

Smart Sharing and Last-Mile Solutions: A Comprehensive Review of Sharing-Economy Models for Urban Delivery and a Conceptual Framework for Sustainable Last-Mile Logistics

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Abstract: Inparcel delivery, the last mile is the most expensive part of the delivery sector and also the one that creates the highest congestion and pollution levels. According to the available forecasts, global parcel delivery volume moved from 103.2 billion parcels in 2019 to 161 billion parcels in 2022, and the number expected to reach 225 billion parcels by 2028, whereas the demand for the last mile delivery service is predicted to grow by 78% by 2030, which will generate more than 36% of additional delivery vehicles in the largest cities of the world, producing an extra 33% in terms of emissions. One of the potential solutions to help with this issue is the use of some of the sharing-economy models that enable the monetization of the excess capacity through various digital platforms. This study provides a comprehensive theoretical overview of the smart sharing models for last-mile parcel delivery covering 29 sources (academic articles and industry papers) from 2010 to 2026. The sharing models analyzed include: crowdshipping and crowd logistics, sharing parcel lockers and pick-up & drop-off points; sharing micro-fulfillment centers and micro-depots, pool-based capacity sharing models; on-demand warehousing and flexible capacity sharing; Mobility-as-a-Service-for-freight models; gig-economy delivery platforms. The summary of the quantitative findings from the literature includes: about 11% cost savings achieved through easy access to stationary parcel lockers located at proven locations, about 8.7% cost savings from the use of mobile parcel lockers and savings of carbon dioxide emissions of up to 5.4%, over 28% gained through the use of dynamically deployed parcel delivery systems, more than 50% cost savings related to your fulfillment center service through the use of micro-fulfillment bundling, and negative consequences of car-based crowdshipping compared to the transit-based fulfillment models. The gap between practice and research is identified, as the problems that practitioners face with regard to courier conditions, pricing, and trust are not studied in most of the commissioned studies. "ShareLM" proposes an initial theory connecting what is shared, how sharing is facilitated, and the goals of sustainability of various options. The paper offers six potential future research avenues.

Keywords: Last-Mile Delivery; Sharing Economy; Crowdshipping; Crowd Logistics; Parcel Lockers; Micro-Fulfillment; Pooled Capacity; Mobility as a Service.

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I. INTRODUCTION

The rapid increase of e-commerce has made the last mile, the last leg of the delivery journey from the hub to the recipient, mean the great logistics challenge of the modern city. By the year of 2019, the world parcel volume was 103.2 billion parcels, the first time in history to cross the 100 billion threshold, it is expected to rise to 225 billion parcels by the year of 2028 growing at a pace of around 6% per year [1]. The vast increase in parcel volumes collides

with the economics of urban delivery such that up to 53% of the total delivery costs is blamed on the last mile [2]. The WEG predicted in the year of 2020 that the urban demand for last-mile delivery will grow by 78% by the year of 2030, resulting in 36% more delivery vans on the roads of 100 cities worldwide, leading to an increase of delivery-related carbon emissions of one-third to around 25 million tons of CO₂ per year and increasing the average commute time by 11 min [3]. According to a report issued in 2025 by WEG, without any intervention delivery trucks and CO₂ emissions

may increase by up to 60% by the year of 2030 with delivery trucks accounting for around 13% of overall carbon emissions of the cities [3].

Traditional answers like adding more cars, forming more warehouses, or engaging in more delivery trips do not address the matter; they merely deal with the scale of the issue at hand. The concept of the sharing economy rests on the belief that the advent of peer networks creates a system in which individuals can consume via access rather than ownership of an object [4]. The basic concept of this approach involves the use of existing infrastructure to increase efficiency. The solution, therefore, would include all sorts of vehicles that can be used for deliveries, such as empty cars owned by commuters, lockers that are used interchangeably by many companies, postal depots used on a shared basis by competing delivery firms, and movable containers that are set up wherever the demand for deliveries is high.

There has been a breakthrough in researching sharing models for last-mile delivery, but it is evident that this field still lacks direction. The multitude of studies has been concerned with crowdshipping behavior, locker-location optimization, or specific pilot projects without trying to create an overall theoretical framework for the field. The survey of Boysen et al. [5] presents an overview of operational-research issues of last-mile delivery. However, it fails to provide a comprehensive taxonomy based on sharing models in this field. The aim of this paper is accomplish this task through its four contributions: (1) a thorough and systematic literature review on smart sharing models in last-mile delivery based on the seven model families; (2) a quantitative analysis of economic and environmental impacts of these models; (3) an identification of research gaps with regard to practical problems and theoretical solutions; and (4) a theoretical framework for the newly developed ShareLM taxonomy and layered framework for the comparative analysis, design, and evaluation of shared last-mile delivery systems. The remaining sections of the paper are organized as follows. Section II illustrates the conceptual background to the study. Section III analyzes the seven smart sharing models. Section IV discusses technologies enabling to implement the models. Section V explains the review methodology, in addition to the literature review and quantitative analysis. Section VI uncovers significant research gaps. Section VII provides information about ShareLM taxonomy and conceptual framework. Section VIII deals with sustainability, business model feasibility, and stakeholder issues. Section IX concludes the paper and presents future research directions.

II. BACKGROUND AND FUNDAMENTAL CONCEPTS

➤ *The Sharing Economy and Collaborative Consumption*

The idea of the sharing economy is based on the theory of collaborative consumption, put into the limelight by Botsman and Rogers (2010) who stated that digital technology allows for a new economy based on access and consumption rather than ownership whereby people can

share cars, homes, tools, and skills with others [4]. There are three requirements for any sharing model to succeed: (i) idle capacity – an asset which has unused time, space, or ability, (ii) a connectivity component that makes idle capacity available to the public for booking, and (iii) a governance and trust mechanism (which can include ratings, insurance, and payment systems) that ensures the safety and feasibility of the transaction between two unknown parties. When applied to logistics, these requirements can easily be translated to the situation of commuters who have empty vehicle space, available lockers or warehouses, and the use of a platform for matching demand and supply.

➤ *Last-Mile Delivery and Its Sustainability Challenge*

The last mile is operationally distinctive: destinations are numerous and dispersed, time windows are tight, first-attempt delivery failures are frequent, and vehicle utilization on final delivery tours is low. The WEF's intervention analysis estimated that switching delivery fleets to battery electric vehicles could cut last-mile carbon dioxide by 16%, while a combined "multiplayer ecosystem" scenario electric vehicles plus off-peak delivery, multi-brand parcel lockers, dynamic rerouting, and load pooling could reduce local emissions and congestion each by about 30% [3]. These figures establish two facts central to this paper: incremental fleet renewal alone is insufficient, and sharing-based coordination (lockers, pooling, rerouting) accounts for a large share of the achievable gains.

➤ *Defining Crowd Logistics*

Buldeo Rai et al. define crowd logistics as "an information connectivity enabled marketplace concept that matches supply and demand for logistics services with an undefined and external crowd that has free capacity with regards to time and/or space" [6]. Through a systematic analysis of 42 papers and interviews with 11 practitioners, they derived 18 characteristics that describe crowd-logistics concepts and traced how each characteristic affects economic, social, and environmental sustainability. Carbone et al., studying 57 initiatives, proposed a foundational taxonomy distinguishing crowd storage, crowd local delivery, crowd freight shipping, and a miscellaneous category, arguing that crowd logistics calls on amateurs and individuals to perform logistics services on an ad hoc basis a model structurally different from traditional logistics service providers [7]. The definition adopted in this paper follows Buldeo Rai et al.: any marketplace mechanism that mobilizes an external crowd's spare time or space capacity to perform logistics functions.

➤ *The Operational-Research Perspective*

From an operational research (OR) point of view, Boysen and colleagues have looked into every aspect of last mile delivery including different options (drones, delivery robots, parcel lockers, crowdshipping, trunk delivery and so on) available and classified the problems of decision making and areas of research that are missing [5]. The survey provides the needed methodology against which this work addresses sharing models: whereas OR literature normally optimizes one delivery method at a time through OR

methods, sharing models look into asset pooling aspects and what mechanisms are needed to enable such pooling.

III. SMART SHARING MODELS FOR LAST-MILE DELIVERY

➤ *Crowdshipping and Crowd Logistics*

Crowdshipping is the most studied sharing model: ordinary people commuters, public-transport users, store customers, or social-network contacts deliver parcels along trips they make anyway, coordinated through a digital platform. Devari et al. showed that exploiting the social networks of retail-store customers for last-mile delivery greatly reduces delivery costs and total emissions while preserving speed and reliability and mitigating privacy concerns and the not-at-home problem [8]. Mode choice, however, is decisive. Simoni et al., using a hybrid dynamic traffic simulation of Rome, found that car-based crowdsourced deliveries generally produce higher negative impacts than public-transit-based ones, and that limiting detours, providing adequate parking, and incentivizing off-peak deliveries significantly reduce externalities [9].

The demand and supply sides of crowdshipping have been studied empirically. Punel and Stathopoulos modeled consumer acceptance of crowdsourced delivery with choice models, finding that context and prior experience shape willingness to use crowdsourced couriers [10]. Ermagun and Stathopoulos analyzed the supply side the determinants of whether occasional couriers bid for delivery tasks in decentralized, auction-like platforms informing platform design [11]. Le and Ukkusuri surveyed both requesters and prospective crowd-shipper driver-partners in the United States, measuring willingness to work, expected payment levels, route-diversion tolerance, and willingness to pay [12]; their data also revealed that public awareness of crowdshipping remained limited, a baseline fact for adoption studies. Qi et al. developed an analytical model of shared-mobility-based last-mile delivery, deriving operational prescriptions and quantifying environmental impact [13]. Seghezzi et al. performed an economic analysis of a "pony express" crowdsourcing model for business-to-consumer e-commerce, assessing the cost viability of crowd-based delivery [14], while Akeb et al. designed and evaluated a collaborative crowd-delivery model for dense urban Paris, showing that collaborative delivery can materially improve parcel-delivery performance [15].

Despite this richness, Pourrahmani and Jaller document a troubling disconnect: reviewing both the state of practice and the state of research, they proposed four typological factors differentiating crowdshipping services (platform/service type, delivery type, delivery mode, pricing strategy) and six categories of challenges and opportunities, and concluded that practical challenges couriers' working conditions, pricing are underexplored while most papers remain exploratory with hypothetical instances [16].

➤ *Shared Parcel Locker and PUDO Networks*

Pick-up and drop-off (PUDO) networks stationary parcel lockers, mobile (relocatable) lockers, multi-brand

lockers, and parcel shops convert failed home deliveries into consolidated, carrier-shared pickups. They are among the most quantitatively validated sharing models. Peppel and Spinler formulated a mixed-integer linear programming (MILP) location model with a multinomial logit choice component for stationary locker networks, finding that optimal locker locations yield cost savings of up to 11.0% and carbon-dioxide-equivalent (CO_{2e}) savings of up to 2.5% in urban areas but add roughly 4.6% emissions in less populated areas because of longer consumer pick-up trips [17]. Extending this line, Peppel et al. showed that integrating mobile parcel lockers into a network of home delivery and stationary lockers delivers additional cost savings of 8.7% and extra CO_{2e} savings of up to 5.4%, with benefits concentrating in highly populous cities [18]. Schwerdfeger and Boysen treated mobile lockers as dynamic, reusable shared infrastructure, optimizing the changing locations of locker units over the day in last-mile distribution [19].

The environmental case for lockers depends critically on consumer behavior. Bonomi et al. solved a location-routing mixed-integer program minimizing combined company and consumer-travel environmental impact across 1,680 instances, showing that eco-conscious consumer behavior willingness to walk or cycle to lockers is a decisive lever for environmental benefit [20]. Rose took a consumer-participation lens, arguing that combining locker pickup with already-planned trips minimizes consumer cost and marginal emissions, a mechanism that "activates" the consumer as a co-producer of sustainable delivery [21].

➤ *Shared Micro-Fulfillment and Micro-Depots*

Moving inventory closer to consumers through small urban nodes is the second major infrastructure-sharing family. Rosenberg et al. introduced the shared micro-depot network: micro-depots used jointly by multiple logistics providers as handover points for the last leg, typically performed by cargo bikes [22]. This is a pure infrastructure-sharing model competing carriers share the same physical node while retaining their own fleets and brands. Yang et al. studied micro-fulfillment centers (MFCs) for quick commerce with a location-routing model, finding that slightly extended lead times enable bundling effects with cost savings exceeding 50% of fulfillment costs, and that multiple small MFCs outperform larger automated ones on both lead time and cost [23]. Perboli et al. modeled last-mile delivery with satellite depots under on-demand-economy dynamics, linking flexible depot networks to on-demand business models [24]. The strongest pooled-capacity result in the literature comes from Faugère et al.: a two-stage stochastic optimization for the dynamic deployment of pooled, relocatable storage-capacity modules across an urban access-hub network achieved up to 28% last-mile cost savings and 26% capacity savings relative to static deployment [25].

➤ *On-Demand Warehousing and Flexible Capacity*

On-demand warehousing short-term, marketplace-mediated access to warehouse space and handling capacity is the least theorized sharing model in the reviewed

literature. No verified academic paper dedicated specifically to capacity-marketplace models (of the Flexe type) was found in this review's literature pass; the theme is covered indirectly through Perboli et al.'s treatment of satellite depots under on-demand-economy dynamics [24] and Faugère et al.'s pooled-capacity deployment [25]. Because flexible capacity is conceptually adjacent to both shared micro-depots and pooled delivery capacity, this paper retains it as a distinct model family while flagging its thin evidence base as an explicit research gap (Section VI).

➤ *Passenger–Freight Integration and MaaS-for-Freight*

A more radical sharing logic pools freight with passenger flows. Mobility as a Service (MaaS) concepts, originally designed for passengers, are being extended to freight: parcels ride on public-transport vehicles, and delivery tasks are assigned to travelers. Bruzzone et al. developed a key performance indicator (KPI) framework for evaluating integrated passenger-and-freight first-/last-mile operations against conventional schemes; their Venice lagoon and Velenje (Slovenia) cases showed reduced distances traveled and lower externalities [26]. Fessler et al. ran a stated-choice experiment in the Capital Region of Denmark on willingness to act as crowdshippers during public-transport trips, estimating acceptable compensation levels by shipment characteristics direct user-acceptance evidence for transit-based crowdshipping [27]. Labarthe et al. designed an on-demand urban delivery service exploiting synchromodality and synergy between passenger and freight mobility, providing a concrete operationalization of MaaS-for-freight [28]. This family directly addresses the mode-choice finding of Simoni et al. [9]: shifting crowdshipping from cars to transit converts a potential source of externalities into a sharing gain.

➤ *Gig-Economy Delivery Platforms*

App-based on-demand courier platforms employing independent contractors represent the commercial mainstream of shared last-mile capacity. Duman et al. categorized sharing-economy business models in last-mile delivery including crowdsourced delivery platforms and shared urban distribution centers and framed the open optimization problems they raise: time windows, heterogeneous vehicles, and time-dependent costs [2]. Mehmman et al. provided one of the earliest systematic literature reviews of crowd logistics together with a maturity model for crowd-logistics initiatives, an early attempt to grade initiatives by their degree of development [29]. Together, these works connect the sharing models above to the platform-economy reality in which most of them are deployed, while also surfacing the labor and governance questions that Section VIII discusses.

IV. ENABLING TECHNOLOGIES

➤ *Digital Platforms and Matching Mechanisms*

Every sharing model that we will explore in Section III exists due to a particular sharing platform that facilitates the process of matching supply and demand. Two main types of platforms can be identified. Centralized matching involves the assignment of tasks to couriers and lockers via

optimization-based algorithms. In decentralized matching, where bidding is utilized, couriers get the chance to bid on available tasks, as investigated in the empirical works conducted by Ermagun and Stathopoulos [11]. Pourrahmani and Jaller's typology looks at how the type of platform/service provided and the pricing mechanism are the primary design variables [16]; this is because the matching mechanism determines who assumes risk, how prices are determined, and whether the platform can control user behavior (i.e., push users in the direction of off-peak delivery versus delivery via transit). The level of maturity of an initiative according to Mehmman et al. [29] is highly correlated to the level of sophistication of the matching layer.

➤ *Internet of Things, Smartphones, and Smart Lockers*

Smartphones make crowdshipping possible by combining identity, location, communication, and payment into one product. The Internet of Things (IoT) further develops this model for product distribution by providing smart lockers that allow electronic access control and transform a metal box into a multi-tenant and bookable asset through mobile locker units [19]. By receiving immediate updates that facilitate bulk collection, consumers have visibility into the process [21].

➤ *Optimization and Artificial-Intelligence Methods*

The research literature in this area is very methodological. MILP facility-location models that include consumer-choice models optimize the configuration of locker networks that are not changing [17]; two-stage stochastic programming that uses decomposition as a technique deals with the problem of deployment of pooled capacities dynamically in a situation of uncertainty of demand [25]; location-routing models help to plan micro-fulfillment networks [23]; location-routing mixed-integer programs measure the environmental effect of locker usage for thousands of cases [20]; and hybrid dynamic traffic simulation assesses crowdshipping impacts on the city level [9]. Machine learning (ML) and artificial intelligence (AI) are used mainly in demand forecasting, dynamic pricing, and real-time matching of functions within platform performance. The important point in methodology is that shared situations have transformed static problems of network design into ones that are dynamic and stochastic.

➤ *Low-Emission Vehicles and Cargo Bikes*

Shared micro-depots deliver their environmental benefit only when the final mile is completed with a zero-emission vehicle, normally an electric cargo bike [22]. As the World Economic Forum calculated with the fleet-renewal lever, using battery electric vehicles dramatically decreases last-mile CO₂ emissions by 16% [3]. The shared model further leverages this gain because common shared nodes enable electric vehicle and cargo bike tours to be economical at urban densities.

➤ *Automation as a Complementary Intervention*

On the WEF's registry of 24 last-mile options that it has analyzed, delivery robots and drones are included [3], as is also the case in Boysen et al.'s review of operations

research [5]. Even though automation in itself does not represent a sharing scheme, it can relate to sharing in two ways: autonomous lockers and mobile depots can provide infrastructure used in common, and robot/drone fleets will be more economic when pooled by carriers instead of being assigned to individual owner/operators. For the purposes of this paper, therefore, automation will be considered as an enabler of the sharing layer rather than a separate model family.

V. REVIEW METHODOLOGY AND LITERATURE ANALYSIS

➤ Review Protocol

This review was performed as a systematic literature review. In theory, the search for resources involved the leading bibliographic databases for logistics, transportation, and operations research (Scopus, Web of Science, publisher platforms such as ScienceDirect, SpringerLink, Wiley,

Emerald, and INFORMS) as well as institutional archives and reference lists. The inclusion criteria were that: i) literature was published between 2010-2026, ii) resources dealt explicitly with a sharing, pooling, crowdsourcing, or other collaborative mechanism used within the context of last-mile or urban delivery, iii) only peer-reviewed literature was included (i.e., journal articles, scholarly book chapters, and credible industry documents), and (iv) all sources were verified (each one was confirmed through at least one other source such as a publisher page, RePEc/IDEAS, DOI resolver, or institutional archive). A total of 27 academic sources and two industry documents were retained in the final corpus. Thematic synthesis was employed to classify the literature into seven families described in Section III, produce quantitative results, and identify gaps. No new empirical data were collected; no simulations were conducted.

➤ Comparison of the Seven Smart-Sharing Models

Table 1 Comparison of the Seven Smart Sharing Models for Last-Mile Delivery

Sharing model	Shared asset (WHAT)	Crowd participants	Platform role (HOW)	Cost evidence	Environmental evidence	Maturity
Crowdshipping / crowd logistics [6][7][8][9][10][11][12][13][14][15][16]	Spare vehicle space and courier time	Commuters, transit users, store customers, social contacts	Centralized matching or decentralized bidding [11][16]	"Greatly reduces" costs vs. dedicated trips [8]; pony-express economics analyzed [14]	Mode-dependent: car-based worse than transit-based [9]; limits on detours and off-peak incentives reduce externalities [9]	Commercially deployed; scientifically exploratory [16]
Shared parcel locker / PUDO networks [17][18][19][20][21]	Locker compartments and pickup points	Carriers (multi-brand) and consumers	Location optimization; consumer trip-chaining [17][21]	Up to 11.0% savings, stationary optimal [17]; +8.7% additional with mobile lockers [18]	Up to 2.5% CO ₂ e urban savings [17]; +5.4% with mobile lockers [18]; +4.6% in rural areas [17]; eco-behavior critical [20]	Operational at scale; strong OR evidence
Shared micro-fulfillment / micro-depots [22][23][24]	Urban fulfillment nodes and handover space	Multiple competing carriers; cargo-bike operators	Joint node use; location-routing planning [22][23]	50%+ fulfillment-cost savings via bundling [23]	Cargo-bike last legs cut local emissions [22]	Pilots and early networks
Dynamically pooled capacity [25]	Relocatable storage modules; shared fleets	Carrier coalitions; platform operators	Two-stage stochastic deployment [25]	Up to 28% last-mile cost savings [25]	26% capacity savings imply fewer assets in circulation [25]	Analytical; limited pilots
On-demand warehousing / flexible	Short-term	Shippers;	Capacity	Indirect	Unquantified	Conceptual;

capacity [24]	warehouse space and handling	warehouse operators	marketplace s (thin literature)	via satellite-depot models [24]		flagged as gap
Passenger–freight integration / MaaS-for-freight [26][27][28]	Public-transport vehicle capacity; traveler time	Transit passengers as crowdshippers	KPI frameworks; synchromodal orchestration [26][28]	Reduced distances traveled [26]	Reduced externalities vs. conventional schemes [26]; compensation levels estimated [27]	Experimentally; early designs
Gig-economy delivery platforms [2][12][29]	On-demand courier labor	Independent contractors	App-based dispatch and pricing [2]	Core of platform business models [2]	Unquantified in reviewed corpus	Commercially mature; labor concerns

➤ Summary of Key Reviewed Studies

Table 2 Summary of Key Reviewed Studies

Study	Model focus	Method	Key finding
Peppel & Spinler (2022) [17]	Stationary lockers	MILP location + multinomial logit choice	Cost savings up to 11.0%; CO ₂ e –2.5% urban, +4.6% rural
Peppel, Spinler & Winkenbach (2024) [18]	Mobile lockers	Operational network design	+8.7% extra cost savings; up to +5.4% extra CO ₂ e savings
Faugère et al. (2022) [25]	Pooled relocatable capacity	Two-stage stochastic optimization	Up to 28% cost and 26% capacity savings vs. static deployment
Yang, Ostermeier & Hübner (2024) [23]	Micro-fulfillment centers	Location-routing model	50%+ fulfillment-cost savings via lead-time bundling
Simoni et al. (2020) [9]	Crowdshipping	Hybrid dynamic traffic simulation (Rome)	Car-based crowdshipping worse than transit-based; detour/off-peak management matters
Devari, Nikolaev & He (2017) [8]	Social-network crowd delivery	Survey-informed modeling	Greatly reduced costs and emissions vs. dedicated trips
Le & Ukkusuri (2019) [12]	Crowd-shipping supply/demand	US revealed/stated-preference surveys	Willingness to work, expected payment, diversion tolerance quantified; awareness still limited
Bonomi, Mansini & Zanotti (2022) [20]	Parcel lockers	Location-routing MIP, 1,680 instances	Consumer eco-behavior (walk/cycle to lockers) is the decisive environmental lever

➤ Quantitative Synthesis

Aggregating the reported effects across the corpus yields a consistent picture with one structural caveat: the numbers come from different cities, demand assumptions, and baselines, and are therefore indicative rather than directly additive. On the demand side, global parcel volume grew from 103.2 billion (2019) to 161 billion (2022) toward a forecast of about 225 billion by 2028 [1], while the WEF projects +78% urban last-mile demand by 2030 with +36% more vehicles and nearly +30% emissions absent intervention [3]. Against this baseline, the sharing models report: stationary locker optimization up to 11.0% cost savings [17]; mobile-locker integration a further 8.7% cost and up to 5.4% CO₂e savings [18]; dynamic pooled capacity up to 28% cost and 26% capacity savings [25]; micro-fulfillment bundling above 50% of fulfillment costs [23]; and battery-electric fleets about 16% CO₂ reduction, rising to roughly 30% emission and congestion reduction under a combined sharing-oriented ecosystem scenario [3]. Two

countervailing findings discipline the optimism: locker networks can add about 4.6% emissions in sparsely populated areas [17], and car-based crowdshipping can worsen externalities relative to transit-based alternatives [9]. The social-network crowd-delivery evidence [8] and the pony-express economic analysis [14] support cost viability, but systematic social-sustainability quantification courier earnings, working conditions is absent from the corpus, a gap taken up in Section VI.

➤ Research Gaps

- Practice–research mismatch. The most consequential gap is the one diagnosed by Pourrahmani and Jaller [16]: the challenges practitioners actually face couriers' working conditions, pricing strategy, liability, and trust are the least studied, while the literature concentrates on exploratory models with hypothetical instances. Closing

this gap requires field-calibrated studies of real platforms.

- Thin evidence on on-demand warehousing. As noted in Section III.D, no verified academic paper dedicated to capacity-marketplace models for warehousing was found; the theme survives only through satellite-depot modeling under on-demand dynamics [24]. A dedicated research stream on flexible-capacity marketplaces pricing, contracting, and network effects is missing.
- Cargo-bike sharing and shared micro-mobility for freight. Cargo bikes appear as the last leg of shared micro-depots [22], but bike-sharing systems applied to freight, shared e-cargo-bike fleets, and their pooling economics have almost no dedicated literature. Given their centrality to zero-emission last legs, this is a disproportionate blind spot.
- Consumer behavior in rural and low-density settings. Peppel and Spinler's finding that optimal lockers add about 4.6% emissions in less populated areas [17] generalizes to a broader question: most sharing models are validated in dense cities, while rural logistics longer distances, thinner demand is understudied. The equity dimension (who gets access to shared infrastructure) is likewise underexplored.
- Social sustainability and labor. Buldeo Rai et al.'s 18 characteristics [6] include social effects, but the corpus offers almost no quantification of courier earnings, job quality, or distributional impacts of gig-economy delivery platforms. The labor question is the Achilles' heel of the sharing narrative.

- Regulatory and governance frameworks. Cities control curb space, zoning for micro-depots, and access rules for low-emission zones, yet the literature treats regulation as background rather than as a design variable. Comparative studies of municipal governance of shared logistics infrastructure are scarce.
- Real-world pilots at scale. Most quantitative results come from optimization models and simulations on synthetic or single-city instances. Longitudinal evaluations of operating shared networks measuring realized versus modeled savings are rare.
- Operationalization of MaaS-for-freight. The KPI framework [26], the stated-choice evidence [27], and the synchromodal design [28] are promising but disconnected: no integrated, operational MaaS-for-freight system has been evaluated end to end.

VI. PROPOSED CONCEPTUAL FRAMEWORK AND TAXONOMY

The literature reviewed above is rich but fragmented: each model family is studied in isolation, with its own vocabulary and its own performance metrics. The novel theoretical contribution of this paper is **ShareLM** (Shared Last-Mile), an original synthesis in two parts a three-axis taxonomy that classifies any sharing model for last-mile delivery, and a four-layer conceptual framework that shows how such models are built, operated, and governed. Both are synthesized by the author from the reviewed corpus; no single source proposes them.

➤ The Three-Axis Taxonomy

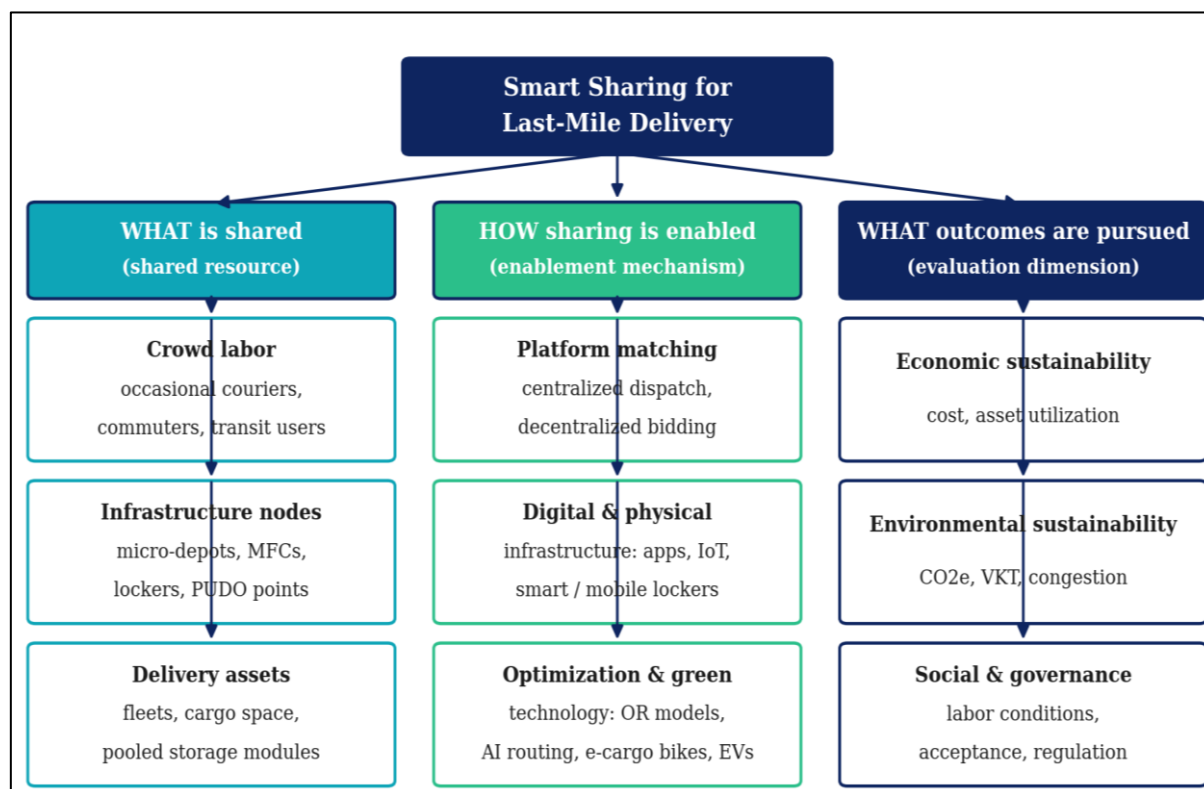


Fig 1 Three-Axis Taxonomy of Smart Sharing Models for Last-Mile Delivery: What is Shared (WHAT), How Sharing is Enabled (HOW) and what Outcomes are Pursued.

• *Any Smart Sharing Model can be Positioned along Three Orthogonal Axes:*

- ✓ Axis 1 WHAT is shared (the shared asset). Three asset classes cover the corpus: (i) *labor and crowd capacity* spare courier time and vehicle space contributed by commuters, transit passengers, store customers, or social contacts (crowdshipping [8][9][10][11][12][13][14][15], gig platforms [2], passenger–freight integration [26][27][28]); (ii) *infrastructure nodes* physical points in the network whose slots are pooled across users, namely parcel lockers and PUDO points [17][18][19][20][21], shared micro-depots [22], micro-fulfillment centers [23], and satellite depots [24]; and (iii) *delivery assets and capacity* vehicles, relocatable storage modules, and short-term warehouse space pooled across carriers [25], including on-demand warehousing capacity [24].
- ✓ Axis 2 HOW sharing is enabled (the enabling mechanism). Three mechanism classes recur: (i) *platform mechanisms* centralized matching, decentralized bidding/auctions [11], dynamic pricing, and reputation systems [16][29]; (ii) *physical and digital infrastructure* smart and mobile lockers [18][19], IoT tracking, smartphone apps, and shared micro-depot facilities [22]; and (iii) *green and smart technologies* electric cargo

bikes, battery-electric vehicles [3], and automation (robots, drones) treated as pooled assets [5].

- ✓ Axis 3 WHAT outcomes are pursued (the sustainability and governance target). Following Buldeo Rai et al.'s sustainability mapping [6], outcomes divide into (i) *economic* cost reduction, asset utilization, fulfillment efficiency [17][18][23][25]; (ii) *environmental* CO₂e and local-pollutant reduction, congestion relief, fewer vehicle-kilometers [3][9][17][18][20]; (iii) *social* courier working conditions, consumer convenience and participation [21][27], equity of access across dense and rural areas [17]; and (iv) *governance* the regulatory and contractual arrangements that make sharing legitimate and durable [16][26].

The taxonomy's value is comparative: two models that look different say, mobile parcel lockers [18] and pooled relocatable storage modules [25] reveal themselves as neighbors (shared infrastructure/capacity × smart infrastructure × economic/environmental outcomes), while crowdshipping [8] and gig platforms [2] share the labor-capacity asset class but diverge sharply on the outcome axis, where labor conditions separate sustainable sharing from extractive platform work.

➤ *The Four-Layer Conceptual Framework*

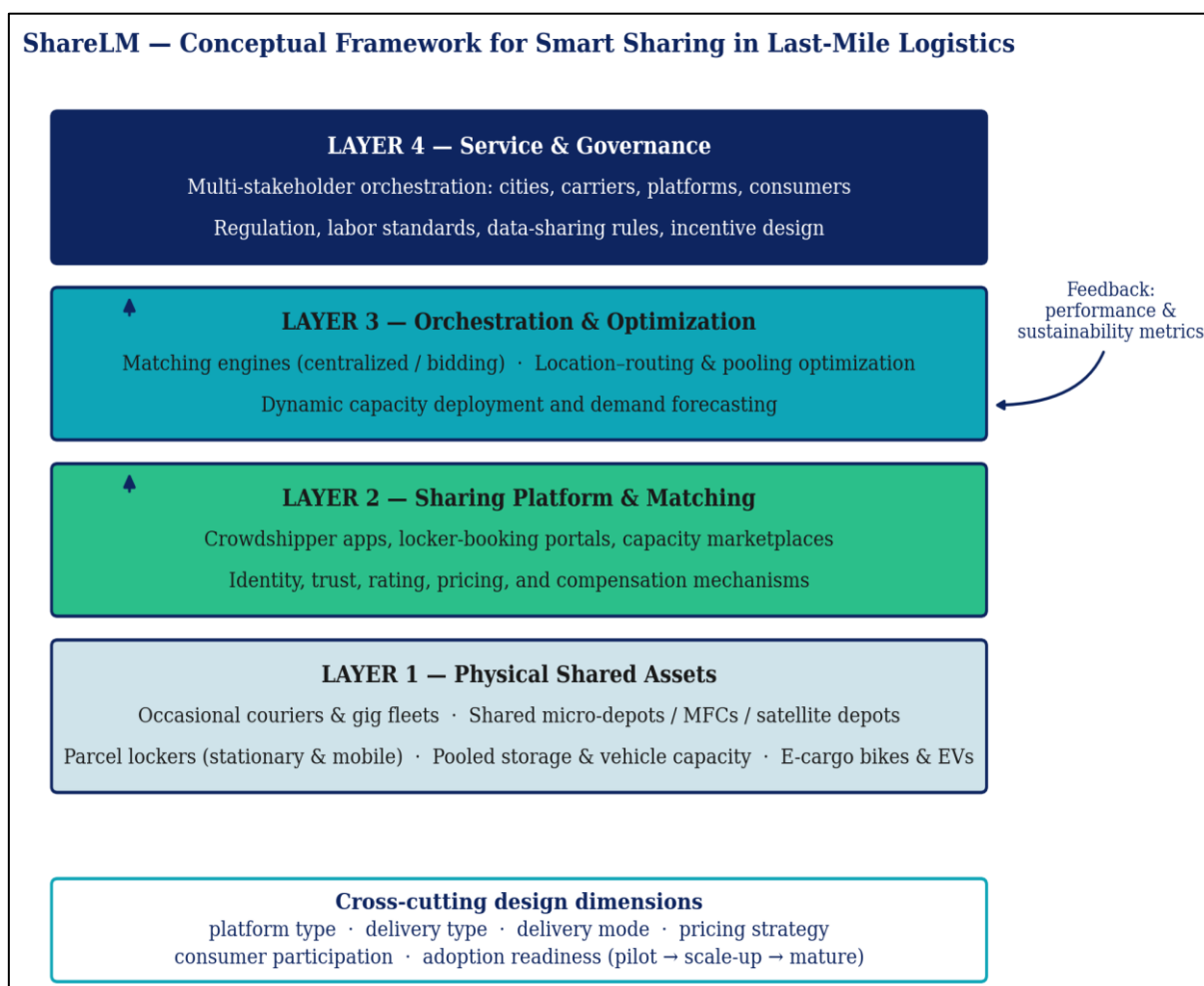


Fig 2 ShareLM Conceptual Framework: A Four-Layer Architecture for Designing, Operating, and Governing Shared Last-Mile Logistics Systems.

The taxonomy defines the model categories, while the framework helps people understand the process of constructing a model. The ShareLM System is structured into four cumulative layers, arranged according to levels of design and ability to launch. There are design components for designing tiers and stages of the layout of each layer, as well as whether that layer can be implemented or not.

- **Layer 1 Physical asset layer.** Crowd vehicles and courier time as poolable assets, (vehicles, time, lockers, micro-depots, MFCs, mobile resources, or startup) are determined by the way that they are combined, the ability to relocate them, and whether they are being used by a single carrier, multi-brands, or open crowd. They may also be referred to as either proprietary (used for one carrier only) or pooled (used by multiple carriers) [22][25].
- **Layer 2 Sharing platform and matching layer.** Virtual marketplaces include participant registration, assignment of tasks, related tasks (matching, centralized optimization/decentralized bidding [11]), cost, payment and credibility. Matching architecture, pricing strategy, and trust mechanisms [16] are design elements. Onboarding can range from manual coordination to real-time algorithm evaluation [29].
- **Layer 3 Orchestration and optimization layer.** Using intelligence to facilitate the sharing of information

effectively includes designing networks (e.g., locker placement [17], — mobile fulfillment center [MFC] location and routing [23]), deploying pooled capacity under uncertain conditions dynamically [25], selecting routes with timing constraints and mixed fleet types [2], forecasting demand, and using mode steering (such as promoting transit-based over automobile-based crowdshipping [9]). The elements involved in design include the time frame for the planning (strategic, tactical, or operational), how uncertainty is managed (deterministic or stochastic), and realism with respect to human behavior (including choice aware modeling, [17]). Readiness ranges from static procedures based on deterministic rules to stochastic, behaviorally sensitive plans.

- **Layer 4 Service and governance layer.** The client-facing and institutional framework: service commitments (delivery timeline, dependability), user-involvement elements like trip-chained parcel pickup [21], employment rights and courier protections, information-security standards, government laws (curbside access, land use, emission-reduction areas), and assessment metrics via KPIs [26]. Design aspects: degree of service provision, workforce structure, and legal compliance. Preparedness extends from unregulated experiments to institutional programs, city-based.

Table 3 ShareLM Framework: Layers, Components and Design Dimensions

Layer	Purpose	Core components	Design dimensions	Adoption-readiness indicator
1. Physical asset layer	Pool shareable resources	Crowd vehicles/time; lockers; micro-depots; MFCs; relocatable modules; cargo bikes; transit spare capacity	Asset granularity; relocatability (fixed vs. mobile); sharing regime (single/multi-brand/open)	From proprietary assets to fully pooled multi-user infrastructure [22][25]
2. Sharing platform & matching layer	Clear supply and demand	Onboarding; task posting; centralized or bidding-based matching [11]; pricing; payment; reputation	Matching architecture; pricing strategy; trust mechanisms [16]	From manual coordination to real-time algorithmic clearing [29]
3. Orchestration & optimization layer	Make sharing efficient	Locker/MFC location [17][23]; dynamic pooled deployment [25]; routing; forecasting; mode steering [9]	Planning horizon; uncertainty treatment; behavioral realism [17]	From static rules to stochastic, behavior-aware optimization
4. Service & governance layer	Deliver and legitimize the service	Service promises; consumer participation [21]; labor standards; privacy; municipal regulation; KPIs [26]	Service-level design; labor model; regulatory alignment	From unregulated pilots to institutionalized city-integrated services

A complete sharing initiative must make explicit choices in every layer: a mobile-locker network [18], for example, pools relocatable infrastructure (Layer 1), matches consumers to locker-time slots through an app (Layer 2), optimizes locker repositioning over the day [19] (Layer 3), and depends on consumer trip-chaining participation and municipal parking permissions (Layer 4). Initiatives that innovate in the upper layers while neglecting the lower ones for instance, a sophisticated matching app without pooled physical assets cannot capture the savings the quantitative literature reports.

VII. DISCUSSION

➤ Sustainability Across Three Dimensions

Economically, the evidence is the strongest: locker optimization [17][18], pooled capacity [25], and micro-fulfillment bundling [23] all report double-digit percentage savings, and crowdshipping models show cost viability [8][14]. Environmentally, the direction is favorable but conditional: benefits concentrate in dense urban areas and depend on mode choice [9], consumer eco-behavior [20], and trip-chaining [21]; in low-density settings, sharing can backfire [17]. Socially, the evidence is thinnest Buldeo Rai et al.'s 18 characteristics [6] map where social effects should

appear (job creation, inclusion, working conditions), but the corpus rarely measures them. A sharing model that cuts costs and emissions while degrading courier livelihoods is only partially sustainable, and the literature's silence on this point is itself a finding.

➤ *B. Business-Model Viability*

Sharing models face a classic platform chicken-and-egg problem: lockers need density to be attractive [18], crowdshipping needs liquid supply and demand [12], and pooled capacity needs carrier participation to reach critical mass [25]. The viable models in the corpus share two traits: they monetize an asset with near-zero marginal sharing cost (a locker compartment, a commuter's detour), and they align incentives across participants (carriers sharing a micro-depot [22] each save on last-leg costs). Pricing strategy one of Pourrahani and Jaller's four typological factors [16] remains the least theorized lever.

➤ *C. Stakeholder Roles and Challenges*

Cities will continue to play a critical role in controlling some of the most highly constrained resources used within transportation to facilitate e-commerce, including curb-side space, micro-depot zoning, and Low Emission Zone Regulations. Additionally, Cities must transition from being passive regulators of shared infrastructure to active orchestrators of the infrastructure. Carriers must also continue to work on overcoming barriers to coopetition and pooling nodes and capacity, enabling a more effective network of carriers [22][25]. In addition, platforms will have to create matching and pricing mechanisms that guide the marketplace towards more sustainable modes of transport rather than simply clearing the marketplace [9][16]. Consumers will need to become "activated" as co-creators by using a combination of existing trips and their respective deliveries to pick up items from drop-off lockers [20][21]. Throughout all of these stakeholders, four themes recur across many of these challenges: Labor Standards in gig and crowd work; Trust and Data Privacy in Peer/Peer logistics [8]; Regulatory Fragmentation across municipalities; and the effects of Rebound, whereby a lower price of delivery leads to increased consumption and eroded gains as identified by the WEF's Demand Projections [3].

VIII. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

This report has explored the new area of sharing based models for last-mile delivery by classifying three solutions into seven groupings which include crowdshipping, shared lockers, shared micro-fulfillment and depot, pooled transport, warehousing on-demand, integration of passenger and freight, and gig-economy. There is enough data to support the positive conclusion that different arrangements (i.e. lockers, mobile lockers, pooled transport, and micro-fulfillment) provide significant savings in both operational costs and emissions whereas environment impact of crowdshipping depends on mode of transport and of lockers on level of urbanization. The main issue here is significant discrepancy between practical difficulties (e.g. labor shortages, pricing mechanisms, trust, regulation, etc.) and

lack of sufficient literature in this area as most studies are theoretical. A new taxonomy and four-layer model proposed in this work will create a universal understanding between scholars and practitioners with respect to how sharing works.

Moving forward, researchers could pursue multiple areas of activity. The first is empirical studies examining on-the-ground experiences with existing crowdshipping and locker networks over time, looking at the savings that resulted from using these systems against those predicted when these systems were configured. The second is a focused stream of inquiry into pricing, contracting, and the impacts of network effects on freight logistics in the emerging on-demand warehousing marketplace. The third is the pooling of cargo bikes and freight-micro-mobility, and support for a zero-emission last mile of delivery. The fourth is the development of rural and other low-distribution-area logistical-sharing relationships where users share common logistical infrastructures equally. The fifth is to quantify the social sustainability of courier pay, job quality, and the distributional aspects of platform-mediated delivery work. Lastly is the complete operationalization and assessment of MaaS-for-freight systems using an integrated KPI [26] framework, data on user acceptability [27], and synchromodal [28] designs in evaluated pilot projects. Together, these research areas provide an opportunity to transition the future of last-mile logistics away from the models investigated and into a sustainable urban establishment.

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- **Data and Code Availability:** The datasets produced in this investigation, together with the simulation code, configuration files, and random seeds, can be obtained from the corresponding author upon a fair request.
- **Ethical Approval:** Not relevant. This research is exclusively based on computer simulations and does not include any human subjects or animals.

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