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*Review*

# The Last-Mile Delivery of Heavy, Bulky, Oversized Products: Literature Review and Research Agenda

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**Abstract:** *Background*: Last-mile delivery (LMD) is a challenging and costly supply chain process that involves direct customer interaction. In a recent study by the World Economic Forum, it was emphasized that last-mile logistics is an emerging research area. In particular, the European Commission Directorate General for Energy and Transport provides guidelines for abnormal road transport, such as heavy, bulky, and oversized (HBO) products. In the last few years, many research articles have been published on the topic of LMD. Several literature review studies from the perspective of different stakeholders have also been published. The delivery of HBO products is more challenging in many ways compared to parcel delivery. Although HBO products yield the most profitable sales, the LMD of HBOs is less studied compared to parcel deliveries. *Methods*: This research employed a descriptive review method to scan 195 published articles and reports related to LMD and HBOs. *Results*: Our results identified the challenges in the field and identified the need for separate approaches for different customer segments, such as rural and urban customers, as well as older and younger customers, when formulating delivery strategies. *Conclusions*: This paper highlights the research gap in this field by using a descriptive literature review methodology and presents academic contributions available so far, as well as challenges for further research.

**Keywords:** logistics; last-mile delivery; heavy; bulky; and oversized products; literature review



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## 1. Introduction

The home delivery of goods, especially heavy, bulky, and oversized (HBO) products, such as recreational and exercise equipment, furniture, and appliances, is at an all-time high. Sales of these products are only considered complete when the customers are completely satisfied with the delivery to the final destination and installation at the place of their choice [1,2]. Last-mile delivery is a crucial aspect of the supply chain, playing a significant role in customer satisfaction and the success of a business. As more consumers shift to online shopping, companies have increasingly been focusing on enhancing the final leg of delivery to meet growing customer expectations. During the pandemic, 64% of Americans bought oversized items online, such as furniture and exercise equipment. Among them, 73% continued purchasing these items online at the same or higher frequency as they did before the COVID-19 pandemic [3].

Last-mile delivery (LMD) is the final step in the delivery process, where a parcel is transported from a hub to its ultimate destination [4]. According to a recent report, the online market for heavy-goods order delivery in 2020 was valued at USD 11.8 billion and was shown to be experiencing a yearly growth rate of 18% [5]. Today, LMD is characterized by "fast delivery, precise order tracking, security, and convenience that requires having people with the right skill sets to manage the rigors of the demanding delivery of big and bulky products" [6]. Furthermore, according to a recent report, last-mile deliveries account

for over 41% of the overall supply chain costs [7]. The same report also mentioned that customers are "dissatisfied" with the present state of delivery services, complaining about the cost of delivery, late delivery, and not being able to receive same-day delivery. This report also mentioned that retailers who provide great LMD service will reap significant benefits.

In light of growing e-commerce, the rising population in cities, customer requests for fast, on-time, and clean delivery, and concerns about the ongoing climate crisis, there is significant pressure on logistic providers to improve delivery processes. Innovative delivery solutions utilizing novel technology and business concepts are essential for maintaining customer satisfaction while ensuring sustainable and cost-efficient deliveries [2,8,9]. In a recent report by eMarketer, it was emphasized that "as a share of the total cost of shipping, last-mile delivery costs are substantial—comprising 53% overall [10]. And with the growing ubiquitousness of 'free shipping', customers are less willing to foot a delivery fee, forcing retailers and logistics partners to shoulder the cost. As such, it has become the first place they are looking to implement innovative technologies and drive process improvements".

In spite of its growing share in e-commerce, the LMD of HBO products is an under-researched area. This paper aimed to help fill this gap by identifying challenges and complexities in this field, as well as draw scholarly attention.

To identify such challenges, we propose the following research question:

RQ: What are the areas that should be focused on in the LMD of HBO products in order to close the gap between the industry and academic research?

This paper makes the following contributions: By scanning a wide range of literature, we first discuss challenges that arise in the delivery of HBO products. Consequently, we indicate under-researched areas in the LMD of HBO products as a direction for future research. The rest of the paper is organized as follows: Section 2 discusses the challenges that arise in the delivery of HBO products. The methodology of our literature review process is explained in Section 3. We then focus on the literature review of HBO product deliveries in Section 4. Section 5 provides a discussion of our summary of the findings, as well as the limitations of our approach. Finally, Section 6 presents our conclusions and provides recommendations.

## 2. Challenges of HBO Product Deliveries

In light of the figures above, it is clear that there is a fundamental need for an innovative LMD response to customers—in particular, the LMD of HBO products. Although many studies exist on LMD problems, the focus of most of these studies is on parcel delivery (small-sized package deliveries) and is mostly centered on densely populated urban areas. The LMD of HBO products is the most challenging and the least studied. Interestingly, HBO products yield the most profitable sales [11,12]. The online share in the US furniture and homeware market is 31.1% and is expected to reach 37.2% by 2027 (Statista market insights). The delivery of HBO items increases the costs of storage and transportation, requiring more space and effort to manage. LMD-related costs make up anywhere between 40% and 50% of an organization's delivery cost. Handling large goods presents various challenges, including a more complex delivery process [13–15]. In an attempt to maintain lower costs while accelerating the rate of deliveries, more retailers are planning to automate their fulfillment locations by using micro-fulfillment centers, pop-up distribution centers, dark stores, etc. (BlueYonder). These items are more susceptible to damage during delivery, necessitating extra caution from delivery personnel. Depending on the level of service to be provided, specific attention and different skills are required to process HBO deliveries [16]. The complexity of delivering large goods is compounded by the issue of responsibility. With the heightened risk of damage, determining who is accountable for the product during delivery stages becomes crucial [14]. In these cases, traditional pallet and material handling tools may not even be suitable for packaging [15].

Sundström and Södergrenluo indicated that even though the delivery of bulky items involves larger markets, the number of studies on how LMD innovations should be used for larger items is limited [14]. Luo et al. indicated that producers of HBO products often

outsource the order delivery task to 3PLs, while many 3PLs have limited information technology capacity, and often, the transmission of information relies on paper documents [17]. Additionally, route planning relies on manual experience, lacking real-time traceability and visibility during deliveries.

Another major difficulty with logistics and HBO deliveries includes the cost of return and environmental effects [2,18].

In some cases, e.g., the furniture customization process, the delivery is even integrated with the design, and the production process involves measuring the space, furniture design, part and component production, and delivery and installation of the parts onsite [17]. Moreover, the characteristics of some HBO items further exacerbate the difficulties of the delivery process (e.g., irregularly and long-shaped products and various order sizes).

Lee et al. provided a technological disruption and innovation analysis of LMD [19]. One of their emphases in the near term is the opportunities that may arise for how products are delivered, where they are delivered, and what products are delivered. They further mentioned the kind of challenges that could arise, including the continual emergence of innovative technologies and offering sound business models that are economically, environmentally, and socially efficient and sustainable. As a possible solution, the authors emphasized algorithmic and analytic-based approaches. In a recent interview, Phillip Yeager, the President and Chief Operating Officer of Hub Group, also emphasized that "what we do not really have today is the ability to do appliance delivery and installation. That would be an area of interest to us" [20].

The aforementioned discussion clearly highlights the need for further study on the LMD of HBO products. A review of the academic literature on the LMD of HBOs also revealed that the academic research is behind [17,21]. In recent years, many literature reviews on last-mile parcel deliveries from the perspective of different stakeholders have been proposed. However, a review of the literature on HBO product delivery is nonexistent. The main purpose of this paper was to conduct a descriptive review of the literature in this field to identify the research gaps that need scholarly attention. We used a descriptive literature review methodology, explained in the next chapter, identified academic contributions available so far, and highlighted challenges for further research.

## 3. Materials and Methods

This study involved a descriptive review of the literature by collecting and summarizing research articles meeting the pre-specified criteria. In order to perform a comprehensive review of the literature on the LMD of HBO products, we conducted a search of 15 major databases: Google Scholar, Web of Science, Scopus, EBSCO, Ingenta, ProQuest, Emerald, Sage, Springer, Taylor and Francis, Science-direct, Social Science Citation Index, IEEE Explorer, INFORMS Pubs Online Search, and the powerful database of the library at the University of Mississippi. In each database, we used the following keyword combinations: "last-mile" AND "bulky"; "last-mile" AND "over-size"; "last-mile" AND "big-size cargo"; and "last-mile" AND "heavy products". Academic journals, conference proceedings, and unpublished theses were included in our search. There are also many relevant reports and/or white papers on the LMD of HBO products available from logistics companies or governmental agencies; in order to benefit from these studies, we used the same combination of keywords in Google and found several reports or white papers. In all cases, only English documents were chosen. Overall, from academic journals, conference proceedings, and unpublished theses, we found 195 papers that included at least one of the above keyword combinations. Out of these 195 papers, only 40 focused on the LMD of HBOs, while a further 32 papers were partially relevant to the LMD of HBOs. The rest of the papers were irrelevant. We also identified 23 short or long reports relevant to HBO product delivery that we cited in the text where appropriate. Furthermore, many logistics companies, magazines, and newspapers, also emphasize the importance of HBO deliveries, suggesting the need for further studies and innovative delivery responses. To access some of these reports, we searched Google and used their contents in different sections of the paper as appropriate.

At the end, we reviewed the content of each of the 40 academic papers thoroughly. We categorized the delivery of HBO products into two general areas: (i) Home delivery of HBOs and (ii) big-sized cargo delivery.

Although there are diverse ways to conduct literature reviews, we chose the descriptive literature review (DLR) methodology. There is much scientific research across all fields, including the sciences, social sciences, engineering, and business, using DLR methodology. The main reason is the importance of the subject while lacking enough literature (for example, a Google search using "descriptive literature review" popped up over 100 review papers). An initial search in Google revealed the urgent need, from the perspective of practicing companies, for an innovative HBO product delivery response to consumers. Our initial search also showed a lack of academic literature on this topic. Thus, DLR seemed to be an appropriate method to conduct this search. Our search process included four phases. In Phase I, we emphasize the importance of HBO delivery from the perspective of industry, which we carefully discussed in the earlier sections. Phase II shows the general methodology of the search process. Phase III provides an analysis of the available literature. Phase IV provides recommendations for future studies. Figure 1 shows a schematic of the search process.

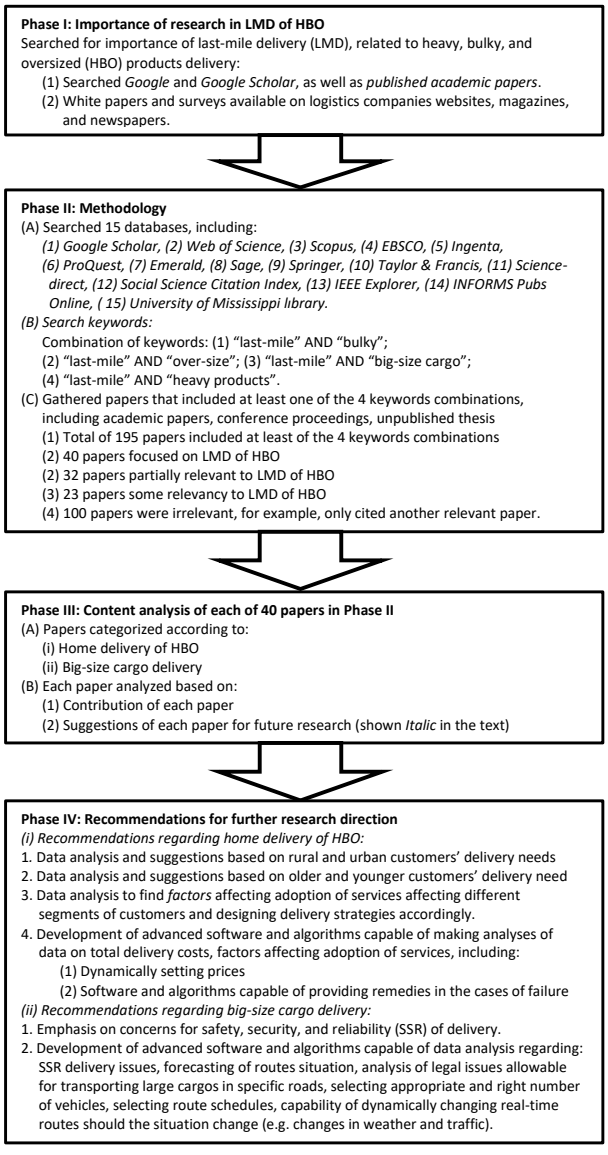


**Figure 1.** Schematic of the research design.

In the following sections, we briefly explain the contribution of each paper, as well as their suggestions for further research, indicated in Italic font here. Using the analysis of these papers, we finally provide several recommendations in each area ((i)–(ii)) for further study. Note that in (i), we use the terminology "home delivery"; however, the same concept is applied to the delivery of any final destinations, such as office buildings.

## 4. Review of the Literature

Last-mile delivery is a field attracting significant interest from both industry and academia. Among many factors contributing to this growing interest, population growth and urbanization, advances in e-commerce, customers' evolving shopping behavior, and increasing awareness on sustainability can be mentioned [18,22]. Using Google Scholar with the keywords "last-mile", "literature review", and "crowdsourcing" popped up more than 20 papers on LMD from different perspectives, all published within the last five years. LMD is one of the most challenging and expensive processes of the supply chain, involving direct customer interaction [1,2]. Yet last-mile delivery is important in order to retain customer loyalty. A recent article on freight transportation pointed out the fact that the current state of freight transportation (FT) is not optimized enough and that the main research stream to improve efficiency is the operations research (OR) approach [23]. Furthermore, it was indicated that although the FT service procurement mechanism plays a significant role in FT operations, it has drawn less interest. Recently, Eliyan et al. discussed inefficiencies in the last-mile delivery of small parcels and proposed various mathematical models for smart parcel station deployment as solution procedures [8]. None of the review papers discussed issues related to the LMD of HBO products. Furthermore, there is evidence that consumers prefer to buy HBO items online and have them delivered [12]. A survey involving participation of 1606 consumers [24] on the delivery of HBOs revealed that "58% of big and bulky deliveries were rescheduled, 47% of which were rescheduled once, 32% twice, 15% three times, and 6% four times or more".

Sections 4.1 and 4.2 provide a descriptive review of the literature on the home delivery of HBO products and big-sized cargo deliveries, respectively.

### *4.1. Home Delivery of HBO Products*

Audy et al. used cooperative game theory to study cost allocation as the key issue during a collaborative transportation agreement in furniture deliveries [25]. The authors evaluated their model on a case involving four furniture companies in Canada. *The authors posed several avenues for further study, including cost–benefit analysis of covering larger areas and the optimal size of coalitions.*

Horta et al. [26] and Sousa et al. [27] emphasized that online buying by rural consumers is growing, especially for HBO products. They differentiated between the rural and urban markets (specific characteristics of customers). The authors further presented an integrated set of recommendations for online retailers to "differentiate strategies" to serve rural markets efficiently related to product assortment, delivery service levels, delivery fees, clearly communicating value proposition, operational model for last-mile fulfillment, and reconfiguration transportation. *They suggested that further studies should emphasize rural markets in developing economies.*

Hodge et al. [28] and Shi et al. [29] studied the use of the Internet in rural communities to access services. The "digital divide" faced by older people in rural communities is exacerbated by their reliance on the Internet for essential services. Service providers often fail to recognize the specific needs of older rural clients, hindering their ability to participate in online service systems effectively.

In a new report, Bondi et al. [30] provided several practical suggestions for the dynamic pricing (DP) of LMD, particularly the delivery of HBO products. DP is the (fully or partially) automated adjustment of prices for different markets and/or customers. One of the suggestions is that retailers should consider the out of the door price, not the item price. The authors suggested that retailers can reap tremendous benefits from merchant-informed,

data-driven algorithms that recommend price changes for selected products at some level of frequency. The authors also suggested that retailers should ensure that all algorithm-recommended price moves are aligned with the brand and desired customer experience.

Peinkofer et al. focused on the delivery of HBO products and studied the choice of carrier that is more likely to diversify into LMD [21]. Drawing upon resource orchestration theory and Penrose's theory of firm growth, the authors devised a middle-range theory that explains why carriers' provision of less-than-truckload (LTL) or expedited services increases their likelihood of subsequently offering LMD services. *The authors suggested that further research should focus on the factors affecting the adoption of services.*

Sundström and Södergren [14] investigated the urban delivery of large goods, focusing on innovative delivery solutions. They highlighted the lack of research on applying novel LMD innovations for larger items despite the substantial market for large goods delivery. Their study specifically examined IKEA delivery in Sweden. They recommended future research to explore the development of regulatory frameworks in the Swedish market and how these LMD solutions would be impacted, especially considering the ecosystem perspective.

In Straubert's study [31], a qualitative framework for B2C logistics strategies was presented, encompassing white-glove service (WGS) delivery, which is a meticulous response to customer LMD needs. The author conducted a descriptive review of the existing literature and analyzed B2C trends, discovering that faster and more convenient delivery options are increasingly vital to customers. Many authors cited advanced software and analytics as potential solutions. This study emphasized that e-tailers can differentiate themselves logistically from competitors by implementing WGS delivery.

Siegfried and Zhang [32] studied the sustainability of urban LMD regarding HBO products. The authors emphasized that to manage the complexity of urban logistics conditions, governments and logistics companies should develop a cooperating strategy, specifically on environmental and regulatory issues. This study was limited to the research of one parcel shop in Germany. *The authors suggested that further studies should (1) extend the range of parcel shops and increase the sample of e-commerce users and (2) connect sustainable urban LMD into a digital and automatic technology-based smart city concept.*

Luo et al. [17] studied a physical Internet-enabled (PI-enabled) customized furniture delivery system. Furniture customization involves measuring a room, designing the furniture, manufacturing the components, and delivering and installing them onsite. This requires logistics services to be integrated along with the design, manufacturing, and installation. The authors mentioned that although the first three processes are fully automated, the logistical technologies of customized furniture are still lagging behind, resulting in a bottleneck in this booming industry. A PI decision support platform was designed to deal with resource planning. Then, a mathematical model and an algorithm based on variable neighborhood search and genetic algorithm were provided. The proposed algorithm was applied to a real-life case study. *For future study, the authors suggested several avenues: (1) possible extension of the proposed model to other product categories, especially for city logistics; (2) consideration of electric vehicles for improving the sustainability of the proposed model; (3) game theory-related research can be further explored in the field of customized furniture logistics due to the heterogeneity of supply chain players.* Qiu et al. [12] studied first-time attempts in LMD. In the case of HBO product delivery, the authors emphasized that once the first delivery fails, it costs much more to compensate by returning as is or delivering again. *The authors suggested several avenues for further study, including the use of machine learning and feature selection to analyze order processing capacity.*

Although there are many papers on the optimization issues of home delivery products, specific applications for HBO products are rare. Most published optimization papers on the home delivery of HBO products focus on variations of vehicle routing problems (VRPs).

Coelho et al. [33] considered a VRP with a lunch break in the context of the LMD of furniture. The authors presented a mathematical formulation based on a mixed integer program with a multi-start randomized local search heuristic as a solution procedure.

In their study, Li et al. [34] focused on a VRP involving discrete demands for bulky products, allowing split deliveries and dynamic service times proportional to the delivered products. Each customer's demand must be delivered within a single time window, permitting multiple vehicles to serve one customer. The authors formulated the problem using vehicle flow and set-covering models, proposing a branch-and-price-and-cut algorithm as a solution. *Two extensions were proposed for further study, allowing each customer to be visited by each vehicle more than once, and assuming real numbers for customer demands.*

Yang et al. [11] considered a fairly comprehensive study of the LMD of HBO products, proposing a cooperative-rich VRP involving three logistics providers in rural areas. The collaboration included local logistics providers (LLPs), integrated delivery and installation (LPDI), and commercial express enterprises (CEEs). They formulated a mathematical program and solved it using a branch-and-price-and-cut algorithm that they proposed. The optimized cooperation scheme's core and Shapley values were used to fairly distribute the cost savings. Their key finding indicated that a long-term grand coalition would benefit all participants. *The authors suggested several avenues for further study: (1) considering dynamic cooperation; and (2) developing heuristic algorithms for solving larger-scale problems due to the sparsity of rural road networks.*

Ruan et al. [35] considered bulky item delivery problems where multiple identical items are loaded onto a vehicle from different warehouses for delivery. The problem was modeled as a double-traveling salesman problem with multiple stacks (DTSPMS). Several GAs and an insertion algorithm were given as a solution procedure. *The authors suggested several avenues for further study, including relaxing the assumption of identical item sizes, considering multi-vehicles with different capacities, and considering more complicated loading constraints such as the vulnerability of items, the loading direction, item weights, and center of gravity.*

Zhang et al. [36] addressed the challenge of flexible delivery time for attended home delivery (AHD) in B2C e-commerce. They focused on a stochastic VRP with uncertain deadlines, aiming to find cost-effective routes meeting pre-specified targets. This service is particularly relevant for bulky items, fresh groceries, and valuable products. They proposed a two-step framework: first, conducting risk analysis to estimate the probability of missing customer deadlines; second, transforming the results into a semi-infinite mixed integer program. *For further study, the authors suggested the development of heuristics that can manage large-scale problems*.

In order to minimize energy consumption, Bányai [37] introduced a mathematical model for last-mile delivery problems to optimize assignment and scheduling. Li and Kunze [38] provided a structured review and web-based research for a comparative assessment of unmanned aerial vehicles and sidewalk unmanned ground vehicles in last-mile home delivery. Ranathunga et al. [39] analyzed the capacitated vehicle routing problem (CVRP) concerning first- and last-mile delivery, focusing on substantial items like home appliances, construction materials, furniture, and delicate goods. They examined models, algorithmic solutions, objectives, and industrial applications, aiming to identify future research directions. Their findings highlighted the importance of the constraints and features of VRP with backhauls in contemporary e-commerce operations. They suggested that future study should consider additional constraints such as human resource availability and parameter stochasticity, explore heterogeneous vehicle fleets, address mixed products, and investigate multiple product types and package sortation processes.

Özarık et al. [40] considered AHD with the possibility of re-visiting on the same delivery day as when the first attempt fails. A VRP and scheduling with time-dependent costs and multiple customer visits were provided. Failed deliveries were represented in the model as customer presence uncertainty. Additionally, a parallel adaptive large neighborhood search heuristic was developed as a solution procedure.

### 4.2. Big-Sized Cargo Deliveries

Often, the delivery of big-sized cargo requires several flat vehicles cooperating to transport one big-sized ship segment or cargo, namely, "multi-vehicle and one-cargo transportation" (MVOC). Such a delivery problem is distinctly different from the general last-mile home delivery of "one-vehicle and multi-cargo transportation" (OVMC) [41,42]. This situation is often characteristic of the delivery of heavy manufacturing products such as shipyard products, construction machinery, and elements of the power industry and large-scale equipment for industry, agriculture, and military use. Delivery of these products requires synchronizing several vehicles for transporting the cargo, and many criteria need to be considered, such as shape, weight, dimension of the cargo, width and length of the road, legal issues allowable for transporting large cargo on the road, number of turns in the road, and number of vehicles to choose for delivery. The key factors affecting the quality of transportation of heavy goods include safety, security, and reliability, as well as being environmentally sound. Most published papers on big-sized cargo delivery focus on the "criteria" for transporting cargo or optimization issues, including the selection of vehicles and routes. Below, we briefly explain the main results discussed in the papers published on this topic.

The routing problem is one of the areas where quantitate methods have been developed in the literature. Optimization of the transportation process can be achieved through various means, including the careful selection of trailers, trucks, and platform lorries, designing effective lashing programs, simulating transportation scenarios, optimizing the transportation route, and implementing real-time monitoring systems to track the cargo's status. Hu and Wei [41] studied big-sized cargo delivery and provided a mathematical program of multi-vehicle and one-cargo transportation with the objective of minimizing makespan. The authors also provided a GA, as well as a greedy solution for large-scale problems. *Several suggestions for further study were also provided, including the inclusion of time windows or precedence-dependent orders of the tasks, consideration of dynamic scheduling methods, and use of advanced computing technologies such as parallel computing and cloud computing for improvement of the algorithms.* Bazaras et al. [42] considered the planning and designing of routing selection for overweight or heavyweight cargo transportation delivery. The authors highlighted safety, security, and reliability as pivotal factors influencing the transportation of heavy goods. They underscored the need to formalize various conflicting interests and impact points for estimation and operational purposes in such deliveries. To address this challenge, they proposed employing a multi-criteria approach for estimating and selecting road transport routes. Park and Seo [43] addressed the transporter scheduling and routing problem at a shipyard. They provided a mathematical programming model based on parallel machine scheduling with the objective of maximizing the workload balance among transporters, then developed a GRASP algorithm as a solution procedure. Petraška and Palšaitis [44] and Petraška et al. [45] addressed the development of a system of criteria for the selection and assessment of heavy and overweight cargo transportation routes. They also provided algorithms for the assessment of cargo transportation routes. Meng et al. [46] considered the route selection of oversized cargo delivery in urban areas where turning direction at road intersections is a major factor. Using a graph theoretic model based on Dijkestra, they provided an algorithm for selecting the optimal path.

Pashkevich et al. [47] discussed the distinct factors that need to be considered in the LMD of large and bulky cargo. They mentioned two main problems that have to be solved: (1) the selection of the optimal road vehicles; and (2) the selection of the best route. They also provided decision support systems to deal with the problem.

Wolnowska and Konickia [48] considered an analytic hierarchy process (AHP) for route selection of the delivery of steel structure transport through urban areas. Three route variants were compared using AHP. They further presented rational premises for planning of the urban transport of oversized cargo in accordance with the Green City concept. Tao et al. [49] proposed an optimization model for the flat transporter scheduling problem in assembly blocks. The objective was to minimize logistics time, encompassing

the empty travel time of transporters, waiting time, and the delay time of block tasks. Their mathematical model accounts for ship block time windows, transporter carrying capacity, and task precedence relationships. Additionally, they introduced a metaheuristic algorithm based on a hybrid topological graph, genetic algorithm, and Tabu search for solving the problem. *The authors mentioned that in reality, transportation tasks are not executed smoothly on the road in shipyards; thus, a dynamic demand should be included in further studies.*

Another cluster of scholars have investigated the challenges in oversized cargo deliveries. Zong et al. [50] addressed the safety issues of oversized cargo delivery. Szczucka-Lasota [51] described the influence of road transport on urbanization development and the transport of oversized loads. The author further discussed obstacles arising from transporting big cargo. Macioszek [13,52] studied oversized cargo delivery based on various categories, including shape, weight, and dimensions. Depending on the type of oversized cargo, diverse types of transport are required. The author studied these problems in Poland, thus offering appropriate legal documentation requirements, as well as delivery supervision for safety and other issues specific to that country.

Wang et al. [53] studied the transporters of vehicles to deliver heavy blocks in shipyards. The authors utilized information and communication technology to develop a real-time positioning and online scheduling system for ship blocks. The objective was the minimization of driving distance and fewer turns in real time. Using the Dijkstra algorithm, the authors developed a hybrid model that takes into account both the number of turns and the optimal path of the transporter.

Luo et al. [54] proposed a model for the multi-route planning problem of multimodal transportation for oversized and heavyweight cargo. This model determines the transportation route, transport modes, and necessary reconstruction of lines or nodes simultaneously to minimize the total cost. A mathematical model based on the K shortest paths algorithm was introduced. The algorithm was further improved by introducing an A* algorithm. *Three areas for further study were suggested: (1) the impact of different constraints (e.g., inclusion of time windows); (2) the location problem of the transshipment sides, since previous studies have paid little attention to this; (3) improvement of the computational efficiency of algorithms for large-scale problems*.

Huang and Han [55] studied the selection of the optimal transportation route among alternative routes for the delivery of oversized cargo in urban areas. The authors provided a multi-objective model that combines the entropy weight method, cloud optimization, and order preference by similarity to an ideal solution. *Consideration of splitting large cargo and delivering it separately to customers was suggested for possible further study.*

Petru and Krivda [56] analyzed the delivery of oversized cargo in cities from the perspective of road network sustainability. This study was based on recommendations provided by the European Best Practice Guidelines for Abnormal Road Transports in 2006 [57].

Jiang et al. [58] studied the "multi-vehicle and one-cargo" green transportation scheduling problem. A bi-objective mathematical model was proposed, combining the routing model with synchronization constraints to minimize non-value-added transportation time cost and total $CO_2$ emissions simultaneously. The authors further designed a Tabu search to solve the problem. *They also suggested several directions for further study: (1) inclusion of road constraints; (2) advanced computing technologies such as cloud computing to improve computational speed; and (3) the creation of a knowledge-based scheduling method, incorporating empirical rules and historical scheduling cases from green shipbuilding domains.* Choi [59] studied the selection of the minimum number of right vehicles for transferring large cargo. The author mentioned that shipbuilding companies often sign rental contracts with 3RD vendors. To cut costs, the author proposed a hybrid approach. First, they determined the minimum number of transport vehicles using their method. Then, they employed a genetic algorithm for task allocation decisions and an exact method for sequencing tasks for individual vehicles. *The author suggested that further study should focus on heterogeneous vehicles.*

Jang et al. [60] explored off-site construction (OSC) as a solution to challenges like labor productivity stagnation, skilled worker shortages, complex site management, stringent safety regulations, and the drive for carbon neutrality, particularly in pre-cast construction. They emphasized the need for specialized management techniques and systems tailored to OSC's unique characteristics. The authors also noted the nascent state of related technologies. *They recommended future research efforts focus on developing project management theories and techniques tailored to diverse OSC construction methods*.

The final section provides a discussion of the results, conclusions, and suggested directions for future research. Table 1 provides a summary of the methods used in the literature, along with their scope.

**Table 1.** Summary of the methods and scopes.

| Subject | Author (Year) | Method | Scope |
|---|---|---|---|
| Home delivery of HBO products | Audy et al. (2011) [25] | Competitive game theory | Cost allocation as the key issue during a collaborative transportation agreement in furniture deliveries |
| | Horta et al. (2017) [26]<br>Sousa et al. (2020) [27] | Review<br>Case study | Examining differences between urban and rural consumers across online shopping preferences |
| | Hodge et al. (2017) [28]<br>Shi et al. (2023) [29] | Case study<br>Multivariate probit approach | Use of the Internet in rural communities to access services |
| | Bondi et al. (2021) [30] | Review | Dynamic pricing (DP) of LMD, particularly the delivery of HBO products |
| | Peinkofer et al. (2020) [21] | Panel data analysis | Delivery of HBO products and study choices of carriers that are more likely to diversify into LMD |
| | Sundström and Södergren (2021) [14] | Explorative and qualitative study | Urban delivery of HBO products and innovative delivery solutions |
| | Straubert (2022) [31] | Framework development | A qualitative framework for logistics strategies of B2C that includes white-glove service (WGS) delivery |
| | Siegfried and Zhang (2021) [32] | Data collection and interview | The sustainability of urban LMD regarding HBO products |
| | H. Luo et al. (2021) [17] | Mathematical modeling and an algorithm based on variable neighborhood search and genetic algorithm | Physical Internet-enabled (PI-enabled) customized furniture delivery system |
| | Qiu et al. (2022) [12] | Review | First-time attempts in LMD |
| Optimization problems for HBO products | Coelho et al. (2016) [33] | Vehicle routing problem (VRP) | LMD of furniture delivery |
| | Li et al. (2020) [34] | VRP | Problem formulation with vehicle flow and set-covering models and a branch-and price-and-cut algorithm |
| | Yang et al. (2020) [11] | VRP | Comprehensive study of the LMD of HBO products proposing a *cooperative-rich* VRP among three typical logistics providers in last-mile logistics |
| | Ruan et al. (2021) [35] | Double–traveling salesman problem with multiple stacks (DTSPMS) | Bulky item delivery problems where multiple identical items are loaded onto a vehicle from different warehouses for delivery |

**Table 1.** *Cont.*

| Subject | Author (Year) | Method | Scope |
|---|---|---|---|
| Optimization problems for HBO products | Zhang et al. (2021) [36] | Stochastic VRP with uncertain deadlines | Finding cost-effective routes to meet the deadlines to a pre-specified target |
| | Ranathunga et al. (2021) [39] | Systematic literature review | Systematic literature review of the capacitated vehicle routing problem (CVRP) |
| | Özarık et al. (2022) [40] | VRP | Attended home delivery (AHD) with the possibility to re-visit on the same delivery day when the first attempt fails |
| | Bányai (2018) [37] | Black hole optimization-based heuristic | Determining the optimal assignment and scheduling for each order for the minimization of energy consumption |
| | Liu and Kunze (2023) [38] | Structured literature review and parameter-based cost calculus model | Assessment of UAVs to SUGVs in the context of urban parcel delivery |
| Big size cargo deliveries | Zong et al. (2009) [50] | Review | Planning and designing of routing selection for overweight or heavyweight cargo transportation delivery |
| | Park and Seo (2012) [43] | GRASP algorithm | Transporter scheduling and routing problem at a shipyard |
| | Petraška and Palšaitis (2012) [44] Petraška et al. (2017) [45] | Algorithms for the assessment of cargo transportation routes | Development of a system of criteria for the selection and assessment of heavy and overweight cargo transportation routes |
| | Meng et al. (2015) [46] | Graph theoretic model | Route selection of oversized cargo delivery in urban areas where turning direction at road intersections is a major factor |
| | Szczucka-Lasota (2017) [51] | Review | The influence of road transport on urbanization development and the transport of oversized loads |
| | Pashkevich et al. (2018) [47] | Decision Support System | Distinct factors that need to be considered in the LMD of large and bulky cargo |
| | Hu and Wei (2018) [41] | Mathematical program of multi-vehicle and one-cargo transportation with the objective of minimizing makespan | Big-sized cargo delivery |
| | Wolnowska and Konickia (2019) [48] | Analytic hierarchy process (AHP) | Route selection for the delivery of steel structure transport through urban areas |
| | Tao et al. (2019) [49] | Metaheuristic algorithm based on the hybrid topological graph, genetic algorithm, and Tabu search | Optimization model for the flat transporter scheduling problem for assembly blocks with the objective of minimizing logistics time |
| | Macioszek (2019; 2020) [13,52] | Presenting the conditions related to oversized cargo and the problems related to permits | Oversized cargo delivery based on various categories, including *shape*, *weight*, and *dimensions* |
| | Wang et al. (2020) [53] | A hybrid model using Dijkstra algorithm | Transporters of vehicles to deliver heavy blocks in the shipyard |
| | Y. Luo et al. (2021) [54] | A mathematical model based on the $K$ shortest paths algorithm | A model of the multi-route planning problem of multimodal transportation for oversized and heavyweight cargo |
| | Huang and Han (2021) [55] | A multi-objective model that combines the entropy weight method and cloud optimization | Selection of the optimal transportation route among alternative routes for the delivery of oversized cargo in urban areas |
| | Petru and Krivda (2021) [56] | Simulation | Delivery of oversized cargo in cities from the perspective of the sustainability of road networks |

**Table 1.** *Cont.*

| Subject | Author (Year) | Method | Scope |
| --- | --- | --- | --- |
| Big size cargo deliveries | Jiang et al. (2021) [58] | Bi-objective mathematical model combining the routing model with synchronization constraints | "Multi-vehicle and one-cargo" green transportation scheduling problem |
| | Choi (2021) [59] | Hybrid method to determine the minimum number of transport vehicles, a genetic algorithm for task-allocation decisions, and an exact method to make the task sequence of the vehicles | Selection of the minimum number of right vehicles for transferring large cargo |
| | Jang et al. (2022) [60] | Presenting characteristics of OSC project management | Off-site construction (OSC) as a solution to challenges like increased safety, skilled worker shortages, complex site management, and the drive for carbon neutrality |

## 5. Results and Discussion

In this paper, we reviewed the LMD of HBO. We categorized the delivery of HBO products into two general areas: (i) home delivery of HBOs and (ii) big-sized cargo delivery. We first discussed practitioners' urgent needs for innovative tools on the delivery of HBO products, then discussed the lack of academic research on these topics. We identified papers in each of the areas explained earlier ((i)–(ii)), and furthermore, briefly explained what was discussed in each paper.

Last-mile delivery has already become a major concern, in parallel with the fast-growing online shopping in today's business environment. The amount of time US Internet users wait for the delivery of their online purchases was only one day for 38% of the respondents in a recent survey [61]. It is safe to say that the COVID-19 pandemic has also led to an increase in online shopping as a result of lockdowns and health concerns. Nevertheless, this change in consumer behavior has resulted in an increase in shipping volumes, placing further pressure on distribution networks.

One of the shortcomings of the research in this area is the lack of consideration of the effects of COVID when studying the LMD of HBO products.

One of the challenges that is agreed upon in the literature is the differences in the urban vs. rural distribution of HBO products. While issues such as traffic congestion and restrictions imposed in city limits need to be considered in urban areas, the lack of transportation infrastructure and high cost of deliveries to remote locations are the main concerns in rural areas.

While an increasing demand for the LMD of HBO products cuts across all segments of the market, not so surprisingly, market reports indicate differences between different customer segments, such as young vs. older people. Thus, the varying expectations and shopping behavior of different customer segments should be taken into account when planning the LMD of HBO products.

Finally, another challenge is the increasing delivery costs and inefficiencies leading to lower profitability and customer satisfaction levels. A lack of quantitative research and advanced software considering the parameters particular to the LMD of HBO products highlights the need for decision-makers to find near-optimal solutions in their planning process.

## 6. Conclusions

In the light of the above-mentioned observations resulting from our descriptive literature review, we suggest several recommendations for the home delivery of HBO products and big-sized deliveries, summarized as follows.

Recommendations regarding the home delivery of HBO products:

1. Using data analysis and distinguishing differences between rural and urban customers' needs then making delivery strategies accordingly.
2. Using data analysis and distinguishing differences between older and younger customers' needs then making delivery strategies accordingly.
3. Using data analysis to find factors affecting the adoption of services for different customer segments (e.g., economic, environmental, and social issues) then making delivery strategies accordingly.
4. Developing advanced software and algorithms capable of analyzing data on the total cost of delivery and factors affecting the adoption of services capable of:
    (1) Dynamically setting prices, analyzing packaging, sorting, special truck loading and choices of routing, installation procedures, cleaning, picking the right teams of skilled workforce, forecasting success and failure rates of delivery and the effect on the behavior of different customer segments, and, in some cases, the ability to integrate design, manufacturing, and logistical issues.
    (2) Providing remedies in the cases of failure—such as capacity failure—or real-time delivery changes—such as the development of appropriate machine learning based on features related to the delivery constraints or choosing a combination of different service providers and cost–benefit analysis (e.g., using game theoretic models).

Recommendations regarding big-sized cargo delivery:

1. Emphasis on strategies concerns the safety, security, and reliability (SSR) of deliveries.
2. Development of advanced software and algorithms capable of data analysis regarding SSR delivery issues, forecasting of route situations, analysis of legal issues allowable for transporting large cargo on specific roads, selecting the appropriate and right number of vehicles, selecting route schedules, and dynamically changing real-time routes should the situation change (e.g., changes in weather and traffic). In fact, delivery flexibility is demanded by 65% of customers, which is prioritized more than the speed of delivery [62].

As a consequence of employing a descriptive literature review, our review of the broad topic of the last-mile delivery of heavy, bulky, and oversized products is more descriptive in nature. However, the choice of a descriptive review is aligned with our aim of identifying under-researched topics in the LMD of HBO, thus providing a direction for future research. While this paper highlights the importance of LMD in customer satisfaction and business success, we aim to pursue follow-up research to develop mathematical optimization algorithms focusing on the business operations aspect of LMD.

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