



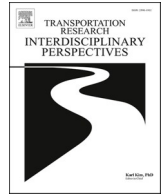
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How e-commerce influences last-mile practices that foster informality

Basilio Restrepo-Betancur^{a,1}, Ivan Sanchez-Diaz^{b,*,2} , Carlos A. Gonzalez-Calderon^{c,3}

^a Department of Civil Engineering, Universidad Nacional de Colombia at Medellín, CL 65 #78-28, Building M1, Medellín, Colombia

^b Department of Technology Management and Economics, Division of Supply and Operations Management, Chalmers University of Technology, Vera Sandbergs Allé 8, Room 3376, SE - 412 96 Gothenburg, Sweden

^c Department of Civil and Environmental Engineering, University of North Carolina at Charlotte, 9201 University City Blvd, Charlotte, NC 28223, USA

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ABSTRACT

E-commerce has significantly altered urban logistics, driving an unprecedented surge in last-mile deliveries while amplifying labor, regulatory, and environmental challenges. In many cities, particularly in developing economies, these challenges are compounded by institutional weaknesses and the widespread emergence of informality in logistics operations. This study examines how informality has evolved into a defining characteristic of last-mile e-commerce, shaping precarious labor conditions, increasing road safety risks, and exposing regulatory gaps. Employing an inductive qualitative approach, this research follows an explanatory and instrumental case study design based on semi-structured interviews with five key stakeholder groups: delivery drivers, e-commerce companies, public sector representatives, logistics and road safety experts, and society representatives. Findings indicate that outsourcing last-mile logistics has allowed companies to minimize costs while transferring operational risks to informal workers, reinforcing a system where economic efficiency takes precedence over labor protections and sustainability. Additionally, the lack of regulatory oversight has led to the institutionalization of informality, perpetuating a cycle in which negative externalities—such as congestion, road crashes, and environmental degradation—are borne by society rather than private actors. These findings underscore the need to reassess governance strategies in last-mile logistics, ensuring operational flexibility does not come at the expense of social and economic sustainability, and informing more inclusive and adaptive transport policy responses.

1. Introduction

1.1. Background and problem statement

E-commerce has rapidly expanded in developing economies, transforming urban logistics and accelerating the demand for fast, low-cost deliveries (Briana & Malindretos, 2025). In 2022, online sales accounted for 19 % of total retail sales in Colombia and Chile, illustrating the region's digital transformation (AMI, as cited in BlackSip, 2023). However, this expansion has exacerbated critical urban challenges, including rising congestion and environmental degradation, while these shifts remain insufficiently captured in conventional transport and freight planning tools. At the same time, the rapid adoption of gig-based logistics has intensified precarious labor conditions, particularly in cities where regulatory frameworks struggle to keep pace with these

transformations (Dablanc, 2023).

These pressures are particularly evident in large urban areas where e-commerce delivery demand interacts with already saturated transport systems. Latin American cities, including Bogotá and Medellín, rank among the most congested globally, with drivers losing 132 and 103 h annually in peak traffic, respectively (TomTom, 2024). The rise of last-mile delivery services, often reliant on motorcycle couriers, intensifies urban transport pressures, contributing to increased emissions and road safety risks. Medellín's PM_{2.5} pollution levels exceed WHO's recommended limits by threefold, and 88 % of its inhabited areas experience excessive noise pollution, further highlighting the environmental costs of fragmented logistics networks (SIATA, 2023). Beyond mobility and environmental impacts, last-mile delivery operations also generate conflicts over public space, including poor curbside management, double parking, and interactions that heighten risks for vulnerable road

* Corresponding author.

E-mail addresses: brestepob@unal.edu.co (B. Restrepo-Betancur), ivan.sanchez@chalmers.se (I. Sanchez-Diaz), ca.gc@charlotte.edu (C.A. Gonzalez-Calderon).

¹ ORCID: <https://orcid.org/0000-0003-3249-6242>.

² ORCID: <https://orcid.org/0000-0003-0213-9711>.

³ ORCID: <https://orcid.org/0000-0002-0633-2650>.

users in dense urban areas where delivery activity remains weakly regulated (Iacobucci et al., 2022).

In developing economies, these challenges are often amplified by structural constraints, including weak regulatory oversight and persistent informality across transport and logistics systems. The proliferation of motorcycles in last-mile delivery is closely tied to the fragmentation and informalization of the transport sector. As formal logistics systems struggle to absorb growing demand, independent couriers increasingly rely on motorcycles as a low-cost, flexible alternative to trucks—particularly for small parcel deliveries. This shift reflects the atomization of the operator market, where freelance workers with limited capital opt for motorcycles and informal arrangements over formal employment or fleet-based logistics. In Colombia, 21 % of motorcyclists use their vehicles for work, but only 54 % of delivery riders have formal contracts, exposing them to unstable incomes, lack of insurance, and inadequate safety protections (ANSV, 2021). These risks align with global trends, as powered two- and three-wheelers account for nearly 30 % of global road traffic fatalities, with developing regions being the most affected (WHO, 2022). In Medellín, motorcyclists represented 69 % of all traffic-related deaths in 2022, underscoring the dangers associated with last-mile delivery models embedded in weakly regulated and highly fragmented contexts (ANSV, 2022).

1.2. Literature review and research gap

While e-commerce expands access to goods, studies indicate that delivery service disparities persist, particularly affecting marginalized urban populations with limited socioeconomic resources (Sanchez-Diaz et al., 2021). These inequalities are compounded by infrastructure deficits and weak regulatory oversight, which characterize last-mile logistics in developing regions (Jurburg et al., 2023). At the same time, the rapid growth of e-commerce has intensified the demand for last-mile deliveries and contributed to shifts in household freight flows that traditional transport and freight models often fail to fully capture, potentially leading to misestimations of transport impacts (Beckers et al., 2022). More broadly, e-commerce-related last-mile logistics has been associated with interconnected economic, social, environmental, and operational pressures that shape the performance and externalities of urban freight systems (Viu-Roig & Alvarez-Palau, 2020).

A growing stream of research has examined strategies to mitigate last-mile externalities and improve sustainability. Evidence suggests that urban micro-hubs, cargo bikes, and metro-based parcel deliveries can reduce congestion and emissions by leveraging alternative distribution models (Villa & Monzón, 2021). Similarly, shipment consolidation and flexible delivery time windows have been identified as interventions capable of reducing vehicle-miles traveled (VMT) and fuel consumption while maintaining service efficiency (Nogueira et al., 2022). However, rapid delivery and instant fulfillment models may also increase logistical fragmentation, raising concerns about energy consumption and broader sustainability trade-offs in urban freight systems.

Importantly, in many contexts, operational and sustainability interventions unfold within institutional, labor, and governance regimes where informality and platform-based work shape how delivery is performed in practice. The gig economy has reinforced labor precarization, exposing workers to unstable conditions, lack of formal contracts, and the absence of social protections (Novoa Márquez et al., 2017). Research on platform couriers in Latin America highlights that these workers frequently experience low wages, hazardous conditions, and legal uncertainty, situating delivery work within broader dynamics of informal employment (Bogoya Viasus et al., 2021). In platform-mediated delivery markets, algorithmic management systems based on performance monitoring and key performance indicators may further intensify work pressure, uncertainty, and risk transfer to workers (Asadullah, 2024). While some countries have enacted labor protections such as Spain's "Riders Law," others continue to classify couriers as independent

contractors, sustaining informal labor arrangements across platform-based delivery markets (Dablanc, 2023). These regulatory debates underscore the need for frameworks that balance worker protections with operational flexibility, particularly where last-mile systems evolve faster than institutional responses.

In such settings, the widespread use of motorcycles is closely linked to the fragmentation and informalization of the last-mile operator market. As formal logistics systems struggle to absorb growing demand, independent couriers increasingly rely on motorcycles as a low-cost and flexible alternative to trucks, particularly for small-parcel delivery. These operational conditions interact with road safety risks, as strict delivery time pressures can encourage speeding, unsafe maneuvers, and risk-taking behaviors (Dablanc et al., 2017). Studies in Latin America show that gig couriers frequently engage in risky riding practices, including mobile phone use while riding, as a result of job-related stress and financial incentives (Christie & Ward, 2023). Evidence from the region further suggests that informal employment conditions among motorcycle couriers may contribute to unsafe behaviors and elevated crash risk, driven by extended working hours and limited protections (De Oliveira et al., 2024). Addressing these risks requires improved training, stricter enforcement, and stronger safety standards in last-mile delivery operations (Nguyen-Phuoc et al., 2023).

Despite the rapid expansion of e-commerce-driven last-mile logistics, its negative societal impacts remain insufficiently characterized, particularly in developing economies where informal labor arrangements and weak regulatory oversight shape delivery systems. Existing research has provided important insights into sustainability strategies, platform-based labor dynamics, and specific safety or environmental risks. However, this literature remains fragmented across analytical lenses, offering limited integrated explanations of how mobility impacts, labor precarization, governance constraints, and safety risks interact within the same last-mile delivery system. As a result, existing research provides limited explanatory accounts of how these dimensions co-evolve and reinforce one another in contexts where informality becomes structurally embedded in last-mile operations. Against this backdrop, understanding which contextual conditions most strongly shape and connect these externalities remains an open empirical question — one that this study addresses through inductive inquiry into the societal impacts of e-commerce last-mile delivery.

1.3. Study overview, objectives, contribution, and research questions

Using an inductive qualitative approach and an explanatory case study design, the research draws on semi-structured interviews with five stakeholder groups: delivery drivers, e-commerce companies, public sector representatives, logistics and road safety experts, and society representatives. Although the empirical focus is on Medellín, the patterns identified are consistent with dynamics documented across diverse urban contexts. Similar dynamics—such as informal labor arrangements, weak regulatory oversight, and fragmented last-mile systems—have been documented in both developing and developed cities, although they manifest differently depending on institutional capacity and labor regimes. This highlights the need for comparative analysis and adaptive policy responses that account for structural vulnerabilities across diverse urban settings. Medellín thus serves as an instrumental case to generate broader insights into how informal practices reshape last-mile logistics.

In this study, informal workers are understood as individuals engaged in work arrangements that lack formal contractual relationships, social protection, and regulatory oversight, in line with established international and national statistical frameworks. According to the International Labour Organization, informal employment refers to work that is not regulated or protected by legal or institutional frameworks and is characterized by the absence of formal contracts, employment benefits, and access to social protection systems (ILO, 2013; ILO, 1993). In the Colombian context, informality is commonly

operationalized through the absence of formal employment contracts, lack of contributions to social security systems, and employment in small or unregistered economic units (DANE, 2022).

In this context, last-mile delivery workers are approached as operating under labor arrangements that often lack formal contracts, clearly defined obligations, and access to employment-related benefits. These conditions are evident across different organizational models of last-mile delivery, including both platform-mediated systems and more traditional logistics operations, where work is frequently structured through flexible, subcontracted, or partnership-based schemes. Such arrangements may blur the boundaries between formal and informal employment, particularly in contexts where responsibilities and risks are not clearly assigned.

The study pursues two objectives: (1) to identify the negative societal impacts associated with e-commerce last-mile delivery, and (2) to explain the mechanisms through which e-commerce-driven last-mile practices generate and amplify these impacts in urban contexts.

This paper contributes to the literature on urban freight and transport governance by offering an integrated explanation of the societal externalities generated by e-commerce last-mile delivery, highlighting how informality becomes structurally embedded in last-mile practices and amplifies interrelated impacts across mobility, labor, and governance domains. By doing so, it helps bridge sustainability, labor, and mobility perspectives that are often treated separately in last-mile research. While the study is concerned with the broader societal impacts of e-commerce last-mile delivery, the inductive analysis revealed informality as a central mechanism through which many of these impacts are produced, reinforced, and distributed across stakeholders. This was a finding that emerged from the data rather than a predefined focus of the inquiry.

The following questions guide the research: RQ1. What are the negative impacts of e-commerce last-mile delivery on society? RQ2. Why does e-commerce generate these negative effects?

1.4. Preliminary conceptual framework

Drawing on the literature reviewed above, this study adopts a preliminary conceptual framework to organize the main dimensions through which e-commerce last-mile delivery may generate negative societal impacts and externalities. Rather than proposing a formal causal model, this framework provides an analytical structure to guide data collection and interpretation, supporting an integrated reading of how impacts on mobility, labor conditions, governance, and environmental

performance can co-exist and reinforce one another within the same urban delivery system. In particular, the framework highlights how e-commerce delivery configurations (including platform-mediated models), operational time pressures, and fragmented delivery flows may interact with regulatory capacity and the use of public space, potentially shaping risk exposure and externalities across different stakeholders. Specifically, the drivers and operational features dimension draws on evidence regarding e-commerce growth, delivery speed expectations, and platform-mediated coordination (BlackSip, 2023; Briana & Malindretos, 2025; Asadullah, 2024); the contextual conditions dimension is informed by literature on regulatory capacity, infrastructure constraints, and the structure of informal labor markets (Jurburg et al., 2023; Sanchez-Diaz et al., 2021; Bogoya Viasus et al., 2021), as well as by the authors' contextual observations regarding the atomization of operators in the last-mile market; and the societal impacts dimension synthesizes evidence on mobility, environmental, safety, and governance externalities (TomTom, 2024; SIATA, 2023; ANSV, 2021, 2022; Nguyen-Phuoc et al., 2023). This preliminary framework is presented in Fig. 1 and serves as an analytical reference point for the subsequent qualitative analysis.

Source: Authors' elaboration based on the literature reviewed. This preliminary framework summarizes key dimensions discussed in prior research and provides an orienting lens for the empirical inquiry. It is not intended as a deterministic causal model; rather, it offers a structured starting point that was subsequently refined through inductive analysis of stakeholder interviews. The arrows represent an analytical ordering rather than a deterministic causal chain.

2. Methodology

This study employs a qualitative approach with an explanatory and instrumental case study design to examine the societal impacts of e-commerce last-mile logistics in a developing country context. The research is based on semi-structured interviews with key stakeholders, followed by inductive thematic analysis informed by grounded theory coding procedures to identify patterns and relationships.

2.1. Study design

The study follows an inductive, theory-building logic (Ketokivi & Choi, 2014), whereby empirical findings serve as the foundation for developing new theoretical insights. This logic is implemented within an explanatory and instrumental qualitative case study design, which

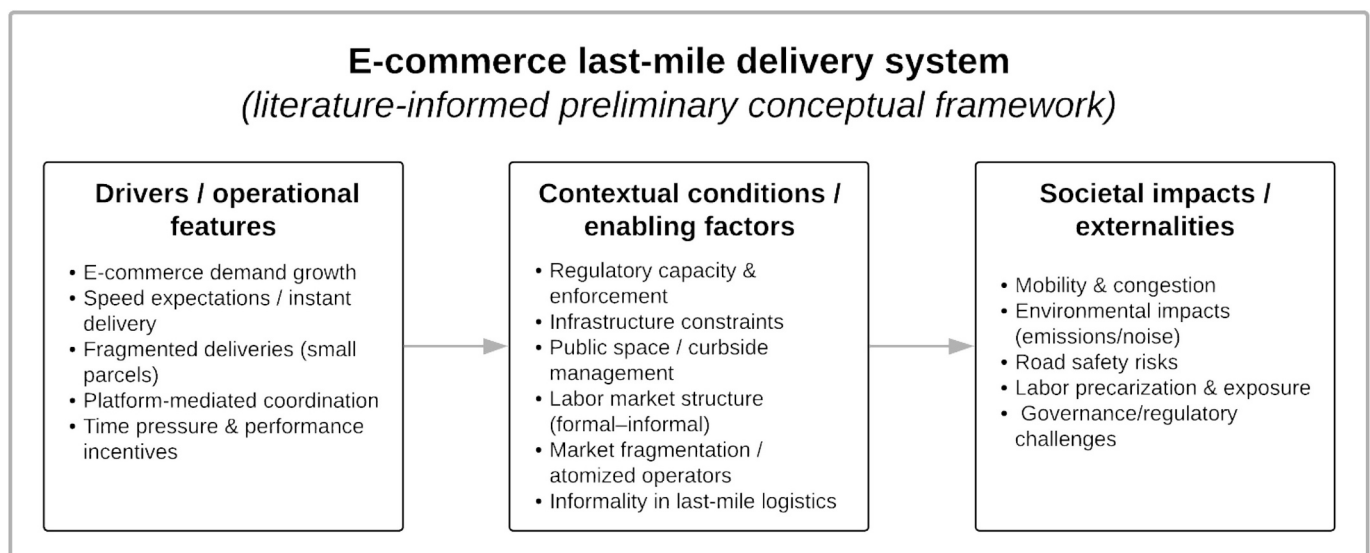


Fig. 1. Preliminary conceptual framework of societal impacts in e-commerce last-mile delivery.

allows for an in-depth examination of a bounded spatial and temporal system (Bell et al., 2022).

Medellín, Colombia, was selected as the empirical setting due to its complex urban logistics landscape, characterized by high inequality (Gini coefficient: 0.512), a vibrant economic activity (160,173 establishments), and a contribution of 12 % to Colombia’s Gross Domestic Product (DANE, 2024). Medellín represents a context where logistical challenges intersect with informal practices, making it a suitable setting for examining last-mile delivery issues in developing economies.

This design was selected because the research aimed to identify the societal impacts of e-commerce last-mile delivery as recognized across diverse actor groups, to understand how these impacts relate to one another, and to explain the mechanisms through which they emerge and are sustained within a specific urban context. This kind of integrated, mechanism-oriented explanation requires primary evidence generated within a bounded real-world setting, where the interplay between actors, institutions, and operational conditions can be examined in depth (Flyvbjerg, 2006; Creswell & Poth, 2016). Case study designs with qualitative interviews are well established in last-mile logistics research (Olsson et al., 2019) and have been applied to examine stakeholder perspectives on urban freight challenges in contexts where multiple actors — including public authorities, private companies, and workers — hold divergent views on the same system (Maxner et al., 2022).

2.2. Participant Selection and sampling

A purposive sampling strategy was employed to capture diverse perspectives on last-mile logistics. 64 semi-structured interviews were conducted across five stakeholder groups (see Table 1). Recruitment continued until thematic saturation was reached, defined as the point at which additional interviews no longer generated substantively new codes or relationships relevant to the research questions (Guest et al., 2006; Morse, 2000).

2.3. Data collection instruments

Semi-structured interviews were conducted with five stakeholder groups to capture diverse perspectives on last-mile logistics (Ryen, 2013). A purposive sampling approach ensured the inclusion of participants directly involved in or affected by last-mile delivery (Mertens, 2019). The interview guides were refined through a pilot test to improve clarity and contextual relevance. Given the study’s focus on internal perceptions and societal impacts, interviews were the most suitable method (Janesick, 2015). They were conducted in person or virtually, lasting 15 to 45 min, recorded with informed consent, and transcribed for qualitative analysis.

Table 1
Stakeholder Groups and Sample Distribution.

Stakeholder group	Participants	Description
Society	22	Residents, pedestrians, and cyclists affected by last-mile delivery
Delivery drivers	20	Drivers involved in last-mile delivery for e-commerce platforms, marketplaces, and retail businesses use trucks, vans, motorcycles, or bicycles. This includes platform workers, informal couriers, and transport companies' employees.
Logistics experts	10	Academics and professionals in transportation and urban logistics
E-commerce companies	6	Representatives from marketplaces, logistics firms, and delivery operators
Public sector	6	Government officials and policymakers

2.4. Data analysis procedure

Data analysis followed an inductive, structured qualitative coding process informed by grounded theory procedures, implemented within the explanatory case study design (Strauss & Corbin, 1998; Creswell & Poth, 2016).

In the open coding phase, interview transcripts were reviewed to identify key concepts and assign initial codes. Axial coding was then used to group and reorganize these codes into higher-order categories and to establish relationships among them. Selective coding integrated the most salient categories into a coherent explanatory account of the case, which informed subsequent analytical synthesis. These coding procedures were used as analytical tools to structure the inductive interpretation of the case, rather than to develop a formal grounded theory.

Data triangulation ensured credibility by comparing findings across stakeholder groups (Miles, Huberman & Saldana, 2014). NVivo software facilitated data organization, coding precision, and category visualization, enhancing interpretative depth. Peer review, transferability, and confirmability were systematically applied to ensure rigor.

2.5. Validity, reliability, and ethical considerations

The study ensured validity and reliability through data triangulation, comparing findings across stakeholder groups to reinforce the consistency of emerging categories (Miles et al., 2014). Peer review assessed the coherence of coding structures, and thematic saturation confirmed that no new insights emerged from additional interviews. Dependability and credibility were maintained through transparency in the coding process and detailed contextual descriptions, supporting transferability to other urban settings (Mertens, 2018; Given & Saumure, 2008). Researcher reflexivity minimized bias, ensuring confirmability (Savin-Baden & Major, 2013).

Ethical principles were strictly followed. Informed consent was obtained, and confidentiality was ensured through anonymization. Participants had the right to withdraw at any stage, and data was securely stored following ethical research guidelines.

3. Findings

This section presents the qualitative findings derived from the three-stage coding process (open, axial, and selective coding). Collectively, the findings address the study’s two research questions by identifying the main societal impacts associated with e-commerce last-mile delivery and by explaining the organizational, regulatory, and labor-related mechanisms through which these impacts are generated and sustained. Consistent with the inductive logic of the study, informality was not posited in advance but emerged from the coding process as the central explanatory category most consistently connecting the societal impacts identified across stakeholder groups.

3.1. Phase 1. Open coding

In this phase, the interview transcripts were decomposed into meaningful units and initial codes reflecting emerging key concepts through Open Coding. The complete set of Open Coding labels is visually synthesized in the framework presented in Section 3.3, which also incorporates the subsequent axial and selective coding phases.

3.1.1. Top-Cited open codes across stakeholders

To capture recurring discursive patterns we identified which codes from the open coding phase were not only frequently mentioned but also cited across the broadest range of stakeholder groups. Fig. 2 presents a subset of the most salient codes, plotted by total number of references and the number of groups that referred to them. These codes—such as *delivery time pressure*, *lack of regulation*, and *informality as a competitive*

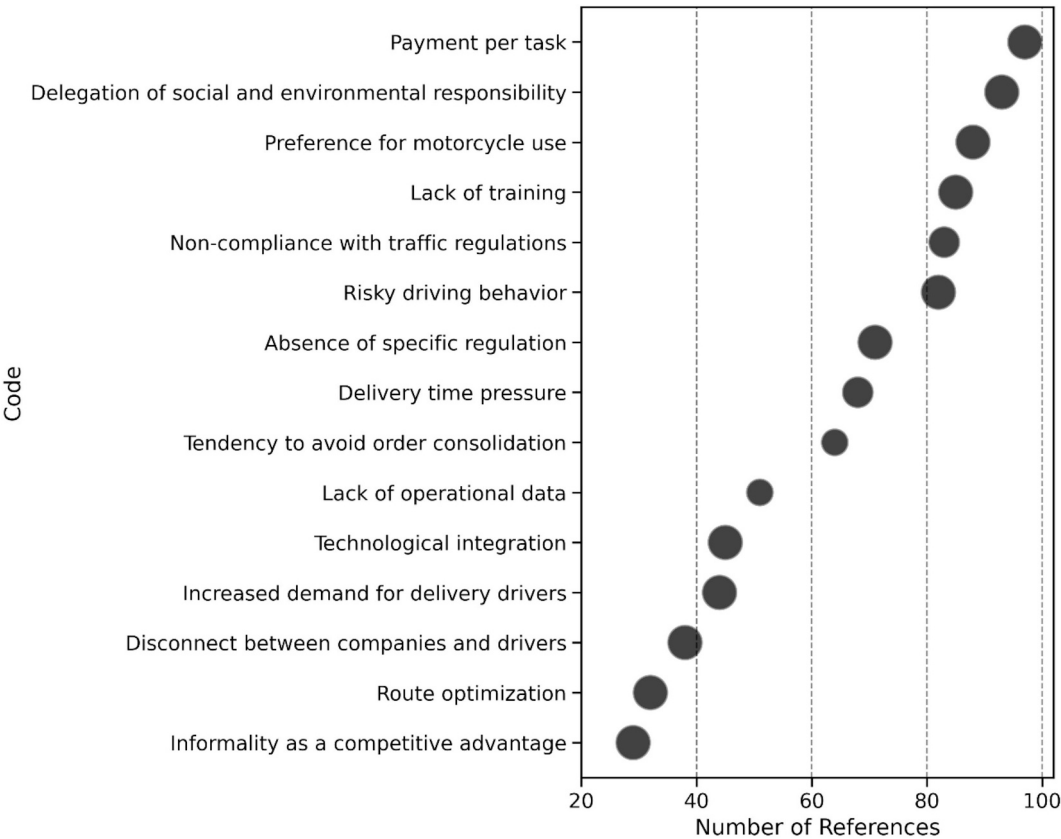


Fig. 2. Most Frequently Mentioned Open Codes Across Stakeholders. .
Source: Authors’ elaboration based on interview coding using NVivo

advantage—emerged as structurally relevant themes rather than actor-specific concerns. This reinforces the analytical argument that certain dynamics—particularly those related to informality, precarious labor conditions, and weak regulatory oversight—are widely recognized across actors and play a foundational role in shaping the last-mile e-commerce delivery model in developing urban contexts.

The figure displays the most frequently cited open codes, based on total number of references and the number of stakeholder groups (out of five) that mentioned them. Each bubble represents a code, and the size reflects the number of groups referring to it.

3.2. Phase 2. Axial coding

The second phase, Axial Coding, focused on grouping and reorganizing the initial codes into broader categories to establish relationships and connections between categories. These categories include Road Safety Risks, Labor Precarization, Public Regulation, Informal Transporters or “Popular Economy”, Company Adaptation, Consumer Behavior, Sustainability and Social Responsibility, and Informality. This phase enabled the identification of relationships between categories and the structuring of the analytical framework that underpins the subsequent analysis.

In this phase, where the initial codes identified in Phase 1 are grouped and reorganized, various relationships and thematic groupings within last-mile logistics become evident. One of the main emerging aspects is technological integration, which companies drive to optimize logistics operations. Technologies such as digital applications, APIs, and data analytics facilitate process automation and inventory management, aiming to reduce costs and delivery times. However, this transformation also promotes outsourcing last-mile deliveries, shifting operations to informal workers.

Recurrent characteristics and motivations among informal

transporters are also identified. On one hand, easy market access and lack of financial planning are common traits in this sector. On the other hand, key motivations include immediate income, flexible schedules, and work independence, making this sector particularly attractive to migrants and other vulnerable workers. These dynamics contribute to consolidating an unregulated market within the delivery sector.

Within this phase, relationships between the lack of regulation and labor precarization become evident. The absence of regulation creates a normative gap, limiting control over negative externalities such as traffic accidents and tax evasion. At the same time, informal transporters face unstable working conditions, characterized by long working hours, lack of insurance, and absence of protective equipment, exposing them to greater risks.

Additionally, connections between informality, road safety, and sustainability are observed. Risky behaviors, such as speeding and distractions, are frequent among informal transporters, increasing the likelihood of accidents. In terms of sustainability, the predominant use of traditional vehicles and the lack of incentives for adopting sustainable fleets emerge as factors that worsen environmental issues, such as air pollution and urban noise.

3.2.1. Stakeholder engagement with axial categories

To deepen the qualitative findings and illustrate how perceptions of last-mile logistics vary across actor groups, a heatmap was developed (Fig. 3). This visualization cross-references the number of mentions for each axial category by stakeholder group, based on the total number of coded references across interviews. The density of references serves as a proxy for thematic salience.

Several patterns emerge. Delivery drivers most frequently referred to issues related to labor precariousness and risk exposure, while e-commerce companies emphasized operational adaptations and consumer-driven demand. Logistics experts demonstrated a more evenly



Fig. 3. Heatmap of Stakeholder References by Axial Category. .

Source: Authors' elaboration based on interview coding using NVivo

distributed concern across categories, including sustainability and regulatory gaps. Meanwhile, public sector representatives focused predominantly on the lack of governance tools and institutional fragmentation, and society mainly expressed concerns around road safety and the visible impacts of informality in public space.

3.3. Phase 3. Selective coding

This final phase involved the integration of axial categories into a coherent explanatory account of the case, which was subsequently synthesized into an emergent conceptual framework to visually represent the relationships among key factors surrounding informality. This interpretive model—highlighting the central role of informality and its relationship with other thematic dimensions—is visually incorporated into Fig. 4, along with the outputs from the open and axial coding phases. At the center of the model lies informality, which both influences and is shaped by five key dimensions: company adaptations, such as the outsourcing of last-mile deliveries; consumer behavior, which reinforces dynamics like the preference for fast and low-cost deliveries; public regulation, characterized by normative gaps that limit control over the informal sector; labor precariousness, marked by unsafe and unprotected working conditions; and road safety risks and sustainability and social responsibility, which are exacerbated by these dynamics. Informality lies at the center of this framework, emerging as the key factor that connects and amplifies the negative impacts of e-commerce last-mile delivery. Its persistence is linked to regulatory gaps, economic incentives, and business strategies that favor flexible, low-cost operations, further intensifying challenges such as labor precarization, road safety risks, and environmental sustainability. Within this dimension, the absence of specific regulatory frameworks has allowed informality to thrive. Factors such as weak law enforcement, lack of reliable data, and gaps in public policies have shifted external costs to society while increasing operational risks in last-mile logistics.

Likewise, informality significantly contributes to road safety risks. Many transporters lack proper training, protective equipment, and insurance, leading to higher accident rates and affecting both workers and other road users. Additionally, e-commerce companies prioritize operational efficiency, frequently relying on informal logistics networks to cut costs and accelerate deliveries. Digital platforms and marketing

strategies reinforce this model by promoting fragmented orders and fast delivery cycles, embedding informality as a structural feature of last-mile logistics.

3.3.1. Stakeholder perspectives on informality in last-mile logistics

This section combines a comparative matrix with a thematic profile of each stakeholder group to enrich the analysis of how informality operates across institutional and operational dimensions. While Table 2 concisely synthesizes the main concerns, perceived structural causes, and proposed responses, the following paragraphs offer a more nuanced reading of the discursive emphasis, interpretive frames, and tensions identified by different actors. This dual approach reinforces the idea that informality is not experienced uniformly, but refracted through the distinct positionalities of those who participate in, govern, or are affected by e-commerce last-mile logistics.

Beyond the shared issues captured in the matrix, the qualitative data reveals specific discursive patterns and symbolic framings that shape how each group relates to informality. These thematic profiles summarize the dominant narratives and highlight the key contradictions, justifications, or proposed solutions articulated by stakeholders.

Delivery drivers express deep concern over labor precariousness, insecurity, and the absence of labor rights. Their discourse revolves around unstable incomes, unsafe conditions, and the lack of institutional support. Informality is not perceived as a temporary condition but as a normalized operating mode reinforced by subcontracting, algorithmic control, and performance-based compensation. Although some acknowledge the flexibility and autonomy of the work, most drivers report intense time pressure, exposure to violence, and economic vulnerability. Few propose collective solutions, but many call for formalization, insurance coverage, and regulatory delivery incentive structures.

E-commerce companies focus primarily on operational efficiency and rapid delivery fulfillment. Their narratives reveal a preference for outsourcing last-mile operations, which is framed as a necessary strategy to remain competitive in a demanding market. Informality is often downplayed or regarded as external to their core business. Although some firms are experimenting with sustainable practices or formal alliances, these efforts remain limited in scope. The responsibility for externalities—such as road safety or labor conditions—is rarely

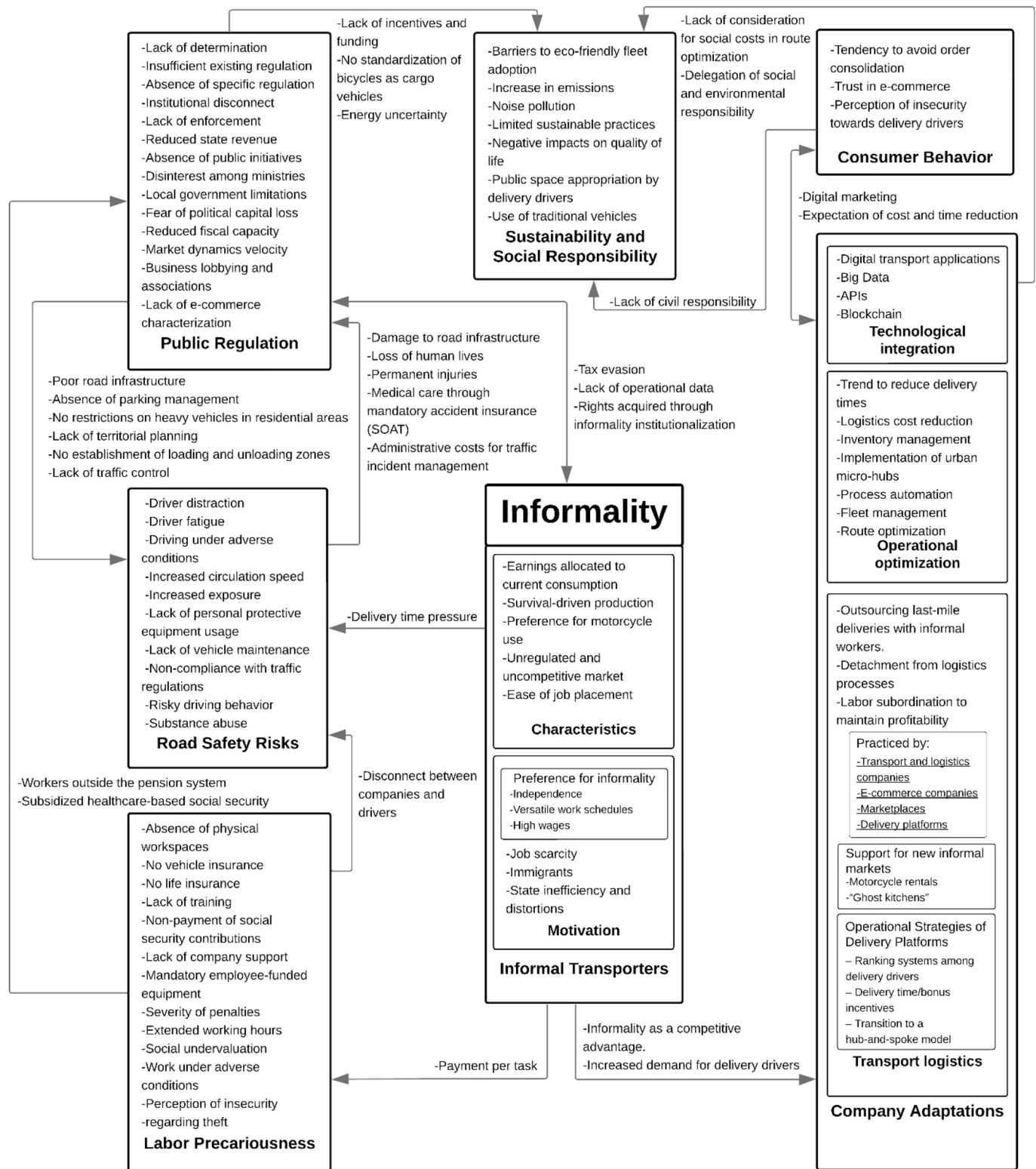


Fig. 4. Emergent Conceptual Framework of Informality in Last-Mile E-commerce Logistics: An Analytical Synthesis of Open, Axial, and Selective Coding. .
 Source: Authors' elaboration based on interview coding using NVivo. This figure presents an emergent conceptual framework that synthesizes the explanatory insights derived from the open, axial, and selective coding phases. It displays the complete set of labels derived from the open coding phase, some grouped into axial categories, while others function as connectors between them. The figure visualizes the thematic relationships that emerge across dimensions such as road safety risks, labor precarization, public regulation, consumer behavior, sustainability, and company strategies. At the center of the framework lies informality—not as a marginal issue, but as the structuring logic that links and amplifies these interconnected elements within the logistics system

Table 2
Stakeholder Perspectives on Informality in E-commerce Last-Mile Logistics.

Stakeholder group	Main Concern	Perceived Cause	Suggested Solution
Delivery Drivers	Precarious working conditions, insecurity, and lack of rights	Subcontracting schemes, absence of social protections, performance-based pay, and algorithmic pressure	Labor formalization, access to insurance, safety training, regulation of incentives and rankings
E-commerce Companies	Operational efficiency, meeting delivery times	Market competition, demand for speed, preference for flexible labor arrangements	Strategic outsourcing, pilot sustainability initiatives, partial recognition of externalities
Public Sector	Weak enforcement, lack of regulatory tools and data	National vs local gaps, fragmented governance, lobbying by private actors	Comprehensive platform regulation, fiscal reforms, public data systems, territorial planning mechanisms
Logistics Experts	Structural informality, unchecked externalities	Business models based on externalization, absence of regulatory innovation	Integrated governance, sustainability standards, enforcement of social and environmental obligations
Society	Road safety risks, noise, lack of transparency	Informal labor dynamics, insufficient public awareness	Consumer education, courier-friendly infrastructure, demand-side responsibility policies

acknowledged, and proposals for change are framed in terms of efficiency rather than equity.

Public sector representatives describe structural limitations in regulating e-commerce logistics. They highlight regulatory gaps, lack of institutional coordination, and limited access to operational data as major obstacles. Informality is recognized as a governance failure and a politically sensitive issue, given the social vulnerability of many informal workers. While there is awareness of the need for regulation and planning instruments, actors emphasize their restricted capacity to intervene in platform-based markets. Few local governments have implemented logistics policies, and those often lack support at the national level.

Logistics experts present a more systemic view of informality, linking it to platform business models, deregulation, and externalized costs. Their narratives frame informality as a structural feature rather than a peripheral issue or isolated deficiency. Many criticize the passive role of the state and highlight the need for integrated governance, planning frameworks, and sustainability benchmarks. Informality is associated with labor exploitation, environmental degradation, and road safety risks. Experts also point to technological and fiscal tools that could redistribute costs more equitably, including data regulation, taxation, and public investments in infrastructure.

Representatives of society express ambivalence toward last-mile delivery. While appreciating the convenience of rapid deliveries, many interviewees raise concerns about traffic safety, noise, and public space occupation by delivery drivers. Informality is not always clearly identified, but its effects—such as reckless driving and lack of accountability—are frequently mentioned. Public discourse reflects a limited understanding of the logistics chain, reinforcing the idea of e-commerce as a “black box.” Still, some participants suggest infrastructure improvements and stricter controls on driver behavior as partial remedies.

3.3.2. Informality as the structural challenge of e-commerce last-mile logistics

The growth of e-commerce has transformed urban logistics globally, reshaping the distribution of goods and transportation models. However, this transformation has been accompanied by an increase in informality, which has allowed companies to reduce labor and operational costs while shifting risks onto workers and society. As one expert interviewee stated, “*Platforms promote informality and also encourage an unregulated market to take control of distribution processes.*” This informality has become the structural axis of the sector, affecting couriers’ working conditions, road safety, and market regulation. One of the main consequences of this model is labor precarization, as most couriers operate without formal contracts, social security, or stable working hours. A delivery worker expresses this reality: “*I have no fixed salary, I manage my own schedule, but my daily goal depends on how much I can work, and customers often do not respect couriers.*” The absence of labor guarantees and the lack of formal recognition of these workers as employees is a deliberate strategy by platforms, as acknowledged by a company representative: “*There is no written employment relationship; everything is managed as independent work.*” This implies that the safety and well-being of couriers depend entirely on their individual ability to cover costs that should be borne by the platforms. Another worker states, “*The uniform and thermal box are paid for by us, even though they are mandatory; the platform does not contribute a single penny.*”

The pressure to complete deliveries quickly has also affected road safety, as working conditions encourage risky behaviors. A public sector regulator warns, “*There is no regulation over platforms. They do not require insurance policies for their couriers, and this causes the system and formality to disappear.*” This regulatory void allows companies to operate without assuming responsibility for their workers’ safety, leaving couriers highly vulnerable. As one delivery worker explains, “*You can never be certain that you’ll make it home; accidents are common, especially in the rain or when rushing to meet deadlines.*” The need to meet tight delivery schedules and the lack of adequate safety measures make accident rates among motorcycle couriers alarmingly high. As an expert succinctly puts it, “*The business model based on fast deliveries encourages couriers to violate traffic regulations, increasing risks.*” Another critical aspect of this issue is the lack of effective regulation, allowing companies to outsource transportation responsibilities. As described by a logistics sector representative, “*All our logistics are outsourced, and subcontracted companies have their own standards, but the ultimate responsibility for road safety falls on them.*” This outsourcing creates a disconnect between platforms and workers, enabling companies to evade any labor or safety regulation. From the public sector’s perspective, the absence of specific regulations is one of the biggest barriers to addressing this issue: “*There is no specific law that allows us to regulate them. They are currently governed by existing mobility regulations, such as the National Traffic Code, but there is nothing focused on planning their movement across the territory.*”

Moreover, the lack of regulation not only affects workers but also the sustainability of the logistics system. An industry expert highlights how e-commerce incentives have increased urban traffic, exacerbating environmental and mobility problems: “*People tend to place small and multiple consecutive orders. They do not consolidate; they buy a pencil today and a sharpener tomorrow.*” This fragmented distribution model has increased city congestion and emissions, without companies bearing the associated environmental costs. Another expert further elaborates, “*Social costs, such as congestion and road accidents, are not borne by the producer or the consumer. They fall on society as a whole, but no one internalizes them.*”

On the other hand, informality has also created barriers to adopting more sustainable logistics models. One expert explains, “*The problem with informality creates obstacles for more formalized actors to access sustainable processes.*” Many formal companies seeking to implement clean technologies or more efficient models cannot compete with informal platforms operating without regulatory compliance costs. A public sector regulator emphasizes the difficulty of regulating this market:

“Regulating informality is very difficult because these workers acquire rights, and taking them away later becomes a social and political problem.”.

From the consumer perspective, e-commerce is perceived as a ‘black box’, where the entire distribution chain remains hidden. One citizen interviewee notes, *“I think it’s like a black box, right? For both the e-commerce store and the user. It’s just that I bought from the store, and they deliver it to my door. Whatever happens in between is unknown to all of us.”* This lack of transparency contributes to perpetuating the informal model, as consumers prioritize fast delivery times without questioning the conditions under which they are carried out. The findings of this study demonstrate that informality is not merely an isolated problem but rather a structural axis that amplifies the challenges of last-mile e-commerce logistics. The outsourcing of transportation, lack of regulation, and labor precarization have created an environment where platforms maximize their profits at the expense of unprotected workers and unaccounted externalities. As one expert warns, *“Companies outsource transportation, but that means they avoid the social responsibility they should have.”.*

However, this informality is no longer just a side effect of market expansion; it has become an embedded and institutionalized feature of last-mile logistics, reinforced by weak regulatory frameworks and an absence of enforcement mechanisms. A public sector official acknowledged this challenge: *“The state is losing revenue because we are moving from a tangible, formal economy to something intangible that is not regulated.”* Without clear policies or intervention strategies, informality continues to thrive, shifting economic and social costs onto the public while depriving the state of necessary tax revenues. This self-reinforcing cycle suggests that informality is not just a challenge for workers and regulators but a defining characteristic of e-commerce logistics, particularly in developing economies, where the lack of regulation and oversight reinforces it. However, its effects are also evident in developed economies, where it manifests differently, often through flexible work

schemes and avoiding labor responsibilities via atypical contracts. In this context, the debate on regulation and governance strategies becomes central to understanding how logistics models can evolve without relying on informality as a competitive advantage. Analyzing these challenges in different urban settings is key to rethinking the regulatory and operational frameworks that shape last-mile logistics and its long-term sustainability.

3.3.3. Business model configuration based on informality

To consolidate the empirical findings and provide a systemic representation of how informality is embedded within last-mile logistics, the Business Model Canvas framework (Osterwalder & Pigneur, 2010) was adapted to examine the organizational configuration of platform-based delivery systems critically. This section focuses on digital platforms that mediate last-mile deliveries—such as food delivery and on-demand courier services—given their high prevalence of informal labor and their central role in shaping the sector’s operational logic. Although informality in e-commerce last-mile logistics also emerges through broader outsourcing arrangements and informal courier networks, platform-based delivery services represent a particularly influential configuration because they centralize coordination, incentive-setting, and operational control across fragmented delivery systems.

As shown in Fig. 5, practices repeatedly identified across interviews—such as subcontracting schemes, flexible contractor-type arrangements, algorithmic incentive structures, and centralized operational control over couriers—are not marginal operational choices but structurally integrated elements of the platform model. The canvas was inductively derived from the qualitative analysis and illustrates how these practices become embedded in the value proposition, cost architecture, and key activities of platform-based urban logistics. In this configuration, operational speed and convenience are sustained through the systematic externalization of labor and compliance costs, while

Key Partners - Partner restaurants and merchants. - Outsourced courier companies. - Payment platforms and insurers. - Public regulatory bodies with limited enforcement capacity.	Key Activities - Software development and algorithmic coordination of orders. - Digital marketing and user acquisition. - Design of gamified incentive systems for couriers. - Design of subcontracting schemes and performance monitoring. - Full externalization of logistical operations.	Customer Segments - Urban consumers demanding fast and convenient deliveries. - Small businesses outsourcing their logistics. - Large marketplaces integrating last-mile services. Key Resources - Technological infrastructure (apps, algorithms, servers). - Large workforce of outsourced or informal couriers. - Brand, data, and digital network as core assets.	Customer Relationships - Self-service and algorithmic customer support. - Minimal human interaction. - Algorithmic opacity regarding who delivers and under what conditions. Channels - Mobile apps and automated digital platforms. - Integration with online stores and push notifications.	Value Propositions - Fast, low-cost, on-demand deliveries. - Flexible earning opportunities for couriers. - Frictionless shopping and delivery process. - Convenience enabled by logistical opacity. - Externalization of labor, social, and environmental costs.
Cost Structure - Limited to digital infrastructure and advertising. - No investment in vehicles, insurance, training, or safety equipment. - Cost structure strategically relies on labor externalization and absence of regulatory enforcement.	Revenue Streams - Merchant commissions: percentage charged per transaction (typically 10%–30%). - Consumer delivery fees: including surge pricing based on demand, weather, or distance. - Data monetization: through predictive analytics, ad targeting, and commercial partnerships. - Platform advertising: paid placement for merchants and services. - Regulatory arbitrage: profit margins increased by avoiding labor benefits and social contributions.			

Fig. 5. Critical Business Model Canvas of Platform-Based Last-Mile Logistics Structured by Informality. This model synthesizes the organizational logic of platform-based logistics systems in urban e-commerce. It highlights how informality—through labor externalization, regulatory evasion, and cost shifting—functions as a foundational component embedded in the value proposition, operational architecture, and revenue model of last-mile delivery platforms.

Source: Adapted from Osterwalder and Pigneur (2010)

responsibilities related to occupational safety, insurance, and social protection are displaced to workers and, indirectly, to public systems.

Accordingly, Fig. 5 functions as an integrative synthesis of the mechanisms identified in the findings rather than as a predefined analytical model. By clarifying how the platform business architecture enables and reproduces informal operational arrangements, the figure directly supports the explanatory aim of the study and strengthens the empirical response to the second research question.

3.3.4. Redistribution of value, risk, and responsibility in informal last-mile logistics

To synthesize the operational architecture of informality in last-mile e-commerce logistics, a value flow map was developed (Fig. 6) as an interpretive representation grounded in the empirical findings. This conceptual diagram identifies seven key actors—consumers, digital platforms, merchants, delivery workers, informal courier networks, public institutions, and society—and illustrates the main flows between them: economic transactions, labor input, data/information, externalized risks, and control dynamics.

The map reveals how value circulates asymmetrically through the

system. Digital platforms and merchants concentrate revenue, data, and operational decision-making, while couriers absorb labor, financial, and safety risks without guarantees or institutional protections. Public institutions and society bear the broader externalities of the model, such as fiscal losses, congestion, and environmental degradation. Informal courier networks—organized via alternative channels like WhatsApp—reproduce these same dynamics outside regulatory frameworks, particularly in peripheral or underserved areas. Rather than treating informality as a peripheral failure, the map shows how it becomes structurally embedded in the logic of urban e-commerce logistics, enabling the redistribution of responsibility and cost away from the core actors and toward unprotected individuals and the public sphere.

Accordingly, Fig. 6 functions as an integrative synthesis of the study's results: it supports the first research question by making the distribution of societal impacts explicit, and it reinforces the second research question by illustrating how value capture by central actors is enabled through the displacement of risks and costs to delivery workers and public institutions.

This Value Flow Map was developed inductively from qualitative data, reflecting an interpretive synthesis grounded in empirical findings

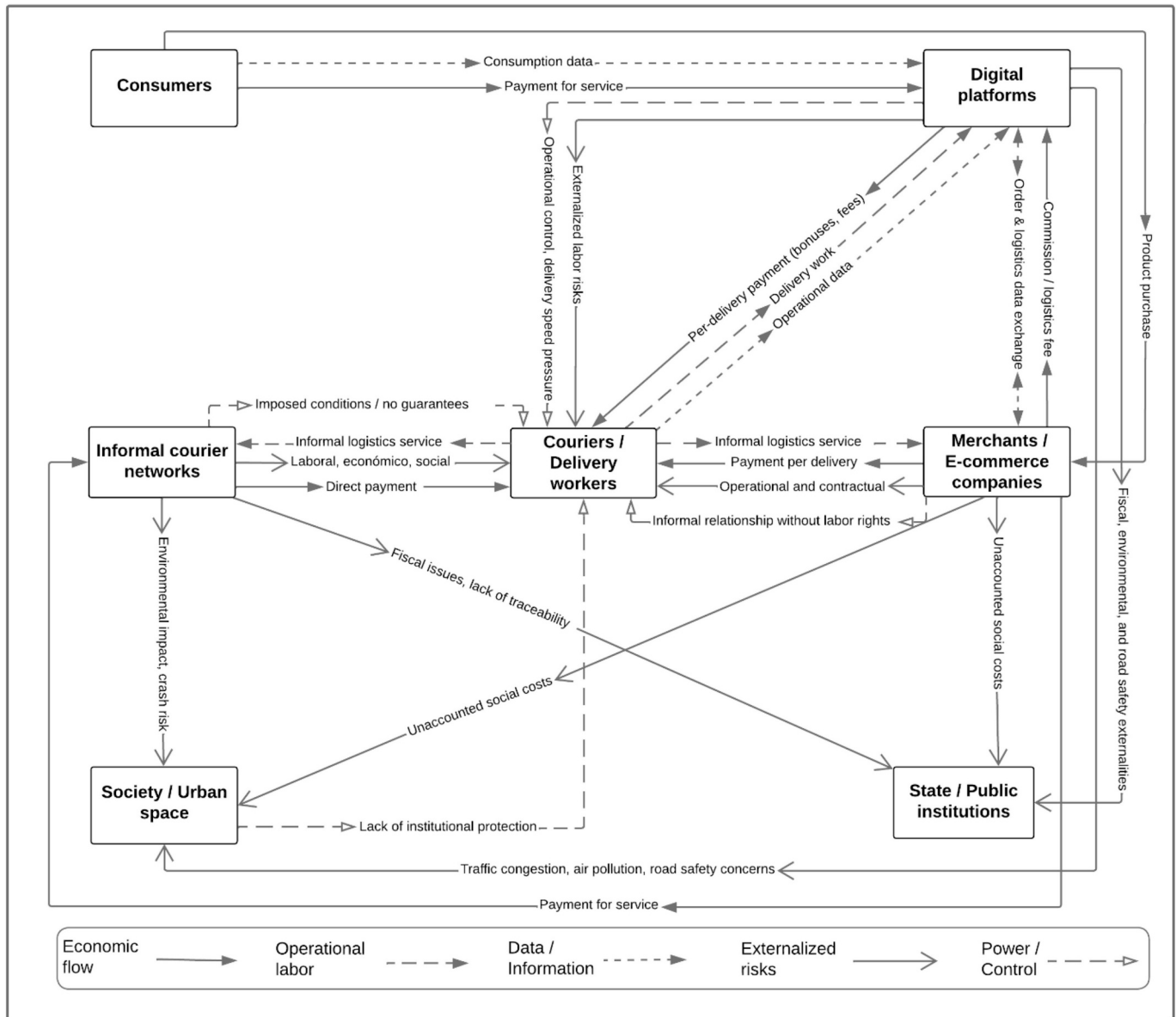


Fig. 6. Value Flow Map of E-commerce Last-Mile Logistics Based on Informality.

rather than a predefined analytical model. While it draws inspiration from broader traditions of value flow and system mapping (e.g., Porter, 1985; Hines et al., 2000), the diagram constitutes an original construction specifically tailored to the dynamics of informal last-mile delivery in developing urban contexts.

3.4. Synthesis of findings in relation to the research questions

To make explicit how the empirical findings address the study objectives and research questions, this subsection synthesizes the main results in relation to each question.

Regarding the first research question (What are the negative impacts of e-commerce last-mile delivery on society?), the findings indicate a set of interrelated societal impacts recognized across stakeholder groups. These include heightened road safety risks driven by time pressure and risky driving practices, labor precarization through informal work arrangements and limited social protection, governance burdens linked to regulatory gaps and weak institutional oversight, and sustainability-related externalities associated with fragmented delivery flows, congestion, emissions, and conflicts over public space. The recurrence of these impacts across diverse actors suggests that they represent widely experienced outcomes of current last-mile delivery configurations in contexts where informal practices shape daily operations.

Regarding the second research question (Why does e-commerce generate these negative effects?), the findings indicate that these impacts are produced through a systemic mechanism of risk and cost externalization embedded in the organization of last-mile delivery. Informality becomes sustained through the interaction of company strategies based on outsourcing and flexible labor arrangements, incentive structures that intensify time pressure and normalize unsafe practices, consumer preferences for rapid and low-cost delivery that fragment distribution flows, and governance constraints that limit enforcement and accountability. Together, these dynamics consolidate informality not as a marginal condition but as a structuring logic that supports the competitiveness of last-mile e-commerce logistics while displacing costs and risks to workers, public institutions, and society.

To further clarify the alignment between the study objectives, research questions, and empirical findings, Table 3 summarizes the main results in a structured manner.

4. Discussion

4.1. Informality as a structuring logic in e-commerce urban logistics

The swift rise of digital commerce has introduced major shifts in urban freight, characterized by denser last-mile delivery patterns and increasingly decentralized distribution networks. While alternative delivery models—such as multimodal urban freight, cargo bikes, and flexible delivery time slots—have shown potential to mitigate externalities (Villa & Monzón, 2021; Arnold et al., 2018; Nogueira et al., 2022), their widespread adoption remains limited by institutional inertia, fragmented governance, and insufficient alignment among industry actors (Al Mashalah et al., 2022). Our findings resonate with these global trends but emphasize that in weakly regulated urban contexts, logistical fragmentation is not merely operational—it is structurally embedded. Informality, rather than being a residual or transitional condition, emerges as a central logic governing last-mile operations. Taken together, the findings speak directly to the two research questions guiding the study. They show that informality amplifies societal impacts through interconnected road safety risks, labor precarization, governance burdens, and sustainability-related externalities, while also clarifying the mechanisms through which business model configurations, outsourcing dynamics, and weak regulatory oversight reinforce such impacts within the last-mile delivery system.

This structural role of informality is evidenced by widespread subcontracting, lack of labor protections, and systematic risk transfer to

Table 3
Alignment between study objectives, research questions, and key findings.

Study Objective	Research Question	Key Findings
To identify the negative societal impacts associated with e-commerce last-mile delivery	RQ1: What are the negative impacts of e-commerce last-mile delivery on society?	The findings identify four interrelated categories of societal impacts consistently recognized across stakeholder groups: (1) road safety risks associated with delivery-time pressure, risky driving practices, and limited occupational protections; (2) labor precarization reflected in informal work arrangements, lack of formal contracts, and restricted access to social protection; (3) governance challenges linked to regulatory gaps, fragmented institutional arrangements, and limited enforcement capacity; and (4) sustainability-related externalities, including congestion, emissions, noise, and conflicts over public space generated by fragmented delivery operations.
To explain the mechanisms through which e-commerce-driven last-mile practices generate and amplify these impacts	RQ2: Why does e-commerce generate these negative effects?	The findings indicate that these impacts are produced through a systemic mechanism of risk and cost externalization operating through four interrelated dynamics: (1) outsourcing strategies that transfer operational risks and responsibilities to delivery workers; (2) incentive structures and delivery-time pressures that encourage unsafe practices; (3) consumer demand for rapid and low-cost deliveries that reinforces fragmented logistics operations; and (4) governance constraints that limit enforcement and accountability. Together, these dynamics consolidate informality not as a marginal condition, but as a structuring logic that supports the competitiveness of last-mile delivery systems while displacing costs and risks onto workers, public institutions, and society.

workers and public systems—dynamics consistently revealed in our empirical research, conducted in Medellín as a representative case of broader dynamics observed in many Latin American cities. Platform-mediated delivery services and informal courier networks coexist and overlap, operating with minimal state oversight and reinforcing labor precarity. Workers interviewed described persistent algorithmic pressure, lack of insurance, and exclusion from social security systems, while public officials acknowledged gaps in enforcement and regulatory tools. These findings align with regional studies that identify the normalization of labor informality through digital platforms in Latin America (Bogoya Viasus et al., 2021; Montes de Oca, 2022; Escobar-Forero, 2022; Jirón et al., 2021).

Beyond labor conditions, the proliferation of informal last-mile delivery services has intensified road safety risks. Motorcycles—used by

over 72 % of delivery riders in Colombia—have become emblematic of both logistical flexibility and institutional vulnerability (ANSV, 2021). Between 2010 and 2022, over 1.1 million uninsured vehicles were involved in road crashes in Colombia; 75 % were motorcycles, and 65 % of fatal cases involved motorcycles without mandatory insurance (SOAT) (Observatorio Nacional de Seguridad Vial, 2023). In Medellín, our interviews revealed that many riders operate without proper training or protective equipment, often under performance-based incentives that reward risky behavior. These patterns reflect a broader governance failure: although road safety policies such as the Strategic Road Safety Plans (PESV) mandate risk prevention, local authorities lack the capacity to implement or monitor compliance, resulting in the de facto externalization of risk to informal workers and public healthcare systems (Nguyen-Phuoc et al., 2022; WHO, 2022).

The rise of informal, motorcycle-based delivery is thus not a peripheral issue—it is deeply embedded in urban risk regimes. With 62.2 % of transport sector workers in Medellín classified as informal (DANE, 2024; FRED Engineering et al., 2023), the prevalence of unregulated labor in last-mile logistics contributes directly to traffic violations, infrastructure stress, and increased burden on public insurance schemes such as ADRES, Colombia's public health fund. Our findings show how companies—including delivery platforms—circumvent safety regulations by outsourcing operations, while unregulated actors such as PICAP, Uber Eats, and independent networks coordinated through WhatsApp further blur the boundaries between transport, employment, and legality. The persistence of this model reveals a systemic disconnection between labor, mobility, and safety governance.

These dynamics are reinforced by the economic strategies of firms and platforms, which capitalize on the flexibility and disposability of informal labor. In Colombia, logistics costs represent 15.2 % of product value—rising to 24.1 % for microenterprises (MinTIC, 2021)—incentivizing cost-cutting strategies like outsourcing and informal subcontracting. In Medellín, Rappi alone mobilizes 1.4 million monthly deliveries through a workforce of more than 16,000 riders, most of whom are young men operating under informal arrangements. While platform representatives claim high hourly earnings, our findings underscore income volatility, lack of benefits, and shifting operational costs to workers.

This reflects a deeper structural condition: platforms function as institutional actors that mediate logistics while evading employment responsibilities. They facilitate supply–demand interactions, collect fees, and centralize control, yet they operate without enforceable labor regulation or fiscal transparency. Only 67.2 % of platform workers contribute to social security, and fewer than 36 % are covered by occupational risk insurance. Critically, 79.1 % rely on platform work as their primary source of income, underscoring a dependency that undermines distinctions between gig and formal employment (Fernández & Benavides, 2020; Moreno Restrepo et al., 2020).

Our interviews confirm this fragmentation. While some riders choose platform work for flexibility, many—particularly migrants and workers with limited education—do so out of necessity, lacking access to formal alternatives (Quadrant Strategies, 2021). This heterogeneity complicates regulatory design and confirms that informality is not monolithic but layered across preference and exclusion. These findings are mirrored in the stakeholder matrix and thematic profiles, where informality appears not as a deviation, but as a structuring force that shapes actor behavior, business strategies, and state responses.

Such dynamics resonate with broader debates in transport policy, particularly in showing how informal governance and outsourcing practices undermine efforts to build sustainable, equitable last-mile delivery systems.

Finally, consumer behavior reinforces this system. In Colombia, 86 % of online shoppers prefer home delivery (CCCE & MinTIC, 2024), and over 80 % report satisfaction with service, despite modest delivery expectations. This entrenched demand for fast, low-cost delivery sustains the viability of informal labor arrangements within platform economies.

In the absence of enforceable redistributive frameworks or labor standards, informality persists not as a failure of regulation but as the operational foundation of urban e-commerce logistics.

5. Conclusion

This study demonstrates that in the context of rapid e-commerce expansion, informality is not a residual effect but a structuring logic of last-mile urban logistics. The normalization of precarious labor arrangements, subcontracted delivery networks, and weakly regulated transport practices not only exacerbates congestion, environmental degradation, and road safety risks, but also redistributes associated costs onto public institutions and vulnerable workers, contributing to inter-connected societal impacts, including heightened road safety risks, labor precarization, governance burdens, and sustainability-related externalities such as congestion, emissions, and conflicts over public space. In cities with weak regulatory capacity, informal arrangements persist as cost-saving strategies embedded in dominant business models and sustained by consumer demand for low-cost, rapid delivery.

Taken together, the findings provide a clear response to the research questions guiding the study. They show that the negative impacts of e-commerce last-mile delivery extend beyond operational inefficiencies and disproportionately affect vulnerable workers and urban communities, addressing the first research question. They also explain that these impacts are generated and reinforced through a mechanism of risk and cost externalization, enabled by outsourcing strategies and regulatory gaps that weaken accountability across the delivery ecosystem, addressing the second research question.

The findings call for a fundamental reconsideration of governance approaches to urban logistics—one that moves beyond technical efficiency and addresses the political economy of labor, regulation, and urban risk. Advancing fairer and more sustainable last-mile systems requires regulatory innovation, cross-sector coordination, and stronger institutional mechanisms to reintegrate e-commerce last-mile delivery into inclusive urban policy frameworks, ensuring that the value generated by e-commerce does not rely on the systematic displacement of social and environmental costs.

5.1. Limitations and future research

This study has limitations that should be considered when interpreting its findings. First, it is based on a single explanatory and instrumental case study. While this supports analytical generalization by clarifying mechanisms through which informality becomes embedded in last-mile delivery, it limits empirical generalization across settings with different institutional and labor regimes. Second, the evidence relies on stakeholder accounts, which may involve partial visibility and self-report bias in a highly informal ecosystem. Third, although the study identifies key societal impacts and explains their underlying mechanism of risk and cost externalization, it does not quantify the magnitude of these externalities using administrative or operational datasets.

Future research should build on these insights through comparative multi-city designs and mixed-method approaches combining qualitative explanation with crash data, platform indicators, and spatial analysis of delivery flows. Further work should also evaluate governance interventions—such as data-sharing requirements, labor protection instruments, and incentive redesign—to reduce externalities while preserving service accessibility.

5.2. Contributions and implications for academia and industry

This study contributes to the urban logistics and transport governance literature by offering an integrated explanation of the societal impacts associated with e-commerce last-mile delivery. The findings show that informality is not a residual or transitional condition but a structuring logic that connects and amplifies interrelated externalities

across road safety, labor precarization, governance burdens, and sustainability. By linking these dimensions within a single interpretive account, the study advances a systemic understanding of how impacts co-exist and reinforce each other within the same urban delivery ecosystem, particularly in contexts characterized by regulatory gaps, limited enforcement capacity, and fragmented labor arrangements.

Methodologically, the research demonstrates the explanatory value of an inductive qualitative approach based on multi-actor interviews. By incorporating five stakeholder groups, the design enables triangulation across positions and helps distinguish actor-specific concerns from cross-cutting mechanisms. In addition, combining open, axial, and selective coding with system-oriented visual syntheses—such as the stakeholder matrix, an adapted Business Model Canvas, and the Value Flow Map—strengthens traceability between empirical evidence and analytical explanation, making explicit how value, risk, and responsibility are redistributed within last-mile delivery systems.

For industry, the results suggest that operational flexibility supported by outsourcing and informal arrangements may deliver short-term competitiveness but generates cumulative vulnerabilities, including heightened safety exposure, labor tensions, and increasing regulatory pressure. For policymakers, the study highlights the need to strengthen institutional capacity and regulatory instruments—particularly regarding minimum protection standards, road safety governance, data access, and accountability—to align last-mile delivery systems with broader urban sustainability and equity objectives.

CRedit authorship contribution statement

Basilio Restrepo-Betancur: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ivan Sanchez-Diaz:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Carlos A. Gonzalez-Calderon:** Writing – review & editing, Supervision, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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