



Investigating the Role of Micromobility in Sustainable Last-Mile Delivery

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ABSTRACT

The growth of e-commerce, food delivery, grocery delivery, and quick-commerce services has increased the importance of last-mile logistics in dense urban areas. At the same time, micromobility vehicles such as e-scooters, e-bikes, e-mopeds, and cargo bikes have become increasingly common for short urban trips. This study assesses whether micromobility can be a viable option for last-mile logistics and under which conditions it can be effectively used. For this purpose, data were collected from logistics company reports, delivery platform reports, micromobility operator reports, and city-level shared micromobility evidence. The findings suggest that micromobility is not a universal replacement for conventional delivery systems, but it can be a complementary solution for short-distance, high-density, and small-parcel deliveries. E-scooters are suitable only for very small and light deliveries under safe conditions, while e-bikes provide a more balanced option for food, pharmacy, and small e-commerce deliveries. Cargo bikes appear to be the strongest micromobility vehicle for logistics, especially for grocery, multiple-package, and medium-parcel deliveries in dense urban areas. Overall, micromobility is most viable when suitable parcel types, short delivery distances, high order density, safe infrastructure, and supportive urban policies exist together.

1. Introduction

As centuries passed, humankind's perception of the world changed. This transformation became more visible as humans developed new ways to communicate, record events, and transmit knowledge. One of the most important turning points in this process was the invention of writing. Writing first emerged among the Sumerians in Mesopotamia around 3500–3000 BCE and enabled societies to record information and preserve knowledge across generations [1]. However, social practices and divisions of labor existed long before written records. For instance, cave paintings indicate that different genders may have had differentiated duties even before the invention of writing. In this context, history shows that gender roles have played an important role in the organization of society.

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Traditionally, these roles were defined by rigid boundaries. Essentially, the conventional masculine gender role is a social orientation that prioritizes power and position, while the traditional feminine gender role is a social orientation that stresses intimacy and solidarity [2]. Nevertheless, gender roles in society evolve. Although women have increasingly participated in education and professional life, they remain underrepresented in higher academic positions due to persistent conscious or unconscious bias, limited professional support, and unequal access to networking opportunities [3].

One of the most common examples of traditional gender roles is the association of women with cooking and domestic responsibilities. In many Western nations, a woman cooking for her husband would be viewed as highly stereotypical, whereas a woman working in an office would be viewed as less stereotypical [4]. Today, however, cultural shifts have blurred the boundaries between these roles to some extent. Although many examples still show that cooking is often treated as a feminine responsibility, men have also increasingly started to cook at home [5].

At the same time, broader lifestyle changes have transformed household routines. Individuals' tendency to order food has increased due to time constraints and more individualistic lifestyles. Similarly, this trend also applies to grocery shopping and cargo delivery. Instead of going to stores and buying items themselves, people increasingly prefer to order goods to their homes for the reasons mentioned above, as well as due to limited access to private transportation vehicles.

In parallel with these changes, Micromobility has rapidly become an important trend in urban transportation, with both traditional bicycles and newer electric options such as e-scooters and e-bikes increasingly used in cities worldwide in shared and private forms for flexible short-distance trips [6]. Moreover, their ability to operate in dense urban environments makes them particularly relevant for first-mile and last-mile transportation needs.

Within this broader transformation, micromobility has also started to be considered as an alternative solution for urban delivery activities. Food orders, grocery shopping, and small cargo deliveries can be distributed through micromobility vehicles, especially in areas where conventional motorized vehicles face problems such as congestion, parking limitations, and limited street access. Therefore, micromobility can provide a practical option for short-distance delivery operations in urban settings.

Accordingly, this study aims to assess the viability of using micromobility vehicles for last-mile logistics by examining the distance, cost, delivery time, and parcel-size conditions under which such a system can be effectively implemented.

2. Literature Review

2.1 Last-Mile Logistics

Supply chain management refers to the strategic coordination of business functions and activities both within a company and across firms in the supply chain to improve the long-term performance of each company and the overall supply chain [7]. Within this broader structure, logistics represents one of the core functions of supply chain management, as it is responsible for moving and storing materials and products between suppliers and customers [8]. Although logistics has often been perceived by many organizations mainly as a cost-related activity, it should also be considered a strategic function that can create value across the supply chain [9].

Logistics has developed into a multidimensional field with several different branches and approaches. For instance, smart logistics integrates smart products and smart services into logistics by using connected technologies that enable materials, products, and logistics systems to communicate, react, and be managed more transparently and efficiently [10]. Green logistics, on the other hand, focuses on environmentally responsible and efficient transportation and distribution

systems [11]. These different perspectives increasingly converge under the concept of Logistics 4.0, which refers to a digitally supported logistics system that meets individualized customer demands sustainably without increasing costs [12]. Therefore, Logistics 4.0 can be understood as an integrative framework that brings together digitalization, efficiency, sustainability, and customer-oriented logistics practices.

One important topic within logistics is last-mile logistics, which refers to the final and often most expensive stage of delivery, where products are transported to end-users while balancing cost, efficiency, customer satisfaction, and environmental impacts [13]. Last-mile operations can be conceptualized as an integrated system consisting of logistics, distribution, fulfillment, transport, and delivery components, ranging from strategic planning to the final interaction with the customer [14]. Since this stage is highly complex and costly, different delivery methods have been developed, including branch-based order processing, time- and region-restricted delivery planning, and pre-scheduled milk-run systems supported by customer-selected delivery slots [15].

Recent studies show that the future of last-mile delivery depends on selecting and operating suitable delivery concepts that can balance cost, service quality, sustainability, scalability, and urban constraints [16]. In this context, various technological and organizational solutions have been examined, such as the use of AI to improve delivery forecasting [17], autonomous delivery robots as a promising solution that still depends on infrastructure adaptation, regulatory clarity, and social acceptance [18], and integrated smart logistics approaches that combine cleaner vehicles, proximity delivery points, collaboration, route optimization, and supportive urban policies to reduce external costs [19]. Similarly, sustainable urban last-mile logistics cannot be improved through one universal solution, but requires integrated combinations of vehicles, delivery methods, infrastructure, optimization tools, and collaborative business models evaluated through the triple bottom line of sustainability [20].

Within this search for more sustainable and efficient last-mile delivery solutions, micromobility has gained increasing relevance. Small, lightweight, and low-emission vehicles such as bicycles, e-bikes, cargo bikes, and e-scooters offer flexible alternatives for short-distance urban deliveries, especially in dense city centers where conventional delivery vehicles face congestion, parking limitations, and environmental restrictions. Therefore, micromobility can be positioned as one of the emerging last-mile logistics solutions.

2.2 Micromobility

Micromobility has increasingly been discussed in the literature as an important short-distance urban transportation mode. A review on the role of micromobility in sustainable cities identified benefits, technology, policy, and behavioral mode choice as the main research themes shaping the literature [21]. Similarly, a synthesis of shared e-scooter micromobility studies emphasized that use patterns, user perceptions, environmental impacts, and appropriate policy design remain central issues for sustainable implementation [22]. Another review on the enablers and barriers to micromobility adoption showed that pro-environmental attitudes, convenience, safety concerns, infrastructure quality, and regulation shape adoption differently in urban and suburban contexts [23]. From a social perspective, public opinions on micromobility in the US and EU were examined through social media data, revealing that discussions mainly focus on service, mobility, technical features, acceptance, infrastructure, and regulation [24].

Building on these general discussions, the impact of dockless micromobility on public transit accessibility was assessed, showing that scooters can improve first-mile and last-mile accessibility, although benefits are spatially uneven and sensitive to cost and availability [25]. However, recent research also indicates that the relationship between shared micromobility and public transit is not

always complementary, since different micromobility types may either compete with or support transit depending on land use, location, and service characteristics [26].

In this context, mode choice, substitution patterns, and environmental impacts of shared and personal micromobility were examined, showing that trip distance, precipitation, and access distance significantly influence micromobility use, while environmental benefits depend on which transport modes are replaced [27]. Similarly, a data-driven approach was proposed to assess the sustainability potential of micromobility, demonstrating that a considerable share of short urban car trips can be compatible with micromobility substitution [28]. In another article, shared bikes and private e-scooters in Barcelona were compared, and the findings showed that policy constraints and regulatory frameworks can influence micromobility mode choice and mode replacement patterns [29]. Beyond travel behavior, user profiling in Zurich revealed that shared micromobility users are generally young, educated, employed, and affluent, raising important questions about transportation equity and public space allocation [30].

In terms of safety and infrastructure, a systematic and scientometric review on safe infrastructure for micromobility highlighted the need for tailored bikeway design principles that consider emerging powered micromobility devices [31]. Similarly, an analysis of e-scooter crash patterns based on news reports showed that safety concerns are linked to factors such as helmet use, riding under the influence, rider characteristics, crash location, and data limitations [32]. From a governance perspective, regulatory challenges related to shared dockless e-scooters were discussed, emphasizing that effective governance tools such as geofencing, zoning, data sharing, and parking control are necessary to manage their external impacts [33].

Finally, an agent-based simulation framework for shared autonomous micromobility emphasized that autonomy, demand prediction, and fleet rebalancing can improve the operational efficiency and user experience of shared micromobility systems [34]. In a similar direction, autonomous vehicles for micromobility were examined through the design and evaluation of a low-speed autonomous urban vehicle, highlighting the technical challenges of operating in pedestrian-rich urban environments [35]. Combining these two literature review sections, the viability of micromobility in last-mile logistics should be assessed in terms of distance, cost, parcel size, and operational conditions.

3. Methodology

3.1 Data Collection

This study uses a report-based data collection approach to evaluate the viability of micromobility vehicles for last-mile logistics. Since the study aims to identify the conditions under which micromobility can be used effectively for delivery operations, data were collected from different types of sources. The evidence base includes global logistics company reports, e-commerce and platform delivery reports, micromobility operator reports, city-level shared micromobility reports, safety and infrastructure reports, and real-world cargo-bike delivery evidence. The collected evidence was first organized into four main data groups.

Data Group 1 | Micromobility Travel Characteristics: It includes the travel-related characteristics of micromobility systems. This group covers average trip distance, average trip duration, vehicle type, vehicle utilization, operating geography, first/last-mile role, and general urban use profile.

Data Group 2 | Micromobility Pricing and Cost Variables: It includes both user-facing pricing models and system-level cost indicators. This group covers pay-per-minute pricing, unlock fee logic, subscriptions and passes, flat-rate rides, average trip cost benchmarks, affordability indicators, and deployment or infrastructure costs. A methodological decision was made not to standardize a single unlock fee or per-minute price, because micromobility prices vary by country, city, operator, vehicle

type, subscription status, campaign structure, and market conditions. Therefore, pricing is recorded primarily as a pricing-model variable rather than as a fixed unit-cost variable.

Data Group 3 | Courier and Delivery Characteristics: It includes the operational characteristics of last-mile logistics and delivery platforms. This group covers parcel volume, package volume, delivery time, courier/rider models, order density, service points, parcel lockers, micro-fulfillment, platform dispatching, final-mile partnerships, and real-world cargo-bike delivery evidence.

Data Group 4 | Parcel Constraints and Vehicle Suitability: It includes the physical and service-related constraints of delivery items and vehicles. This group covers parcel weight, parcel volume, handling requirements, cargo type, vehicle carrying capacity, safety, infrastructure, reliability, and regulatory constraints.

Table 1 summarizes how the four data groups are used in the study.

Table 1

Data Group Structure

Data Group	Data Type	Main Variables	Main Sources	Role in the Study
Data Group 1: Micromobility Travel Characteristics	Travel behavior and vehicle-use profile	Average trip distance, average trip duration, vehicle type, vehicle utilization, operating geography, first/last-mile role, urban use case	Marti, BinBin, Bolt, Lime, NACTO, ITF, U.S. DOT	Used to define distance and time thresholds and to classify micromobility vehicle types
Data Group 2: Micromobility Pricing and Cost Variables	User-facing and system-level cost evidence	Pay-per-minute pricing, unlock fee logic, subscription/pass models, flat-rate rides, average trip costs, affordability, deployment costs.	Marti, Bolt, Lime, NACTO, U.S. DOT	Used to evaluate cost and pricing suitability without relying on a single universal per- minute price
Data Group 3: Courier and Delivery Characteristics	Last-mile delivery operations	Parcel volume, package volume, delivery time, courier model, order density, service points, lockers, micro-fulfillment, platform dispatching, cargo-bike delivery evidence	DHL, UPS, FedEx, Amazon, Delivery Hero, DoorDash, Marti, U.S. DOT	Used to understand delivery system requirements and operational compatibility with micromobility
Data Group 4: Parcel Constraints and Vehicle Suitability	Parcel and vehicle compatibility	Parcel weight, parcel volume, handling requirements, cargo type, vehicle carrying capacity, safety, infrastructure, reliability, regulatory constraints	FedEx, UPS, Amazon, Delivery Hero, DoorDash, ITF, U.S. DOT, consolidated template	Used to match parcel types with e-scooter, e-bike, cargo bike, e- moped, and conventional delivery options

Table 2 summarizes the sources used in the study, the key data extracted from each source, and their corresponding data group use.

Table 2

Source Inventory and Data Group Use

Source / Report	Year	Evidence Type	Key Data Extracted	Data Group Use
DHL Group Annual Report [36]	2025	Global parcel and e- commerce logistics	Parcel volume, service points, lockers, delivery quality, cost discipline, seasonal surcharge, electrified pickup, and delivery targets	DG3: courier/delivery characteristics; DG4: operational network and reliability constraints

Table 2
Continued

Source / Report	Year	Evidence Type	Key Data Extracted	Data Group Use
UPS Annual Report / Proxy Statement [37]	2025	Global package delivery	Average daily package volume, annual package volume, average revenue per piece, network reconfiguration, automation, final-mile partnership, healthcare logistics	DG3: delivery scale and unit economics; DG4: sensitive parcel and reliability constraints
FedEx Annual Report [38]	2025	Global parcel and freight logistics	Weight/size/distance pricing, demand surcharge, drop-off network, Network 2.0, DRIVE cost reduction, freight boundary	DG3: delivery network and cost structure; DG4: parcel-size and freight exclusion thresholds
Amazon Annual Report [39]	2025	E-commerce-driven last-mile logistics	Shipping cost, fulfillment cost, same-day delivery, Same-Day Fulfillment Centers, micro-fulfillment, grocery delivery, robotics, Prime Air	DG3: fast delivery and fulfillment logic; DG4: grocery and parcel variability
Delivery Hero Annual Report [40]	2025	Food delivery, grocery, and quick commerce	GMV, revenue, Quick Commerce, Dmarts, 20-30 minute to one-hour delivery promise, order density, rider model, zero-emission delivery ambition	DG3: on-demand delivery model; DG4: food, grocery, and small/medium parcel suitability
DoorDash Annual Report [41]	2025	Local commerce platform delivery	Total Orders, Marketplace GOV, Dashers, Dasher earnings, bike/scooter/car access, pay logic, Drive fulfillment	DG3: courier economics and vehicle mix; DG4: food/local commerce parcel suitability
Marti Technologies Annual Report [42]	2025	Turkish micromobility and mobility platform	E-scooter, e-bike, e-moped vehicle categories, relative distance/price levels, seasonality, per-minute pricing logic, and delivery pilot	DG1: vehicle/travel characteristics; DG2: pricing logic; DG3: delivery connection
BinBin Annual Report [43]	2025	Turkish e-scooter operator	Electric scooter rental model, short-distance micromobility use case, Turkish regulatory context	DG1: Turkish e-scooter context; DG2: pricing-source limitation; DG4: regulatory constraint
Bolt Technology Annual Report [44]	2024	Global multimodal mobility platform	Light vehicle rental, food/grocery delivery, 45+ countries, 600 cities, subscription/pass adoption	DG1: global platform scope; DG2: subscription/pass pricing model
Lime End of Year Report [45]	2020	Global shared micromobility operator	Total rides, total distance, average trip duration, average trip distance, transit connection, and car substitution	DG1: average trip distance and duration benchmark
LimePrime webpage [46]	Accessed 2026	Micromobility subscription pricing	Monthly subscription, flat-rate rides up to 20 minutes, free unlocks, discounted overage, market-dependent pricing	DG2: subscription and market-dependent pricing model
NACTO Shared Micromobility in the U.S. and Canada [47]	2023 report, published 2024	City-level shared micromobility	157 million trips, 11-12 minute dockless trips, e-bike utilization, annual pass costs, average dockless trip cost	DG1: city-level travel characteristics; DG2: pricing/cost benchmarks
NACTO Member Agencies web report [48]	2025	City-level shared micromobility	150 million trips, trips per bike per day, dockless costs for 10/15/30 minute rides, subscription costs	DG1: current utilization benchmark; DG2: current trip-cost benchmark
ITF Safer Micromobility [49]	2024	Safety and vehicle classification	Type A-D vehicle classification, crash factors, infrastructure quality, speed, rider experience, nighttime risk.	DG1: vehicle classification; DG4: safety and infrastructure constraints

Table 2

Continued

Source / Report	Year	Evidence Type	Key Data Extracted	Data Group Use
U.S. DOT ITS Executive Briefing: Micromobility [50]	Last modified May 2025	Deployment costs and cargo-bike delivery evidence	Micromobility definition, deployment costs, NYC cargo bike pilot, delivery growth, 5M+ packages, loading corrals, GPS data sharing	DG1: policy definition; DG2: system-level cost; DG3: cargo-bike delivery case; DG4: infrastructure and policy constraints

3.2 Evaluation Criteria

After organizing the evidence into four data groups, the collected data were evaluated through five main criteria. These criteria were developed to connect the data collection process with the threshold-based discussion in the following section. Instead of evaluating micromobility only as a transport mode or only as a delivery vehicle, the criteria assess whether micromobility can become viable under specific combinations of distance, time, cost, parcel type, vehicle type, network density, reliability, safety, and urban conditions, Table 3.

Table 3

Evaluation Criteria and Related Data Groups

Evaluation Criterion	Main Question	Related Data Groups	Main Evidence Used
Distance and time suitability	Does the required delivery distance and time fit the natural operating range of micromobility?	DG1, DG3	Lime average trip distance and duration; NACTO 11-12 minute dockless trips; Marti vehicle hierarchy; Delivery Hero and Amazon fast delivery models
Cost and pricing suitability	Is micromobility economically reasonable under pricing, subscription, fleet, or courier-cost models?	DG2, DG3	Marti per-minute pricing logic; LimePrime subscription model; Bolt pass model; NACTO 10/15/30 minute trip costs; UPS revenue per piece; DoorDash pay logic; Amazon shipping/fulfillment costs
Parcel and vehicle suitability	Is the parcel compatible with the vehicle in terms of weight, volume, handling, and stability?	DG3, DG4	FedEx weight/size pricing and surcharges; UPS healthcare/cold-chain evidence; Delivery Hero and DoorDash food/grocery/local commerce; NYC cargo bike delivery case; ITF safety evidence
Operational and network suitability	Does the delivery system have enough density, local nodes, dispatching, and access infrastructure to support micromobility?	DG3, DG4	DHL service points and lockers; FedEx drop-off network; Amazon same-day fulfillment and micro-fulfillment; Delivery Hero Dmarts; DoorDash Drive; NACTO utilization; NYC cargo bike corrals
Safety, urban context, and policy suitability	Is the urban environment safe, regulated, and physically suitable for micromobility logistics?	DG1, DG2, DG4	ITF infrastructure and crash-risk evidence; U.S. DOT cargo-bike rules and deployment costs; BinBin regulatory context; NACTO city-level evidence; NYC GPS data sharing and loading zones

The first criterion, distance and time suitability, evaluates whether the required delivery distance and duration align with observed micromobility use. Data from Lime and NACTO provide the main benchmarks for this criterion, while Marti helps distinguish between e-scooter, e-bike, and e-moped travel profiles. Delivery Hero and Amazon are also used to compare micromobility travel times with quick-commerce and ultra-fast delivery expectations.

The second criterion, cost and pricing suitability, evaluates whether micromobility can be financially reasonable under different cost structures. This criterion does not assume that commercial

logistics operators pay the same prices as individual micromobility users. Instead, user-facing prices are used as market cost proxies, while subscription models, pass structures, fleet operation, courier payments, and system-level deployment costs are considered as alternative cost frameworks.

The third criterion, parcel and vehicle suitability, evaluates whether a parcel can physically and operationally be carried by a micromobility vehicle. This criterion considers weight, volume, packaging, stability, service requirements, and handling needs. It also distinguishes between very small parcels, small parcels, medium parcels, large parcels, and regulated or sensitive goods. E-scooters, e-bikes, cargo bikes, e-mopeds, and conventional vans/trucks are assessed separately.

The fourth criterion, operational and network suitability, evaluates whether the surrounding logistics system supports micromobility delivery. Micromobility is expected to be more viable when order density is high and when delivery operations are supported by local nodes such as service points, lockers, Dmarts, micro-fulfillment centers, drop-off points, or cargo-bike corrals. Dispatching, tracking, rebalancing, charging, and loading/unloading infrastructure are also considered under this criterion.

The fifth criterion, safety, urban context, and policy suitability, evaluates whether micromobility can operate safely and legally in the urban environment. This criterion includes road surface quality, separated infrastructure, nighttime conditions, speed management, rider experience, vehicle maintenance, parking/loading areas, data sharing, local regulation, and operator-city coordination. Safety is treated as a threshold condition rather than a secondary issue. In the Results and Discussion section, these five evaluation criteria are further divided into ten operational threshold variables to provide a more detailed assessment of micromobility viability.

4. Results and Discussion

4.1 Distance Threshold

This section evaluates the viability of micromobility for last-mile logistics through the threshold variables derived from the data collection. The discussion is structured around ten threshold variables: distance, time, cost, parcel type, vehicle type, network density, reliability, safety, urban context, and policy/infrastructure.

The first threshold concerns whether typical delivery distances overlap with the natural operating range of micromobility vehicles. The collected evidence indicates that shared micromobility is mainly used for short urban trips. Lime's report shows that average trip distance increased from 1.7 km before COVID-19 to 2.1 km during COVID-19. This suggests that micromobility is naturally concentrated around short-distance travel rather than long-distance urban movement.

This finding is important for last-mile logistics because not every delivery movement is suitable for micromobility. Deliveries originating from nearby restaurants, pharmacies, convenience stores, parcel lockers, local service points, or micro-fulfillment centers are more compatible with micromobility than deliveries starting from distant warehouses. In this sense, distance is not only a spatial variable but also an operational variable: micromobility becomes more viable when the delivery origin is already close to the final customer.

A practical distance interpretation can therefore be developed. Deliveries within approximately 0-2 km represent the strongest suitability zone, especially for e-scooters and e-bikes. Deliveries between 2-5 km remain suitable, but vehicle choice becomes more important; e-bikes, e-mopeds, and cargo bikes become more appropriate than e-scooters. Deliveries beyond 5 km become conditional because rider time, cost, exposure, and operational complexity increase. For trips exceeding roughly 8 km, conventional delivery vehicles or motorized courier systems are generally more suitable unless the route is highly clustered or supported by a specialized cargo-bike/e-moped operation.

Overall, the distance threshold suggests that micromobility is most defensible for short, localized, and dense urban delivery tasks. It should not be evaluated as a replacement for long-distance parcel logistics.

4.2 Time Threshold

The second threshold concerns the travel time required for delivery. NACTO data show that typical dockless e-bike and e-scooter trips last approximately 11-12 minutes. Lime's data similarly indicate average trip durations of 9.7 minutes before COVID-19 and 13.1 minutes during COVID-19. These values support the idea that micromobility is most naturally aligned with short-duration urban travel.

For last-mile logistics, the most defensible operational window appears to be around 10-15 minutes. In this range, micromobility can provide speed and flexibility without excessive exposure to cost, safety, weather, and rider fatigue constraints. This time band is especially relevant for food delivery, pharmacy delivery, documents, and small e-commerce packages originating from nearby urban nodes.

Trips between 20 and 30 minutes should be treated as conditional. They may still be possible with e-bikes, e-mopeds, or cargo bikes, but they require stronger justification. For example, if the delivery route is clustered, if multiple packages are carried in one trip, or if the delivery is linked to a micro-fulfillment center, longer micromobility trips may remain viable. However, for single low-value deliveries, longer trip times may weaken the cost advantage.

Time also connects directly to quick-commerce expectations. Delivery Hero's Dmart model often promises delivery within 20-30 minutes to one hour, while Amazon Now is built around a 20-minute delivery promise. These models show that fast delivery is increasingly central to urban logistics. However, micromobility can only support such time promises when the delivery distance is short, and the vehicle is positioned close to demand.

Therefore, the time threshold indicates that micromobility is strongest for 10–15-minute delivery tasks, conditional for 20–30-minute tasks, and weak for longer delivery times unless supported by high order density, appropriate vehicle type, and localized logistics infrastructure.

4.3 Cost Threshold

Micromobility is least suitable for large, bulky, heavy, freight-like, or highly regulated deliveries. These deliveries require conventional vans, trucks, freight systems, or specialized vehicles. Similarly, low-density and long-distance delivery contexts weaken micromobility viability.

The third threshold concerns cost. The data show that micromobility pricing should not be reduced to a single universal per-minute value. Pricing differs by operator, city, vehicle type, subscription status, promotional campaigns, and market conditions. For this reason, the study treats micromobility cost primarily through pricing models rather than fixed TL/min or USD/min values.

Several pricing structures appear in the data. Marti uses a time-based pricing logic where the trip price is generally determined by the period of use and a predetermined per-minute rate. LimePrime illustrates a subscription model with flat-rate rides up to 20 minutes, free unlocks, reservations, and discounted per-minute pricing after 20 minutes. Bolt also shows the operational importance of subscription/pass models, with nearly half of its rental trips made through fixed-term subscriptions or passes.

NACTO provides useful benchmark costs for dockless systems. A 10-minute dockless e-bike/e-scooter ride averages around \$5.40, a 15-minute ride around \$7.65, and a 30-minute ride around \$14.30. These values show that micromobility costs rise sharply as trip duration increases. This

strengthens the earlier time threshold: short trips are more economically defensible, while longer trips need stronger operational justification.

However, user-facing micromobility prices should not be interpreted as direct logistics operator costs. Delivery firms may use owned fleets, leased fleets, subscriptions, platform-based courier systems, or internal cost structures rather than casual user pricing. Therefore, the NACTO and LimePrime data should be used as market cost proxies, not exact commercial delivery costs.

The cost threshold also needs to be interpreted together with parcel value and delivery model. UPS reports average revenue per piece, DoorDash links courier pay to time, distance, and task desirability, and Amazon reports very high shipping and fulfillment costs. These data show that last-mile delivery is already a cost-sensitive field. Micromobility becomes cost-viable only when it reduces delivery cost, improves delivery speed, increases order density, or supports more efficient use of urban space.

Overall, the cost threshold suggests that micromobility is most economically reasonable for short-duration, high-density, small-parcel deliveries. Its cost advantage weakens as delivery duration increases, unless supported by subscriptions, fleet ownership, route clustering, or micro-fulfillment.

4.4 Parcel Threshold

The fourth threshold concerns parcel characteristics. The evidence clearly shows that micromobility suitability depends not only on distance and time but also on parcel weight, volume, and handling requirements.

Very small parcels, such as documents, medicine, and small items between 0-2 kg, are the most compatible with micromobility. These parcels have very low volume and can be carried by e-scooters or e-bikes if the route is safe and short. Small parcels between 2-5 kg, including food delivery, pharmacy orders, and small e-commerce parcels, also show high suitability, especially for e-bikes.

Medium parcels between 5-15 kg, such as grocery bags, multiple packages, or local retail orders, are more conditional. These deliveries may exceed the practical carrying capacity of e-scooters and may be uncomfortable or unsafe for standard e-bikes, depending on volume and packaging. Cargo bikes become more suitable in this category because they provide higher carrying capacity and better load stability.

Large parcels above 15 kg or high-volume items are generally unsuitable for micromobility. FedEx's pricing logic supports this conclusion because delivery rates and surcharges are strongly affected by weight, size, length, girth, and additional handling needs. FedEx Freight data also provides a clear upper boundary: freight-like shipments are far outside the micromobility suitability range.

A separate category is required for regulated or sensitive parcels. Healthcare, cold-chain, high-value, or controlled goods may be small in size, but size alone is insufficient to determine suitability. These deliveries require temperature control, compliance, tracking, and reliability. Therefore, a small parcel is not automatically suitable for micromobility if it has special service requirements.

The parcel threshold therefore shows that micromobility is strongest for very small and small parcels, conditional for medium parcels, and weak for large or freight-like deliveries. Parcel size, weight, volume, and handling needs must all be included in the viability assessment.

4.5 Vehicle Threshold

The fifth threshold concerns vehicle type. Micromobility should not be treated as a single vehicle category. E-scooters, e-bikes, cargo bikes, and e-mopeds have different strengths, limitations, and logistics applications. E-mopeds are included as a borderline micromobility-related category because they extend the range of two-wheeled delivery but are closer to motorized courier systems in terms of speed, regulation, and safety profile.

E-scooters have the narrowest logistics suitability. Their main advantages are flexibility, low space requirement, and short-distance convenience. However, they have very limited carrying capacity and weaker stability compared with e-bikes or cargo bikes. ITF safety evidence also shows that e-scooters are sensitive to poor road surfaces, nighttime conditions, rider experience, and vehicle design. Therefore, e-scooters should be limited to very small and light parcels on short and safe routes.

E-bikes provide a stronger balance between range, stability, comfort, and parcel suitability. NACTO evidence shows that e-bikes are used more intensively than pedal bikes in several station-based systems. Marti also positions e-bikes as suitable for longer and more comfortable trips than e-scooters. For logistics, e-bikes are therefore suitable for food delivery, pharmacy orders, small e-commerce parcels, and small grocery orders.

Cargo bikes and e-cargo bikes are the strongest micromobility logistics vehicles. They can carry medium parcels, grocery orders, multiple packages, and local retail deliveries. The New York City cargo bike program provides the clearest real-world evidence: cargo bikes were used by commercial package delivery companies, expanded from 100 cargo bikes to more than 350 cargo e-bikes, and delivered more than five million packages in 2022. This shows that cargo bikes can support commercial last-mile delivery at scale in dense urban environments.

Moped-style scooters and e-mopeds can extend the range of food and grocery delivery, but they should remain a borderline category rather than being treated as equivalent to e-scooters or e-bikes. Conventional vans, trucks, and freight vehicles remain necessary for large, heavy, bulky, regulated, or long-distance deliveries. Micromobility can complement these vehicles in dense and short-distance contexts, but it cannot replace them in all delivery segments.

4.6 Network Density Threshold

The sixth threshold concerns the internal density of the delivery network. Micromobility becomes viable when delivery origins and destinations are close enough to create dense, repeatable, and assignable delivery patterns. Without sufficient order density, micromobility loses its advantage because vehicles and riders spend too much time traveling between dispersed delivery points.

Several reports support the importance of localized logistics networks. DHL has more than 167,000 service points and 53,000 parcel lockers in Europe. FedEx has around 63,000 drop-off locations. Amazon operates same-day fulfillment centers and micro-fulfillment systems. Delivery Hero's Dmarts are small local warehouses placed close to demand. These examples show that modern last-mile logistics increasingly depends on decentralized nodes.

For micromobility, this is critical. E-scooters, e-bikes, and cargo bikes work best when they start from nearby restaurants, stores, service points, lockers, Dmarts, or micro-fulfillment centers. If parcels must first travel long distances from large warehouses, the advantage of micromobility declines.

Order density is equally important. Delivery Hero explicitly links quick commerce with increased order frequency and order density, improving unit economics. DoorDash also depends on platform-based dispatching, courier supply, and task assignment. NACTO utilization data show that high-use systems can generate several trips per vehicle per day, especially for e-bikes. This supports the idea that micromobility logistics requires dense demand and high vehicle utilization.

The network-density threshold, therefore, suggests that micromobility is most viable in localized delivery systems with high order density, nearby fulfillment nodes, service points, lockers, or cargo-bike corrals. It is much less suitable for dispersed, low-density, or long-zone delivery systems.

4.7 Reliability Threshold

The seventh threshold concerns reliability. Logistics systems require predictable service performance, tracking, and delivery quality. Micromobility cannot be viable if it reduces reliability, even if it performs well in distance or cost terms.

Corporate logistics reports show the importance of service reliability. DHL reports high delivery quality and punctuality. UPS and FedEx emphasize tracking, visibility, automation, route optimization, and network reliability. These examples show that last-mile logistics depends not only on movement but also on system coordination.

For micromobility logistics, reliability has several dimensions. First, the vehicle must be available at the right place and time. Second, the rider or courier must be able to complete the delivery within the promised time. Third, the parcel must remain secure and undamaged. Fourth, tracking and customer communication must be preserved. Fifth, weather, battery range, charging, maintenance, and parking/loading access must not disrupt the delivery process.

This threshold is especially important for food, pharmacy, grocery, and high-value small parcels. Food delivery depends on time and temperature. Pharmacy delivery may require careful handling and reliability. Grocery delivery may involve variable weight and perishability. Small e-commerce deliveries may require proof of delivery and tracking.

Therefore, micromobility is viable only if it can be integrated into a reliable delivery management system. Vehicle flexibility alone is not enough. Reliability requires dispatching, tracking, maintenance, rider management, charging, parking, and route planning.

4.8 Safety Threshold

The eighth threshold concerns safety. Safety is not a secondary issue in micromobility logistics; it is a core viability condition. Even if a delivery is short, cheap, and lightweight, micromobility may not be suitable if the route is unsafe.

ITF evidence shows that infrastructure quality strongly affects micromobility safety. Poor road surfaces, potholes, and irregularities contribute to 30-40% of e-scooter crashes. Sidewalks and high-speed traffic lanes are among the least safe places for e-scooters. Separated and connected micromobility infrastructure reduces injury risk and improves safety outcomes.

Nighttime and reduced lighting conditions are another important factor, accounting for 30-44% of e-scooter-related casualties. Speeding also contributes to injury crashes. Rider experience matters as well, since a significant share of injuries occurs among inexperienced or low-frequency riders. For commercial delivery, this suggests that professional training, route management, and operational controls may improve safety compared with casual shared use.

Vehicle design also matters. E-scooters are less stable than bicycles or cargo bikes because of their smaller wheels, standing posture, and limited load-carrying capacity. Adding packages may further affect balance and handling. This makes e-scooters less suitable for logistics than e-bikes or cargo bikes unless the parcel is very small and the route is safe.

Safety, therefore, modifies all other thresholds. A delivery may be short, low-cost, and lightweight, but if it requires riding on poor surfaces, sidewalks, or high-speed mixed traffic, micromobility suitability decreases. The safety threshold requires safe infrastructure, good lighting, speed management, rider training, vehicle maintenance, and appropriate vehicle selection.

4.9 Urban-Context Threshold

The ninth threshold concerns the broader physical and spatial context of the city. Unlike the network-density threshold, which focuses on logistics nodes and order concentration, the urban-

context threshold focuses on congestion, curb-space pressure, parking conditions, street form, and the spatial structure of delivery areas.

Micromobility is most suitable in dense urban areas where short delivery distances, congestion, curb-space pressure, and high demand concentration exist together. Dense areas increase the relative advantage of micromobility because conventional vans and trucks face congestion, parking difficulty, double-parking problems, and curb-space conflicts. Cargo bikes and e-bikes can move more flexibly and require less space.

The New York City cargo bike case supports this interpretation. The program aimed to reduce congestion, replace trucks and vans in dense areas, reduce illegal and double parking, and use more context-appropriate vehicles for last-mile delivery. This shows that urban form and street pressure can create conditions where smaller delivery vehicles become more appropriate than conventional delivery vans.

However, density alone is not sufficient. If dense areas lack protected lanes, loading space, or clear curb management, micromobility operations may create safety or sidewalk conflicts. Therefore, the urban environment must provide both demand concentration and physical conditions that allow micromobility vehicles to operate without increasing conflicts.

Rural or low-density delivery is less suitable. Amazon's rural delivery expansion shows that low-density delivery requires large-scale network investment and long coverage areas. These conditions are not naturally compatible with e-scooters or standard e-bikes. Micromobility may still have limited roles in small towns or campus-like environments, but its main logistics advantage appears in dense urban districts.

The urban-context threshold, therefore, suggests that micromobility is most viable in dense, short-distance, high-demand, infrastructure-supported urban environments. It is weaker in suburban, rural, dispersed, or long-distance delivery contexts.

4.10 Policy and Infrastructure Threshold

The final threshold concerns the governance, planning, and operational support systems needed for micromobility logistics. Micromobility delivery does not depend only on vehicles and operators; it also requires supportive rules, street design, curb management, and coordination between public authorities and private companies.

The New York City cargo bike program shows the importance of policy support. The pilot required operator training, GPS data sharing, cargo bike corrals, and coordination with city agencies. It also faced legal challenges related to vehicle width, showing that cargo bike regulations must be clear and business-friendly. In 2024, New York City officially authorized cargo bikes and finalized usage standards.

Infrastructure requirements also matter. U.S. DOT evidence shows that micromobility deployment can require hubs, counters, parking zones, lockers, traffic signals, data systems, and charging infrastructure. These system-level costs should be considered when evaluating micromobility logistics. The existence of a vehicle fleet alone does not create a viable delivery system.

For e-scooters and e-bikes, cities need clear operating rules, designated parking zones, data-sharing arrangements, charging or rebalancing plans, and coordination between operators and public agencies. For cargo bikes, cities also need loading/unloading zones, curb access, parking areas, and clear vehicle dimension rules. Operators need maintenance procedures, fleet management, geofencing, and accountability mechanisms.

The policy and infrastructure threshold, therefore, shows that micromobility logistics requires an enabling urban governance environment. Without clear rules and supporting infrastructure, micromobility may create operational conflicts rather than solve last-mile problems.

4.11 Overall Viability Assessment

The combined evidence indicates that micromobility is conditionally viable for last-mile logistics. Its strongest use case is not general parcel delivery, but short-distance, high-density, small-parcel delivery supported by localized logistics infrastructure. Therefore, micromobility should be evaluated as a complementary last-mile logistics option rather than a full replacement for conventional delivery systems.

The threshold-based assessment shows that micromobility viability depends on the alignment of several conditions. Distance and time must remain within the natural operating profile of shared micromobility. Parcel size and weight must be compatible with the selected vehicle. Cost must remain reasonable under a pay-per-use, subscription, fleet-based, or platform-integrated model. Network density, reliability, safety, urban context, and policy support must also be present, Table 4.

Table 4
Threshold Variables Derived from the Data Collection

Framework Variable	Operational Coding Logic
Distance threshold	Use the Lime average 1.7-2.1 km and NACTO 11-12 min dockless trip duration as baseline for natural micromobility use. Longer trips become conditional; e-bike/e-moped/cargo bike can extend the range.
Time threshold	10-15 minute trips are the most defensible for dockless e-scooter/e-bike; 20-30+ minute trips should be treated as conditional because NACTO cost data rises sharply and safety/exposure increases.
Cost threshold	Avoid fixed TL/min values. Use pricing model categories: pay-per-minute, unlock fee, subscription/pass, flat-rate ride, discounted overage, and system-level infrastructure/operation costs.
Parcel threshold	Very small and small parcels are the core micromobility segment; grocery and medium/multiple parcels require e-bike/cargo bike; bulky/freight is outside the scope.
Vehicle threshold	E-scooter = very small/light/short/safe routes; e-bike = small/medium short trips; cargo bike = medium/multiple packages in dense areas; moped-style scooter = longer food/grocery trips but closer to motorized delivery.
Network-density threshold	Order density and micro-fulfillment/service points matter: DHL lockers/service points, Amazon SSDs, Delivery Hero Dmarts, FedEx drop-off network, and NYC cargo bike corrals all support localized last-mile operations.
Reliability threshold	Corporate logistics reports show high reliability expectations. Micromobility is viable only if service reliability and tracking are preserved.
Safety threshold	ITF evidence requires safe infrastructure, route quality, lighting, speed management, maintenance, rider training, and vehicle fit. Safety is a core viability condition.
Urban-context threshold	Dense urban areas with congestion, limited curb space, and short delivery distances are the most suitable contexts. Rural or long-zone delivery is less suitable.
Policy/infrastructure threshold	Cargo bike and micromobility logistics require loading zones, parking policy, data sharing, operator-city coordination, and business-friendly rules.

The strongest viability is observed for documents, medicine, food delivery, pharmacy orders, small e-commerce parcels, and selected convenience or grocery deliveries. These delivery types are generally light, frequent, time-sensitive, and compatible with dense urban delivery networks. E-bikes are the strongest general-purpose option for these deliveries because they provide better range, stability, and carrying capacity than e-scooters.

E-scooters have a narrower suitability range. They may be viable for very small and light deliveries, especially under 0-2 km, but their limited carrying capacity and safety constraints reduce their applicability for logistics. Cargo bikes provide the strongest logistics evidence, especially for medium parcels, multiple packages, grocery delivery, and dense urban package delivery. The New York City cargo bike evidence shows that cargo bikes can support commercial delivery operations at scale, Table 5.

Table 5
Vehicle-Suitability Summary

Vehicle Type	Suitable Parcel Type	Distance / Context	Main Advantage	Main Limitation
E-scooter	Very small parcels, documents, and light food orders	Very short distance; roughly 0-2 km as the strongest zone, conditional beyond; safe/continuous infrastructure needed	Fast and flexible; low space requirement	Very limited load capacity; stability/safety constraints; poor surface/nighttime risk; not ideal for grocery/multiple parcels
E-bike	Food, small e-commerce parcels, pharmacy, and small grocery stores	Short to moderate urban trips; stronger than e-scooter for the 2-5 km band	Better comfort, stability, and range; higher utilization in NACTO systems	Still limited volume; needs charging/maintenance; cost can be higher than a pedal bike
Cargo bike / e-cargo bike	Medium parcels, grocery, multiple packages, local package delivery	Dense urban areas and micro-hub/corral-based operations	Best micromobility option for logistics; NYC evidence shows 5M+ packages delivered in 2022	Higher acquisition/parking/curb-space requirements; legal width and loading-zone constraints
Moped-style scooter / e-moped	Food, grocery, and longer small-package deliveries	Longer urban trips than e-bike/e-scooter	Common in courier systems; speed/range advantage	Closer to motorized delivery; safety/regulatory profile differs from strict micromobility
Conventional van/truck/freight	Large, heavy, bulky, or regulated cargo	Longer-distance or heavy delivery	Higher capacity and better suited for bulky goods	Congestion, curb use, emissions, and cost pressures; not replaced by micromobility in all segments

Micromobility is least suitable for large, bulky, heavy, freight-like, or highly regulated deliveries. These deliveries require conventional vans, trucks, freight systems, or specialized vehicles. Similarly, low-density and long-distance delivery contexts weaken micromobility viability.

The parcel-based summary confirms that vehicle suitability should be evaluated together with weight, volume, and service requirements. In particular, small size alone does not guarantee suitability. Healthcare, cold-chain, high-value, or controlled goods may require reliability, tracking, temperature control, or compliance measures that ordinary micromobility operations may not provide, Table 6.

Table 6
Parcel Constraint Summary

Parcel Type	Example.	Weight	Volume	Micromobility Suitability
Very small	Document, medicine, small item	0-2 kg	Very low	High for e-scooter/e-bike if the route is safe and short
Small	Food delivery, pharmacy, small e-commerce parcel	2-5 kg	Low	High for e-bike; conditional/high for e-scooter, depending on packaging and safety
Medium	Grocery bag, multiple packages, local retail order	5-15 kg	Medium	Conditional; best served by e-bike/cargo bike depending on size
Large	Large box, bulky household item, freight-like parcel	15+ kg	High	Low; conventional delivery or cargo bike only under specific local conditions
Regulated/sensitive	Healthcare, cold chain, high-value or controlled goods	Varies	Varies	Depends on temperature control, compliance, tracking and reliability; size alone is insufficient

5. Conclusions

This study examines whether micromobility can be a viable option for last-mile logistics by evaluating evidence from logistics companies, delivery platforms, micromobility operators, city-level

reports, and safety/infrastructure studies. The findings show that micromobility should not be considered a universal replacement for conventional delivery systems. Instead, it is more accurately understood as a complementary solution that can be effective under specific operational conditions.

The strongest viability is observed for short-distance, high-density, and small-parcel deliveries. Food delivery, pharmacy orders, documents, small e-commerce parcels, and selected convenience or grocery deliveries are the most suitable use cases. Among vehicle types, e-scooters have the narrowest suitability range due to limited carrying capacity and safety concerns, while e-bikes provide a more balanced option for short-to-moderate urban deliveries. Cargo bikes appear to be the most promising micromobility vehicle for logistics, especially for medium parcels, grocery deliveries, and clustered package distribution in dense urban areas.

The analysis also shows that distance and parcel size alone are not sufficient to determine viability. Cost structure, order density, micro-fulfillment availability, service reliability, safe infrastructure, loading/unloading space, and supportive regulations are also critical. Micromobility becomes more feasible when deliveries are connected to nearby service points, lockers, Dmarts, local stores, or micro-fulfillment centers. In contrast, long-distance, low-density, bulky, heavy, or highly regulated deliveries remain more suitable for conventional vans, trucks, or specialized delivery systems.

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Conflicts of Interest

The authors declare no conflicts of interest.

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