Tumino, A., 2019. Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review.

Merkert, R., Bliemer, M. C., Fayyaz, M., 2022. Consumer preferences for innovative and traditional last-mile parcel delivery. International Journal of Physical Distribution & Logistics Management, 52, 261-284.

Moroz, M., Polkowski, Z., 2016. The Last Mile Issue and Urban Logistics: Choosing Parcel Machines in the Context of the Ecological Attitudes of the Y Generation Consumers Purchasing Online. Transportation Research Procedia 16, 378–393.

Petit-Boix, A., Llorach-Massana, P., Sanjuan-Delmás, D., Sierra-Pérez, J., Vinyes, E., Gabarrell, X., Rieradevall, J., Sanyé-Mengual, E., 2017. Application of life cycle thinking towards sustainable cities: A review. Journal of Cleaner Production 166, 939–951.

Rizet, C., Cornélis, E., Browne, M., Léonardi, J., 2010. GHG emissions of supply chains from different retail systems in Europe. Procedia - Social and Behavioral Sciences 2, 6154–6164.

Seghezzi, A., Siragusa, C., & Mangiaracina, R., 2022. Parcel lockers vs. home delivery: a model to compare last-mile delivery cost in urban and rural areas. International Journal of Physical Distribution & Logistics Management.

Snyder, H., 2019. Literature review as a research methodology: An overview and guidelines. Journal of Business Research 104, 333-339.

1. Eurostat, 2022. E-commerce\_statistics\_for\_individuals. Retrieved May 20, 2022, from <https://ec.europa.eu/eurostat/statistics-explained/index.php?title=E-commerce_statistics_for_individuals#E-shopping_from_other_EU_countries> [↑](#footnote-ref-1)
2. Idealo, 2021. Il report annuale di Idealo sull’e-commerce italiano. May 2021, Berlino. Retrieved May 20, 2022 from https://www.idealo.it/magazine/e-commerce/e-commerce-italia-report-2021-idealo. [↑](#footnote-ref-2)
3. Jungle Scout, 2022. Consumer trends report. Retrieved May 20, 2022, from https://www.junglescout.com/wp-content/uploads/2022/03/Jungle-Scout-Consumer-Trends-Report-Q1-2022.pdf [↑](#footnote-ref-3)