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Published in:
Research in Transportation Business and Management

DOI:
10.1016/j.rtbm.2024.101198

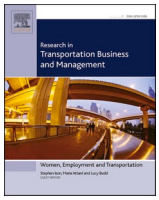
Publication date:
2024

Research in Transportation Business & Management 56 (2024) 101198

Contents lists available at ScienceDirect

Research in Transportation Business & Management

journal homepage: www.elsevier.com/locate/rtbm



Towards sustainable last-mile logistics? Investigating the role of cooperation, regulation, and innovation in scenarios for 2035

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ARTICLE INFO

Keywords:
Last-mile logistics
Scenarios
Cooperation
Regulation
Innovation
Disaggregative Policy Delphi

ABSTRACT

Last-mile logistics is of crucial importance to city life, but negative externalities require a transition to more sustainable modes of operation. Enhancing the capacity for informed decision-making is key in this multi-actor context with interdependent stakeholder views shaped by long-term contextual dynamics. This paper presents six scenarios representing potential futures of last-mile logistics based on the views of 26 logistics stakeholders with various roles in last-mile logistics using a Disaggregative Policy Delphi approach. They offer insight into the interdependencies between stakeholders and key enablers and barriers in the transition. Results suggest that actions of local authorities strongly influence the level and direction of technological innovation and cooperation. This stresses the importance for local authorities to build the capacity required to play a meaningful role in the transition, for example, by facilitating ongoing dialogue that may help actors to navigate their different preferences and negative impacts on quality of urban public space, and to identify joint courses of action towards more sustainable last-mile logistics.

1. Introduction

Transport accounts for almost a quarter of all CO_2 emissions worldwide, with road freight accounting for 29.4 % of the transport-related emissions (Ritchie, 2020). Last-mile logistics refers to the final stretch of the supply chain, typically involving transportation from a distribution centre to the end-user. In larger urban areas, last-mile logistics commonly accounts for only 10–15 % of traffic—passenger cars account for most of the remaining traffic—yet is responsible for a quarter of CO_2 emissions, and substantially contributes to the NO_x emissions and generation of particle matter (Dablanc, 2011; Lebeau & Macharis, 2014). When considering sustainability more broadly, last-mile logistics also clashes with goals for a safe and pleasant public space (Browne, Allen, & Woodburn, 2007; Brusselaers, Macharis, & Mommens, 2023; Haarstad, Rosales, & Shrestha, 2024). At the same time, last-mile logistics plays a vital role in the functioning and flourishing of urban areas. Simply ridding the urban area of last-mile logistics is therefore not an option. Instead, there is a need to transition to sustainable last-mile logistics (European Commission, 2021a).

Urban densification, the rise of e-commerce, and the on-demand economy have increased the importance of last-mile logistics for city life and economic development (Bjørgen, Bråthen, Hansson, & Bjerkan, 2024; Cardenas et al., 2017) but magnified its negative externalities (Hu, Dong, Hwang, Ren, & Chen, 2019). It is often argued that stringent service level targets, small order sizes, high delivery frequencies, and dispersed pickup and delivery locations make last-mile logistics the least efficient part of the supply chain (Macioszek, 2018) and a major contributor to air pollution and road congestion (Gevaers, van de Voorde, & Vanelslander, 2011; Mommens, Brusselaers, Van Lier, & Macharis, 2019). This has increased awareness among stakeholders that the future of last-mile logistics needs to be more sustainable (Cardenas et al., 2017; Gonzalez, Garrido, & Vassallo, 2023; Lindholm & Browne, 2013). Such awareness is manifested in calls of citizens for good quality public space, clean air, and safe streets (Amaya, Delgado-Lindeman, Arellana, & Allen, 2021), in local authorities who are increasingly regulating urban logistics flows and their impacts (Bjørgen & Ryghaug, 2022; Maxner, Dalla Chiara, & Goodchild, 2024; Shrestha & Haarstad, 2023; Shrestha, Haarstad, & Rosales, 2024), and in logistics operators who are equipping themselves with the latest technologies and experimenting with collaborative schemes (Le Pira et al., 2024; Mangiaracina, Perego, Seghezzi, & Tumino, 2019).

While the urgency to transition to more sustainable last-mile logistics

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https://doi.org/10.1016/j.rtbm.2024.101198
Received 30 April 2024; Received in revised form 5 August 2024; Accepted 28 August 2024

is felt broadly, establishing such a systemic change poses major challenges to logistics stakeholders, including authorities, operators, local businesses, and citizens (Correia, Vagos, Marques, & Teixeira, 2024). For instance, the efficiency and sustainability of last-mile logistics could benefit from increased cooperation between stakeholders (e.g., vehicle sharing, consolidation, and the exchange of data and information) but this is impeded by a lack of available data (Buldeo Rai & Dablanc, 2023) and diverging goals of stakeholders (Pan, Trentesaux, Ballot, & Huang, 2019; Russo, Voegl, & Hirsch, 2021). This in turn complicates the alignment of objectives (Amaya et al., 2021; Le Pira, Marcucci, Gatta, Ignaccolo, & Inturri, 2023; Paddeu, Parkhurst, Rosenberg, Carhart, & Taylor, 2024; Przybylska, Kramarz, & Dohn, 2023). For instance, if a last-mile logistics operator offers citizens flexible and on-demand services (Beckers, Cardenas, Le Pira, & Zhang, 2023), this may result in the deployment of large numbers of delivery vehicles in inner cities, which contradicts the goals of local authorities and citizens to maintain or improve safe and liveable streets. Meanwhile, long-term contextual dynamics, such as the economy, demographic trends, and technological innovations—including e-mobility, self-driving delivery vehicles, warehousing, and last-mile delivery platforms—require stakeholders to be responsive to both foreseen and unforeseen threats and opportunities (Dablanc, 2007). Path-dependencies invoked now may constrain possible futures later, and systems are generally inert and slow to change (Åkerman & Höjer, 2006). Successfully transitioning to more sustainable last-mile logistics is therefore a complex endeavour involving many stakeholders and long-term uncertainties (Shrestha et al., 2024).

Enhancing the capacity for informed decision-making in such a multi-actor long-term context is key to foster sustainable last-mile logistics. Scenarios are a useful means to this end as they can "improve the probability of desirable (futures), decrease the probability of undesirable (futures), and gear up to coping with the inconceivable sure to come" (Dror, 2006, p90). They provide a purposeful basis for further inquiry to stakeholders, as they can prevent them from being narrow-sighted and from being locked into their individual decision-making approach while ignoring their dependencies on others (van der Heijden, 2005; Neef, Verweij, Busscher, & Arts, 2020). Improved decision-making starts with gaining a better understanding of the different futures for last-mile logistics that individual stakeholders deem to be possible. Their future images inform their actions (Kaboli & Tapio, 2018; Rubin, 2013) and the sum of these individual actions increases or decreases the collective ability to anticipate on a range of desirable and undesirable futures (Gattringer, Wiener, & Strehl, 2017; Heger & Boman, 2015; Heger & Rohrbeck, 2012).

Several studies have presented scenarios for the future of logistics based on expert panels aimed at identifying, for instance, the barriers and enablers to the adoption of new technologies and the impact of changing consumer preferences on more sustainability in last-mile logistics (Liimatainen et al., 2014; Melander, Dubois, Hedvall, & Lind, 2019; Peppel, Ringbeck, & Spinler, 2022; von der Gracht & Darkow, 2010). These studies are generally aimed at reaching expert panel consensus—either explicitly through study design or implicitly in the discussion of results—and have resulted in mutually exclusive scenarios for likely future states of last-mile logistics. The study presented in this paper complements prior studies by taking a disaggregative approach, deliberately focused on incorporating different viewpoints across stakeholder groups and identifying a broad range of potential future states. The identification of different non-exclusive but coherent futures narratives, contributes to broadening stakeholders' understanding on diverse but uncertain futures they may be confronted with. The scenarios thus provide actionable insight without commenting on the likeliness of these futures taking shape. Such a broad approach can also account for how various potential drivers for change, such as changing customer behaviour and the adoption of new technologies, are interwoven with the level of cooperation between stakeholders, and the different roles local governments may take in fostering change in the last-mile logistics sector. These are key factors to consider as long-term alignment through cooperation or policy frameworks promises efficient and sustainable use of space for logistics and other land-use functions (Bertolini, 2012). Yet, this alignment is challenged by the rapid growth of the last-mile logistics sector and the limited attention for logistics in urban planning to date (Bjørgen et al., 2024; Haarstad et al., 2024; Kin, Buldeo Rai, Dablanc, & Quak, 2024).

This paper also offers important insights for policymakers and industry professionals seeking to enhance sustainability in last-mile logistics. By considering cooperation and policy action as main drivers in addition to technological innovation, the paper links to recent calls for more active guidance in fostering sustainable logistics (ALICE-ETP, Polis, 2021) by offering insight on expectations of local logistics stakeholders on whether and how a shared course of action can be established. The paper presents a set of scenarios representing potential futures of last-mile logistics in 2035 based on the views of a broad range of local logistics stakeholders on stakeholder cooperation, regulation, and innovation. These scenarios can raise awareness across individual stakeholder groups on how expectations about the interplay between these three domains may affect their range of possible actions and explore opportunities for shared courses of action by public and private actors towards more sustainable last-mile logistics. The scenarios also identify interdependencies between stakeholders as well as key enablers and barriers in transitioning towards sustainable last-mile logistics. These can be used to inform policy frameworks and city planning strategies.

2. Background

We identified three themes that are likely to play a crucial role in shaping the sustainability transition in last-mile logistics in the years to come. This section discusses the academic literature on each of these themes in more detail.

2.1. Stakeholder cooperation in sustainable last-mile logistics

The growing demand for e-commerce and desire for ever faster deliveries have fragmented last-mile deliveries (Savelsbergh & van Woensel, 2016). Cooperation between stakeholders in last-mile logistics is therefore considered key in advancing towards sustainable operations, but important barriers still need to be overcome (Gonzalez et al., 2023; Tanco & Escuder, 2021). Stakeholders may have various motives to seek cooperation, such as an expectation of a net positive value of the expected outcomes (Cruijssen, Cools, & Dullaert, 2007), pain and gain sharing (Ferrell, Ellis, Kaminsky, & Rainwater, 2020; Savelsbergh & van Woensel, 2016), legal obligations, or the exchange of knowledge and information (Lindholm & Browne, 2013).

Cooperation between private parties can take on the form of vertical and horizontal cooperation, and these have different benefits (Barratt, 2004). In vertical cooperation, stakeholders in successive stages of the supply chain form a strategic alliance with the goal of more efficient operations and higher responsiveness to consumer demands (Savelsbergh & van Woensel, 2016; Soosay & Hyland, 2015). Horizontal cooperation involves stakeholders operating at the same level of the supply chain. In the context of logistics, the envisioned benefits of horizontal cooperation are improved vehicle capacity utilization, a reduction of empty mileage, and cost reductions in non-core activities to increase competitiveness of logistics networks (Cruijssen et al., 2007; Gansterer & Hartl, 2018).

Cooperation can also take the form of public-private partnerships in which local authorities and private stakeholders involved in last-mile delivery work together (Castillo, Viu-Roig, Nicolàs, & Alvarez-Palau, 2024; Knoppen, Janjevic, & Winkenbach, 2021). Due to the complexity of the logistics sector and the many intersecting and varying interests, a local authority cannot improve last-mile logistics in cities without cooperation with other stakeholders (Kiba-Janiak, 2017; Le Pira et al., 2023; Lebeau, Macharis, van Mierlo, & Janjevic, 2018; Paddeu

et al., 2024; Przybylska et al., 2023; van Duin, Slabbekoorn, Tavasszy, & Quak, 2018). Cooperation between private logistics players and local authorities can facilitate the exchange of knowledge and information, and improves mutual understanding (Lindholm & Browne, 2013). As a result, transport infrastructure could be better attuned to private sector needs (Holguín-Veras et al., 2020a). For example, local authorities can increase the number of loading and drop-off zones in urban areas (Fransoo, Cedillo-Campos, & Gámez-Pérez, 2022; Wilson, Janjevic, & Winkenbach, 2022) or stakeholders might cooperate in city wide management systems that supports carriers in defining optimised routes for their vehicles in specific time window periods, in line with local authorities' regulations (Quak, 2012). Private actors further benefit from public actors' involvement in transport operations through "the latter's long-term planning horizon and social considerations" (Bergqvist & Pruth, 2006, p104). This type of cooperation would require data-sharing between stakeholders (Correia et al., 2024), which shapes barriers for public-private partnerships due to new questions of data ownership, interoperability, and trust (Dalmolen et al., 2018). The implementation of measures to improve last-mile logistics and to reach sustainability does not always mean an improved situation for all logistics stakeholders, but rather a "give and take" for overall improvement (Muñuzuri, Larrañeta, Onieva, & Cortés, 2005): "the objective is, or should be, to reduce the conflict between different stakeholders' requirements" (Lindholm & Browne, 2013, p23).

2.2. Technological innovations in sustainable last-mile logistics

The high pace of technology development in logistics is rapidly transforming last-mile delivery (Le Pira et al., 2024; Mohammad, Nazih Diab, Elomri, & Triki, 2023). Innovations can apply to many aspects of last-mile logistics, ranging from hub locations and infrastructure to vehicle technology, platforms, and logistics operations and business models (Buijs & Ozyavas, 2020; Holguín-Veras, Amaya Leal, Sánchez-Diaz, Browne, & Wojtowicz, 2020a; Holguín-Veras, Amaya Leal, Sanchez-Diaz, Browne, & Wojtowicz, 2020b). Innovations have contributed and can further contribute to the sustainability of last-mile logistics in different ways. First, innovations can help lower emissions of current operations, from vehicles used for last-mile deliveries (Holguín-Veras & Sánchez-Díaz, 2016) to the organisation of last-mile deliveries, such as delivery-to-door or via unattended delivery technology (Allen et al., 2018; Janinhoff, Klein, Sailer, & Schoppa, 2024). Alternatively, new logistics players can enter the market, introducing new business models that fundamentally change how goods are handled (Janjevic & Winkenbach, 2020). These types of innovations are further discussed below.

In last-mile transport, one of the main challenges is the decarbonisation of the last-mile vehicle fleet (Lal, Renaldy, Breuning, Hamacher, & You, 2023). New engine solutions are pushed by regulations and the establishment of low emission zones or environmental zones in cities by local authorities (European Commission, 2019). In response, innovative vehicles take the streets, such as electric vehicles, hybrids, and fuel cell electric vehicles (Bosona, 2020; Patella, Grazieschi, Gatta, Marcucci, & Carrese, 2020). These vehicles reduce last-mile logistics' environmental impact. Innovations also concern non-motorised transport modes, such as (e-)cargo bikes and delivery on foot, potentially with a "follow-me helper" (Quak & Kin, 2020, p5). The relative low costs of cargo bikes (Choubassi, Seedah, Jiang, & Walton, 2016), emission and health benefits (Figliozzi, Saenz, & Faulin, 2020) and flexibility (Thoma & Gruber, 2020) are important advantages over other delivery forms in dense and congested urban areas. Automation of delivery is another technological innovation that may shape the future of last-mile logistics (Figliozzi, 2020). From a technological standpoint, the last-mile services of the future could be widely carried out by unmanned vehicles, robots, and unmanned aerial vehicles (Bosona, 2020). In the meantime, such developments raise new issues around traffic safety, infrastructure, and legal domains (Fehling & Saraceni, 2023).

The organisation of urban freight flows is also changing. Last-mile logistics players are experimenting with (new) methods in the organisation of urban freight flows with aims of increasing sustainability and efficiency. New delivery models, such as collection and delivery points, are challenging business-as-usual in last-mile logistics and are increasingly important for parcel delivery companies (Kim & Wang, 2022). For instance, business-to-consumer delivery through parcel lockers is increasingly considered as a viable alternative to home delivery (Biancolin & Rotaris, 2024; Yuen, Wang, Ma, & Wong, 2019). Delivery companies place parcels in unmanned reception boxes that can be opened by the customer with a reference code or an application on their phone (Janinhoff et al., 2024). Cities are also experimenting with ways to consolidate last-mile delivery, for example through urban consolidation centres (UCCs) or micro hubs (Gillström & Björklund, 2024). Here, deliveries from multiple (national and local) logistics service providers are consolidated, from where last-mile delivery can be executed with sustainable modes (Allen, Browne, Woodburn, & Leonardi, 2012; Browne, Allen, & Leonardi, 2011). This can help making traditional door-to-door delivery, organised by individual service providers, more cost effective (Janjevic & Ndiaye, 2017) and sustainable (Holguín-Veras & Sánchez-Díaz, 2016). Urban consolidation is not without its challenges though. Finding a suitable location involves weighing multiple, potentially opposing criteria (Aljohani & Thompson, 2020) and most initiatives struggle to attract sufficient freight volumes to yield a return on investment and hence require government subsidy to remain in operation (Allen et al., 2012; Dreischerf & Buijs, 2022).

Finally, the future of last-mile logistics is also shaped by new entrants in the market, which might introduce new business models and radically change modes of operations (Janjevic & Winkenbach, 2020). Examples of new entrants in last-mile logistics range from innovative start-ups to big tech companies, community initiatives and public initiatives. Many are digitally oriented (Saénz, Revilla, & Borrella, 2022), such as on-demand warehousing platform Flexe, unlocking unused storage space to companies on a flexible basis. A central question is the extent to which new entrants will impact the operations of established players, gain market share, or lead to new mergers and acquisitions.

2.3. The role of local authorities in sustainable last-mile logistics

Local authorities have a key role to play in the transition to more environmentally friendly, smarter, and healthier last-mile logistics. Large- and medium-sized cities are encouraged to work on this transition with the implementation of sustainable urban mobility plans and sustainable urban logistics plans (CiViTAS, 2015; ELTIS, 2016; European Commission, 2021b). Via these plans, they can set regulations and create opportunities for efficient city logistics transport in line with regional or state governments' legislature (Maxner et al., 2024; Muñuzuri et al., 2005; Shrestha and Haarstad, 2023). Authorities' key concerns are to maintain attractive urban areas and increase quality of life, while attempting to attract businesses and visitors to the area (Ballantyne, Lindholm, & Whiteing, 2013). An objective of local authorities can be to solve conflicts between urban logistics stakeholders by involving them in the implementation of activities to improve city logistics (Amaya, Arellana, & Delgado-Lindeman, 2020; Knoppen et al., 2021; Le Pira et al., 2023; Lebeau & Macharis, 2014; Paddeu et al., 2024; Przybylska et al., 2023; Witkowski & Kiba-Janiak, 2014).

Without bold policy action, last-mile logistics emissions are projected to keep rising. According to the OECD International Transport Forum, two actions need to be undertaken by local authorities: first, the decarbonisation of last-mile logistics transport needs to move higher up on policy agendas. And second, authorities must help create business cases for decarbonisation of the last-mile, as the sector is profit-driven. As such, a long-term vision and associated policies can set regulatory frameworks that favour best practices (ITF, 2021).

3. Material and methods

Table 1 summarises the process of data collection and analysis, which included a document analysis of policy and trend reports and a Disaggregative Policy Delphi study that was conducted in two rounds from February 2021 to June 2021 and from September 2021 to January 2022. The study involved logistics stakeholders from three mid-sized European cities involved in European logistics research project ULaaDS (European Commission, 2020). The cities, Bremen (Germany), Groningen (The Netherlands) and Mechelen (Belgium)—hereafter referred to as "pilot cities"—share similar characteristics, such as high population densities and urban structures consisting of a historic city centre surrounded by sprawling residential areas and industrial zones.

3.1. Document analysis for identification of relevant themes

The first research phase served to identify thematic content for our Disaggregative Policy Delphi. To this end, we conducted a document analysis, selecting logistics trend reports authored by global logistics operators, consultants, and research and policy institutes (Cushman & Wakefield, 2017; DHL, 2018; ITF, 2021; McKinsey and Company, 2016, 2018; PWC, 2019; Roland Berger, 2018; UPS, 2019; World Economic Forum, 2020) and policy documents of the cities under study. These documents were chosen based on their relevance to urban logistics and the future of last-mile delivery. From these sources, we identified three key themes likely to shape the future of last-mile logistics: 1) the role of local authorities in shaping last-mile logistics; 2) the level of technological innovation in last-mile logistics; and 3) the level of cooperation between stakeholders in last-mile logistics. These identified themes were cross-checked with academic literature discussed in Section 2 to further detail them in six subthemes and 16 topics that served as input for the Disaggregative Policy Delphi (see Table 2 for an overview). Overall, this resulted in thirty-six survey items, which are included in Appendix A.

3.2. Disaggregative Policy Delphi for constructing futures scenarios

Delphi is one of the main methods in futures research and especially suitable for generating future information for long-range planning in topics where changes in current trends are expected. The method is used to construct scenarios, which represent fundamentally different futures that are analytically coherent and internally consistent and encompass concrete and plausible end states and their surroundings and wider environments in a concrete and focused narrative (Neef et al., 2020). Importantly, such scenarios are depictions of possible futures rather than predictions (Börjeson, Höjer, Dreborg, Ekvall, & Finnveden, 2006) and can help decision-makers to identify, prepare for, and deal with both desirable and undesirable possible futures.

The anonymous and round-based set-up limits social influences and biases such as groupthink, halo-effects, status, and strong personalities (Hallowell, 2009; Neef et al., 2020; Okoli & Pawlowski, 2004). Whereas a classical Delphi study seeks participant consensus, Disaggregative Policy Delphi (hereafter abbreviated to "DPD") assumes that expert consultation need not lead to consensus but can demonstrate distinctly different views on all sorts of possible futures (Tapio, Paloniemi, Varho, & Vinnari, 2011). DPD explores such diverse views of the future explicitly. Allowing for diverse views is especially important for last-mile logistics for three reasons. First, the complex and dynamic nature of the field makes that innovations appear quickly and on various frontiers (technology, policy, behaviour), which makes one coherent development future pathway unrealistic. Second, due to the wide diversity of stakeholders involved, a shared narrative on a common development course is likely to be largely absent. Third, there is a desire among policymakers to prepare for multiple futures (Janjevic, Knoppen, & Winkenbach, 2019).

During the DPD, participants were asked to reflect on probable and preferable developments that occurred in their envisioned future of last-mile logistics in 2035. This time horizon was chosen to inspire and encourage stakeholders to think beyond current policy documents and action plans, which typically have deadlines set for 2025 or 2030, while still being sufficiently close to be relatable.

3.2.1. Selection of participants

We selected local authorities, logistics operators, citizens, business representatives, and experts from the three pilot cities to inquire their views and future estimates (Table 3). These five groups cover a diversity of vantage points that is desirable for a panel of experts in Delphi studies, in terms of knowledge, experience, and policy influence, as well as panel diversity and heterogeneity (Baker, Lovell, & Harris, 2006; Hussler,

Table 1
Methods employed leading to futures scenarios.

Phase	Method	Analysis	When
1	Document analysis (Section 3.1)	Coded pilot cities' sustainable urban mobility and logistics policy plans	October 2020 – February 2021
2	Disaggregative Policy Delphi round 1: interviews and surveys (Section 3.2.2)	Coded interview transcripts to identify scenario story logics that underly the quantitative future estimates.	February – June 2021
3	Disaggregative Policy Delphi round 2: surveys (Section 3.2.3)	Run multivariate cluster analysis of 36 variables. Use futures table to construct scenarios.	September 2021 – January 2022

Table 2
Delphi themes, subthemes, and variables.

Theme	Subtheme	Survey variables
Government	Regulation	Degree of active regulation by local authorities
		Types of last-mile policies issues by city authorities
		Authorities' role in new delivery models
Innovation	Competition	Extent to which large CEP-logistics players will remain amidst stricter access regulations
		Share of last-mile deliveries handled by logistics newcomers
		Types of logistics newcomers to expect.
	Delivery	Future of business-to-consumer (B2C) deliveries
		Future of business-to-business (B2B) deliveries
		Role of different stakeholders in new delivery models
	Mobility	Types of motorised transport used in last-mile transport
		Types of non-motorised transport used in last-mile transport
		Level of autonomy in last-mile transport
Cooperation	Organisation	Degree of B2B cooperation in supply chain operations to achieve sustainability benefits
		Degree of business-to-government (B2G) cooperation in smart logistics management system to achieve sustainability benefits
		Degree of B2B and B2G data-sharing
	Resources	Degree of B2B cooperation on storage space
		Degree of B2B cooperation on vehicles use
		Degree of B2B cooperation in unattended delivery technology

Table 3
Overview of participants in the first and second round of the Delphi.

Type of stakeholder	Completed round 1	Completed round 2
Local authorities	7	5
Logistics operators	15	10
Citizen representatives	2	2
Business representatives	6	5
Experts	4	4
Total	34	26

Muller, & Rondé, 2011).

Study participants from local authorities were either policymakers or policy administrators in charge of mobility and logistics in their respective cities. The logistics operators consisted of large, global operators with local operations in the cities and smaller logistics operators that were only active locally. The perspective of residents and local businesses in the cities were included in the study by addressing representatives of interest groups. The logistics experts included in the study either worked on scientific and applied research in logistics or as logistics advisers and were familiar with and active in the cities through their research programmes or advisory work. The combination of these five groups of participants represents experts-by-policy influence (i.e., local authorities) experts-by-experience (i.e., logistics operators, citizens, and business representatives), and experts-by-training. More detailed profiles of the participants that completed round 2 are provided in Appendix B.

Persons of first contact at the local authorities assisted in the participant sampling as they were the ones with extensive networks of various logistic stakeholders within their cities. All participants gave their written informed consent prior to the data collection and gave permission for their anonymised data to be used for the purposes of this study.

3.2.2. *Disaggregative Policy Delphi round 1: Interview and survey*

The first-round interviews and surveys were conducted with one participant per session to maintain anonymity. The survey served as the interview guide to conduct structured interviews. For each question, participants provided an expected and a preferred estimate, and were then asked to elaborate. For example, when asked about the expected level of autonomous driving in the last-mile fleet in 2035 (possible answers ranging from level 0 to level 5 autonomy), participants were asked to elaborate on the factors they thought might contribute to achieving such a level of autonomy, the barriers and facilitators in innovation and policies, and how this level of autonomy would translate to the logistics operations. By using the survey as an interview guide, quantitative and qualitative data were collected simultaneously in one round.

This set-up varies from DPD designs where one or more surveys are held first before conducting in-depth interviews as a second step (Tapio et al., 2011). As the study took place during the Covid-19 pandemic, the entire data collection process took place remotely. As remote contact was suspected to impact participants' commitment to the study, the first round was used to establish face-to-face contact with participants (Roberts, Pavlakis, & Richards, 2021), to increase the likelihood that they would complete the second round of data collection, hence reduce inter-round attrition, and improve representativeness of findings.

The survey was built using Qualtrics online survey software and Google Meet was used for online video conferencing during the interviews (Adom, Osei, & Adu-Agyem, 2020). The survey was shared on-screen with the participants, who answered to the questions verbally.

3.2.3. *Disaggregative Policy Delphi round 2: Survey*

Based on the first round, individual feedback reports were compiled and shared with the participants. These individualised reports contained the answers provided by the participant, overviews of the response by other participants (both total group response and response by stakeholder type), and a summary of the qualitative insights from the first round. During the second round, participants were able to adjust their first-round survey answers based on how they interpreted the group response provided to them in the feedback reports. By collecting data in different rounds, the data foundation was built to identify multiple true centres of consensus representing the mental modes of the stakeholders.

3.2.4. *Analysis of qualitative and quantitative results*

Each of the interviews in DPD round 1 took between 60 and 90 min, were audio recorded, and transcribed verbatim. Transcripts were processed and coded using ATLAS.ti software. The 34 interviews resulted in 440 pages of transcripts, 78 interview codes, and 1954 coded quotations. Qualitative arguments were grouped per theme and qualitative directed content analysis was employed to target specifically determined categories of interview transcripts as informed by the cluster analysis (Hsieh & Shannon, 2005).

After finishing DPD round 2, a multivariate cluster analysis was run on the round 2 survey data to analyse the future estimates per survey variable quantitatively. Since each respondent provided both probable and preferable future estimates, the total amount of future estimates was equal to the number of respondents multiplied by two, resulting in a total of 52 estimates per question. The multivariate cluster analysis was used to organise estimates per survey variable into groups. This is done in such a way that each estimate is more similar to other estimates in its group than to subjects outside the group. Using SPSS Version 28 for Mac, first, variables were standardised on a scale from 0 to 1. Then, standardised Euclidean distance was selected as dissimilarity measure, and agglomerative hierarchical clustering furthest neighbour (complete linkage) as clustering algorithm. The selection for a specific number of clusters per survey variable was limited to minimally four or maximally seven to ensure sufficient diversity in the scenarios as well as to enhance the efficient use of the scenarios in a later stage (Varho & Tapio, 2013).

A separate cluster analysis was carried out for each survey variable. Given the parameters of the analysis, each cluster analysis yielded a minimum of four and a maximum of seven clusters of answers, thus representing four to seven "future states" for that theme (for example, four to seven degrees of regulation of city access by local authorities).

As a first step, we then checked whether qualitative data provided sufficient backing for the variation between four clusters (i.e., whether sufficient argumentation was found for each of four "future states" for that theme, e.g., the different degrees of regulation of city access by local authorities, and whether these arguments differed sufficiently from each other based on interviewees' views). If variation between four clusters was deemed to be sufficiently backed by qualitative data, we turned to the analysis yielding five clusters, and performed the same routine checking qualitative data for sufficient argumentation for the variation between five, six, or seven "future states" for that theme. In case argumentation for the variation between a certain number of clusters was judged insufficient, we resorted to highest number of clusters or future states for which sufficient backing was last found in the qualitative data.

Hierarchical trees (dendrograms) were used to visually check for the structure of the responses, that is, sub-clusters and outliers (Neef et al., 2020). In the end, each of the survey questions yielded between four and six clusters, meaning no more than six future states were found in qualitative data for any theme.

3.2.5. *Futures table*

Scenarios were constructed using a futures table in which rows express the themes and variables, columns represent the scenarios, and cells detail the cluster value of a future state. The futures table is shown in Table 4. The quantitative values result from the cluster analysis. Since a cluster analysis was run per theme, different themes can have different numbers of clusters. Initially, when any futures table is created with cluster values, columns do not yet represent a scenario. Therefore, cluster themes were reorganised by connecting them to each other based on qualitative content analysis so that the columns represent a coherent storyline and scenarios are internal consistent. Storylines were written supported by the qualitative data and the scenarios were named accordingly.

4. Results

Six scenarios were constructed, each depicting a different possible future state of last-mile logistics in the year 2035. The columns in the futures table (Table 4) describe the scenarios quantitatively. For instance, in the *New Cool Collective* and *Revolution By Design* scenarios, 32 % of last-mile parcel deliveries in 2035 is handled by newcomers in

Table 4
Futures table.

Themes and variables	Units	1. Old Wild West	2. New Wild West	3. New Cool Collective	4. Revolution By Design	5. Thriving, Individually	6.Good Intentions Abound
GOVERNMENT							
Degree of regulation							
Transport modes	−2 passive, +2 active	0,0	0,0	1,1	1,1	1,6	1,5
Autonomous veh.	−2 passive, +2 active	0,2	0,2	0,7	0,7	1,7	1,4
Inner city access	−2 passive, +2 active	0,4	0,4	1,9	1,9	1,7	1,4
Logistics resources	−2 passive, +2 active	0,3	0,3	0,7	0,7	−0,3	1,4
Type of regulation							
Transport modes	−2 restr, +2 facilit	−1,0	−0,6	0,4	−1,0	1,4	0,6
Autonomous veh.	−2 restr, +2 facilit	1,3	−0,3	1,6	1,3	0,8	0,3
Inner city access	−2 restr, +2 facilit	−1,3	−0,1	2,0	−1,3	1,5	−0,8
Logistics resources	−2 restr, +2 facilit	0,8	0,4	1,0	0,8	1,0	0,5
INNOVATION							
Current CEPs with access to cities in 2035							
Small CEPs	%	44,1	20,8	70,0	10,0	100,0	85,0
Med/Large CEPs	%	53,6	73,9	83,0	10,0	100,0	18,6
Share and distribution of newcomers							
Newcomer share	0–100 %	21,7	29,2	32,0	32,0	23,0	16,9
Startups	%	73,3	37,2	52,0	52,0	34,3	15,0
Big (tech) companies	%	15,8	45,0	0,0	0,0	13,3	63,1
Community initiatives	%	5,0	4,2	1,0	1,0	15,0	8,8
Public initiatives	%	3,3	5,3	9,0	9,0	26,0	6,9
Other	%	2,5	8,3	38,0	38,0	11,3	6,3
Types of delivery							
B2C	−2 traditional, +2 new delivery models	−0,1	0,7	0,8	2,0	1,1	0,7
B2B	−2 traditional, +2 new delivery models.	−0,2	1,0	2,0	1,4	−0,4	1,0
Motorised transport							
Fossil-fuel	%	54,4	24,0	3,3	10,9	1,1	0,0
Fuel-cell	%	13,9	30	76,7	12,5	36,1	37,5
Battery-electric	%	25,7	36,0	6,7	72,2	50,0	12,5
New solutions	%	6,0	10,0	13,3	4,4	12,8	50,0
Non-motorised transp.							
On-foot courriers	%	19,0	51,4	7,8	5,0	12,9	19,0
(*E*-)cargobikes	%	67,0	28,6	87,2	25,0	46,3	67,0
New solutions	%	14,0	20,0	5,0	70,0	40,8	14,0
Level of automation							
Small vehicles	Autom. level 1–5	2,0	2,0	4,5	2,0	3,4	2,0
Large vehicles	Autom. level 1–5	1,9	1,9	4,3	4,0	2,7	1,9
COOPERATION							
CEP cooperation							
Storage space	−2 low, +2 high	0,2	−1,2	1,0	1,8	−1,2	−1,2
Transportation	−2 low, +2 high	0,3	−1,8	−0,6	1,29	−1,8	−1,8
Unattended delivery	−2 low, +2 high	0,2	0,2	0,8	1,7	0,2	0,2
Supply chain cooperation							
B2B	−2 low, +2 high	0,4	−1,0	2,0	1,0	0,8	−1,0
B2G	−2 low, +2 high	0,4	−0,3	1,7	1,1	−1,0	−0,3
Data sharing							
B2B	−2 low, +2 high	−1,3	−1,1	1,6	0,7	−1,3	−1,1
B2G	−2 low, +2 high	0,4	−1,1	2,0	0,7	0,4	−1,1
Stakeholder roles in unattended tech							
Local authorities	−2 passive, +2 active	0,4	−1,0	1,7	1,7	1,5	1,3
CEPs	−2 passive, +2 active	1,6	1,6	1,3	1,3	1,5	−0,7
Consumers	−2 passive, +2 active	0,2	0,9	−2,0	−2,0	1,0	−0,7

the logistics sector (variable Newcomer share). In both scenarios, 52 % of these newcomers consist of innovative start-ups (variable Start-ups). By contrast, in the *Good Intentions Abound* scenario, 16,9 % of all last-mile deliveries is handled by logistics newcomers, with big (tech) companies representing 69 % and innovative start-ups accounting for 15 % of newcomers. The columns represent scenarios as the theme clusters are connected by the qualitative content analysis. For instance, the degree of regulation by local authorities corresponds with different types of regulations in the *New Cool Collective* scenario compared to the *Revolution By Design* scenario. Next, the six scenarios are described qualitatively with emphasis on their main themes and how they cohere.

4.1. The old wild west

The first scenario is called *The Old Wild West* and characterised by overall inaction in the domains of government, innovation, and cooperation. Local authorities are largely absent from the logistics field due to a lack of knowledge, budgets, and dedicated manpower. In the absence of long-term goals set out by government, private actors feel little urgency to innovate. The sustainability potential of innovative delivery models is not realised, and the transition to clean modes of transportation has not been made. Cooperation lacks a clear incentive and is seen by the private sector as making matters unnecessarily complex. Consequently, private business models are optimised individually which results in a low number of supply chain partnerships, low cooperation in resource use (e.g., vehicles, distribution centres, deliveries points), and low levels data sharing.

4.2. The new wild west

The private sector leads the advancement of the last-mile logistics system in *The New Wild West,* where local authorities leave initiative to the market and incentives for innovation come from changing customer demands. Innovation is further driven by fierce competition caused by the high numbers of new entrants ("big tech" and innovative start-ups), resulting in the deployment of new delivery models (such as pick-up and drop-off points, unattended delivery technology) and new transportation modes powered in majority by clean fuels. High competition obstructs structural and intensive cooperation, which is, like innovation, sparse and opportunistic. Cooperation is considered only occasionally, from a perspective of cost-reduction, and lacks broader societal motives.

4.3. New cool collective

In the *New Cool Collective* scenario, public and private stakeholders in the logistics field share the objective to realise sustainable last-mile logistics through high levels of cooperation and innovation. Local authorities have become highly knowledgeable and competent in the logistics domain and formulate clear policy goals laying out ground rules on city access and types of transport modes allowed. Private initiative is strongly encouraged to meet these demands, and growing demand for logistics services is met with higher efficiency in operations, better consolidation, and deployment of new delivery models. A large portion of last-mile logistics is carried out by new players who purposefully built their business models on the premise of sustainability. Cooperation is deemed essential by logistics operators to make use of limited urban space, reduce costs, and meet policy goals on sustainability and liveability to which they are held accountable by the public.

4.4. Revolution by design

Sustainability in last-mile logistics is realised through active government intervention in the *Revolution By Design* scenario. Strong guidance from public stakeholders coupled with restrictive measures is considered indispensable to force change upon the private sector. Classic vehicle access restrictions are coupled with innovative measures, such as minimum requirements on delivery densities, consolidation, and concessions granting logistics suppliers the position of preferred or sole operator in dedicated city districts. Such measures result in high levels of innovation on clean transport modes and delivery models, and drastically change the composition of the sector, where a large share of newcomers cater to an interest in alternative logistics concepts such as niche services, combined and reverse logistics and shorter (locally oriented) supply chains. High cooperation among private parties is required to get deliveries through to customers in inner cities, which is supported by high levels of data sharing.

4.5. Thriving, individually

In the *Thriving, Individually* scenario, a mix of restrictive and facilitative policies spur innovation, but those policies result in limited cooperation between stakeholders. Restrictions on mode use and inner-city access implemented in the early 2020s have been effective to realise a zero-emissions transport fleet, higher levels of automation in transport, networks of micro-hubs, and higher capacity and efficiency in overall logistics operations to meet growing demand. However, this innovations "arms race" between individual companies has swamped the attention to cooperation among stakeholders. Innovations have optimised operations, but for each stakeholder individually. Logistics operators still deliver parcels through their own distribution centres and vehicle fleets, and data sharing is not taking place as data is seen as a critical asset in creating competitive advantage.

4.6. Good intentions abound

In the *Good Intentions Abound* scenario, local authorities aim to instigate change in the sector by implementing restrictive policies and measures on storage, transportation, and delivery. More so, authorities have themselves become an active player in the last-mile logistics domain through the acquisition of real estate, control of inner-city logistics processes, and the development and exploitation of systems of logistics hubs. In response, large logistics operators have mostly reoriented their focus to activities outside of the last-mile, and smaller operators aim to attune their business models to high government demand. However, due to limited capacity to adapt, private capacity in the last-mile domain falls behind on policy ambitions. Those operators that remain guard their positions heavily and shy away from cooperating with authorities and each other. Fierce competition leads to a limited inflow of new players, who need to make significant investments to acquire a position in the last-mile domain.

5. Discussion

The six scenarios were constructed to explore possible futures in last-mile logistics. Collectively, they reveal the broad range of possible futures that logistics stakeholders may be confronted with, building on potentially disruptive changes that follow from a growing demand for logistics services, more attention to sustainability and liveability in city policies and among consumers, changing and interdependent stakeholder interests, new technologies, and the inflow of new players in the sector. The adopted Disaggregative approach makes explicit that future of last-mile logistics in cities is open to different interpretations of how logistics operations are organised, how they affect sustainability and liveability, and what role and actions logistics stakeholders may, could, or should fulfil. Five important insights for logistics and transport policy research are identified.

First, not one of the scenarios shows signs that the growth of e-commerce is expected to slow down. This observation is in line with most expert predictions about e-commerce logistics (e.g., World Economic Forum, 2020) and underscores the urgency to develop sustainable last-mile solutions. The physical accommodation of logistics operations in urban space differs per scenario and may emerge as the government-

led acquisition of logistics space (*Good Intentions Abound*), private-led initiatives in the development of a network of micro-hubs (*Thriving, Individually*), or the joint optimization of use of public space for logistics by local authorities and operators (*New Cool Collective*). Innovation further changes how flows of goods are handled, which is apparent in higher shares of zero-emissions transport in multiple scenarios, varying levels of autonomy of self-driving vehicles in the last-mile fleet (*New Cool Collective*), widespread implementation of unattended delivery initiated by the private sector (*New Wild West*) or mandated by local authorities (*Revolution by Design*). Hence, the sustainability of last-mile logistics systems is affected by the different ways it is accommodated in the urban space and by varying levels of innovation. Because stakeholders have different views on the preferred scenario for last-mile logistics, and all can to a certain degree exert influence over how last-mile logistics will be organised, the future is still very much open.

Second, across all scenarios, an active role of local authorities in the organisation of last-mile logistics is a pre-condition for enhancing cooperation among private parties and between the public and private sector in developing sustainable last-mile solutions. This insight aligns with literature addressing the important role for authorities in the mitigation of negative externalities of logistics in urban areas (Kiba-Janiak, 2017; Witkowski & Kiba-Janiak, 2014). The scenarios show that this role can be fulfilled in different ways, for example, through active facilitation of parties that are identified as receptive to cooperation (*New Cool Collective*) or by mandating high delivery densities, which in turn results in higher stakeholder cooperation (*Revolution By Design*). A comparison across the scenarios offers a warning that active local authorities are not a guarantee for stakeholder cooperation. Imposing restrictions can trigger optimalizations mainly focused on individual business operations (*Thriving Individually*), whereas low trust between public and private actors or high numbers of new entrants can cause fierce competition resulting in general reluctance to cooperate (*Good Intentions Abound*). Collectively, the scenarios suggest that the role of local authorities in last-mile logistics is likely to become more active in the future. Hence, local authorities and private parties are suggested to invest in a continuous dialogue among logistics stakeholders for purpose of better coordination of ambitions and actions (Akgün, Monios, Rye, & Fonzone, 2019).

Third, the scenarios are generally characterised by a strong focus on technological innovation. Participants in our study generally believe technological innovation to be an essential part of the future of last-mile logistics and see it as an important tool for local authorities to reach sustainability goals. Two views can be discerned on the role of technology in logistics' futures. First, a techno-optimist stance, wherein technology is seen as the solution to most of last-mile logistics' problems, suitable solutions are believed to exist already, but prevented from reaching their full potential, for example, by a lack of public acceptance or legal embeddedness. Second, a stance viewing future technological innovation as the wild card, offering a way out of problems for which currently available solutions are not yet sufficient. Data sharing is generally viewed as an important precondition to fully utilise the potential of new technologies, as also highlighted in other studies (Gutierrez-Franco, Mejia-Argueta, & Rabelo, 2021; Karakikes & Nathanail, 2020). However, low levels of data-sharing among stakeholders in most scenarios warn against too much optimism. The scenarios equally show that data-driven decision-making and cooperation are still in their infancy and that important barriers remain, such as privacy concerns and the reservations of mostly private parties to share data. Local authorities especially still have much to learn according to study participants. They must become more data savvy and knowledgeable in the field to better understand the interests of the different logistics stakeholders and be seen as competent conversation partners by those stakeholders. If authorities develop these skills and gain knowledge on data-driven decision-making, cooperation, and mutual interests, the *New Cool Collective* scenario shows technology can be a major contributor to realizing sustainable solutions in last-mile logistics.

Fourth, our study identifies active governments and competitive pressures as main drivers for innovation in last-mile logistics. First, an active role by local governments can be an important driver for logistics innovations as shown in three out of six scenarios. This reflects the notion that governments can exert a profound role in promoting and sustaining innovation (Bjørgen, Seter, Kristensen, & Pitera, 2019; Castillo et al., 2024; Lindholm & Browne, 2013). As examples, innovations can be aided by clear policy visions on last-mile transport (*New Cool Collective*) or by strict regulation of logistics operations (*Revolution By Design*; *Thriving, Individually*). A second important innovation driver for innovation is competitive pressure, resulting either from large numbers of new entrants and the need to reduce costs or from changing customers preferences (*New Wild West*). Innovation requires a productive mix of drivers that fits with the specific characteristics of a city, the processes prevalent towards the scenarios' time horizon, and the opportunities provided by contextual developments.

Finally, despite the more prominent role of local authorities in most scenarios, last-mile logistics systems operations are expected to very much remain the domain of the private-sector logistics operators. In none of the scenarios does last-mile logistics become a purely public affair, as private players maintain a key role in the realization of sustainable last-mile logistics and liveable inner cities. Indeed, compared to the present moment, local authorities take more control in most future scenario, where their actions vary from setting the right conditions (*New Cool Collective*) to actively partaking in the development of logistics resources and services (*Good Intentions Abound*). But wider societal goals can't be reached without the private sector. This is especially visible in the *Good Intentions Abound* scenario: authorities have some success in greening the last mile by restricting the access of heavy and polluting transport mode, but an absence of cooperation between stakeholders means that supply chain and resource inefficiencies remain. In line with prior research (e.g., Bergqvist & Pruth, 2006; Bjørgen et al., 2019), this suggests that public-private partnerships will be key to realise more sustainable last-mile logistics in the future.

6. Conclusion

Actors in last-mile logistics are increasingly aware of the need to transition to more sustainable modes of operation. Both private and public-sector actors facing this complex transition need to prepare for a highly uncertain future. Scenarios are a powerful tool to identify future pathways as they compel last-mile logistics stakeholders to contemplate plausible futures. This paper explored a broad range of possible futures for last-mile logistics adopting a Disaggregative Policy Delphi approach for constructing scenarios. It presents six scenarios, each depicting a possible future of last-mile logistics in the year 2035. The scenarios aim to contribute to more informed decision-making by actors in last-mile logistics by identifying enablers and barriers in the transition towards sustainable last-mile logistics and exploring opportunities for shared courses of action.

Despite the perceived urgency for more sustainable last-mile logistics and associated policy initiatives (CiViTAS, 2015; ELTIS, 2016; European Commission, 2021b) our future scenarios indicate that the required transition is anything but a given. A successful transition to sustainable last-mile logistics only comes to full fruition in two out of six scenarios: one where public and private actors join forces to fundamentally reorganise last-mile logistics in terms of delivery solutions, consolidation schemes, and data management; and one where local authorities enforce the development of a more sustainable logistics system through a comprehensive set of restrictive and facilitative policies. In these scenarios, more active local authorities are thus key in achieving the sustainability transition.

Several take-aways for logistics stakeholders can be provided based on our study. Local governments can guide the way towards more suitable last-mile logistics via a combination of policy actions, such as developing sustainable urban logistics policies and frameworks,

implementing access restrictions, setting operational standards, helping logistics operators to find space on strategic locations, and actively partaking in the exploitation of logistics space. To fulfil this role effectively, local authorities need broad policymaking capacities and invest in becoming more technology savvy and knowledgeable in the field to be seen as competent conversion partner by other, private-sector actors in last-mile logistics. Private-sector actors can then focus on developing and implementing new and existing technologies and business models that enable a successful transition to sustainable last-mile logistics. To ensure that public and private actions mutually reinforce each other, an ongoing dialogue between the involved stakeholders is essential, as our scenarios show that the interplay between stakeholders is very influential in shaping the future of last-mile logistics while. An ongoing dialogue may help stakeholders to become more aware of the positions, interests, and ideas of others and identify possible courses for joint action.

The diversity of scenarios resulting from our study shows that the role of stakeholder cooperation, technological innovation, and regulation by local government serve well as overarching themes to imagine possible futures. The themes prove universal enough to allow for the consideration of more indirect effects from last-mile logistics—such as global climate change, national and global politics, and haphazard events such as a global disease pandemic—yet are specific enough to discuss potential roles for individual stakeholders in the logistics sector. The Disaggregative Policy Delphi was valuable for its ability to demonstrate the wide range of stakeholder views while also allowing for more general insights, for example, on the growing and lasting impact of last-mile logistics on cities, and that in face of this impact, inaction is not an option.

6.1. Limitations

Reflecting on the study, we identify three main limitations. The first pertains to the geographical focus of the study. The cities under study share features with regards to urban morphology, size, and level of attention to the transition towards sustainable last-mile logistics across stakeholders. Thus, transferring our key findings to other urban contexts—such as with different morphology or size, or where the urgency to transition to sustainable last-mile logistic is felt less or spread unevenly across stakeholders—should be done cautiously. However, our approach strengthened the robustness of the findings and their relevance for similar cities, who stand the challenging task to transition to more sustainable modes of operation in last-mile logistics in the coming years.

Second, our study does not specify whether some scenarios are more likely to take shape than others. Not investigating the level of realism or desirability can be seen as a limitation because local actors typically have limited means and thus may want to focus their efforts on those scenarios that are most likely to come into effect. However, our choice for a Disaggregative approach, thereby generating a range of possible scenarios, was a deliberate one as we believe that the logistics sector is a highly dynamic sector and thus robust policies should cater to a range of possible futures.

Third, the set timeframe of the study, focused on 2035, may have prevented more "radical" futuring and the development of even more diverse scenarios. However, it is justified by the goal of the study, namely, to provide input for informed decision-making by local actors who face high degrees of uncertainty beyond the timeframe of current policy plans, but close enough to be relevant for logistics policies and practices today.

6.2. Future research

The presented scenarios show the diverse futures that may lie ahead and as such may help policymakers and other stakeholders to develop joint courses of action that are sufficiently adaptive to uncertain events in the future. This also opens up ample opportunities for future research. One interesting direction could be to present the six scenarios developed in this study to a range of policymakers and other stakeholders to assess their likelihood or desirability. Another option would be to outline the actions needed by each stakeholder group to achieve a particular scenario. Finally, future research could monitor industry trends and the actions taken by policymakers and other stakeholders to identify which aspects of the scenarios are becoming a reality.

CRediT authorship contribution statement

Paul Plazier: Writing – original draft, Methodology, Data curation, Conceptualization. **Ward Rauws:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Robin Neef:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Paul Buijs:** Writing – review & editing, Supervision, Project administration, 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.

Acknowledgements

This work was supported by the European Union's Horizon 2020 research and innovation programme under grant agreement No 861833.

Appendix A. Survey structure for Disaggregative Policy Delphi

	Theme	Question ("In your view, in 2035…")
1.	**[Innovation]** Shares of different types of motorised vehicles.	What types of motorised vehicles will last-mile city logistics be operated with? (% of total fleet) Preference o Fossil fuel vehicles: …% o Fuel cell (H2) vehicles: …% o EV vehicles: …% o New technologies (currently not known or operated): …% Expectation o Fossil fuel vehicles: …% o Fuel cell (H2) vehicles: …% o EV vehicles: …% o New technologies (currently not known or operated): …%

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(*continued*)

	Theme	Question ("In your view, in 2035…")
2.	**[Innovation]** The use of cargo bikes in the last-mile.	What will be the share of (e-)cargobikes in last-mile city logistics? (% of total fleet) • Preference: …% • Expectation: …%
3.	**[Regulation]** The city's influence on transport logistics mode use.	What role will city authorities have in the promotion and use of different types of transportation in the last-mile? Degree of regulation • Preference (−2 passive, +2 active): … • Expectation: (−2 passive, +2 active): … Type of regulation • Preference (−2 restrictive, +2 facilitative): … • Expectation: (−2 restrictive, +2 facilitative): …
4.	**[Innovation]** Self-driving capabilities and level of autonomy in the last mile.	What will be the level of automation of vehicles operating in last-mile logistics in your city? Level of automation • Preference (0–5) … • Expectation: (0–5): …
5	**[Regulation]** City's role in the implementation of self-driving and robotization technology within its borders	What role will city authorities have in the regulation of self-driving technologies within city limits? Degree of regulation • Preference (−2 passive, +2 active): … • Expectation: (−2 passive, +2 active): … Type of regulation • Preference (−2 restrictive, +2 facilitative): … • Expectation: (−2 restrictive, +2 facilitative): …
6	**[Innovation]** Access to the city	With cities implementing access restrictions, logistics players will be challenged to invest and innovate their business models in order to retain access to the inner city. What share of current players will be able to retain access to the inner city? • Preference: …% • Expectation: …%
7	**[Regulation]** City's role in the regulation of access to inner city logistics sphere	What role will city authorities have in the regulation of access to the city? Degree of regulation • Preference (−2 passive, +2 active): … • Expectation: (−2 passive, +2 active): … Type of regulation • Preference (−2 restrictive, +2 facilitative): … • Expectation: (−2 restrictive, +2 facilitative): …
8	**[Innovation]** Attended home delivery versus unattended delivery tech (e.g. parcel lockers)	Will last-mile logistics be dominated by attended home delivery or unattended delivery (e.g. through parcel lockers)? • Preference (−2 traditional delivery to door, +2 new deliver models): … • Expectation (−2 traditional delivery to door, +2 new deliver models): …
9	**[Innovation]** Driving force behind unattended delivery tech	Who will drive the implementation of unattended delivery technology? Preference: • Local authorities (−2 passive, +2 active): … • CEPs (−2 passive, +2 active): … • Consumers (−2 passive, +2 active): … Expectation: • Local authorities (−2 passive, +2 active): … • CEPs (−2 passive, +2 active): … • Consumers (−2 passive, +2 active): …
10	**[Innovation]** Number of new players in the last mile logistics supply chain	Compared to now, what share of last-mile logistics players in your cities' will be new, and what share will be those currently established? • Preference: newcomer share (0–100 %) …% • Expectation: newcomer share (−100 %): …%
11	**[Innovation** Power of new players vs. established players in the last-mile logistics supply chain	Who will dominate last-mile city logistics in your city? (% shipped volume) Preference • Start-ups (0–100 %): …% • Big (tech) companies (0–100 %): …% • Community initiative (0–100 %): …% • Public initiative (0–100 %): …% • Other (0–100 %): …% Expectation • Start-ups (0–100 %): …% • Big (tech) companies (0–100 %): …%

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(*continued*)

	Theme	Question ("In your view, in 2035…")
		• Community initiative (0–100 %): …% • Public initiative (0–100 %): …% • Other (0–100 %): …%
12	**[Cooperation]** Degree of stakeholder cooperation	To what extent will stakeholders cooperate in the logistics chain? Preference • B2b (−2 low, +2 high): … • B2g (−2 low, +2 high): … Expectation • B2b (−2 low, +2 high): … • B2g (−2 low, +2 high): …
13	**[Cooperation]** Degree of data sharing of logistics players to increase efficiency of supply chain	How likely is it that last-mile logistics players share their data with other logistics players (B2b)? • Preference (−2 low, +2 high): … • Expectation (−2 low, +2 high): …
14	**[Cooperation]** Cooperation in city-wide intelligent city management system	To what extent will last-mile logistics players cooperate within a city-wide intelligent city-management system (B2g)? • Preference (−2 low, +2 high): … • Expectation (−2 low, +2 high): …
15	**[Cooperation]** Cooperation on the use of resources	To what extent will logistics players cooperate on the use of resources? (e.g. joint storage space, white label vehicles, white label parcel lockers) Preference • Storage space (−2 low, +2 high): … • Transportation (−2 low, +2 high): … • Unattended delivery (−2 low, +2 high): … Expectation • Storage space (−2 low, +2 high): … • Transportation (−2 low, +2 high): … • Unattended delivery (−2 low, +2 high): …
16	**[Regulation]** Regulation of resource sharing	What role will city authorities have in the regulation of sharing resources? Degree of regulation • Preference (−2 passive, +2 active): … • Expectation: (−2 passive, +2 active): … Type of regulation • Preference (−2 restrictive, +2 facilitative): … • Expectation: (−2 restrictive, +2 facilitative): …

Appendix B. Participant profiles

This appendix provides more detailed profiles of the 26 participants who completed the second round of our study. Local authorities were represented by five policymakers and policy administrators responsible for mobility and logistics in their respective cities. Ten logistics operators participated in the second round, including seven focused on business-to-consumer parcel delivery. This group comprised five local offices of large international parcel delivery companies and two locally operating start-ups. Additionally, two logistics operators specialise in business-to-business last-mile delivery, including larger shipments, and one specialises in foodservice distribution. We invited two citizen representatives to provide their perspectives, each representing a different local community group or neighbourhood in Groningen. Four business representatives were involved, with three representing a business association of local small and medium-sized enterprises or local shopkeepers specifically; the fifth representative provided a business perspective on digitisation. Table B.1 illustrates the distribution of participants across the three cities and four stakeholder types.

Table B.1 City representation of participants completing round 2.

Type of stakeholder	Bremen	Groningen	Mechelen
Local authorities	2	1	2
Logistics operators	3	4	3
Citizen representatives	0	2	0
Business representatives	0	3	2

Finally, the four logistics experts who participated in our study were not directly linked to any of the cities but are familiar with and active in them through their research programmes or advisory work. One expert is involved in scientific and applied research in last-mile logistics at a European university. Another expert works in a network organisation for logistics innovation in Flanders. A third expert works in a network organisation focused on sustainability transitions, particularly sustainable mobility. The final expert is employed by the Flemish Department of Mobility and Public Works.

References

Adom, D., Osei, M., & Adu-Agyem, J. (2020). COVID-19 lockdown: A review of an alternative to the traditional approach to research. *Research Journal in Advanced Social Sciences, 1*, 1–9.

Åkerman, J., & Höjer, M. (2006). How much transport can the climate stand?—Sweden on a sustainable path in 2050. *Energy Policy, 34*, 1944–1957. https://doi.org/10.1016/j.enpol.2005.02.009

Akgün, E. Z., Monios, J., Rye, T., & Fonzone, A. (2019). Influences on urban freight transport policy choice by local authorities. *Transport Policy, 75*, 88–98. https://doi.org/10.1016/j.tranpol.2019.01.009

ALICE-ETP, Polis. (2021). Cities-regions and companies working together. Guide for advancing towards zero-emission urban logistics by 2030 [WWW document]. URL https://www.etp-logistics.eu/wp-content/uploads/2021/12/POLIS_ALICE_Guide-Zero-Emission-Urban- Logistics_Dec2021-low.pdf.

Aljohani, K., & Thompson, R. G. (2020). A multi-criteria spatial evaluation framework to optimise the siting of freight consolidation facilities in inner-city areas. *Transportation Research Part A: Policy and Practice, 138*, 51–69. https://doi.org/10.1016/j.tra.2020.05.020

Allen, J., Bektas, T., Cherrett, T., Bates, O., Friday, A., McLeod, F., … Wise, S. (2018). The scope for pavement porters: Addressing the challenges of last-mile parcel delivery in London. *Transportation Research Record: Journal of the Transportation Research Board, 2672*, 184–193. https://doi.org/10.1177/0361198118794535

Allen, J., Browne, M., Woodburn, A., & Leonardi, J. (2012). The role of urban consolidation Centres in sustainable freight transport. *Transport Reviews, 32*, 473–490. https://doi.org/10.1080/01441647.2012.688074

Amaya, J., Arellana, J., & Delgado-Lindeman, M. (2020). Stakeholders perceptions to sustainable urban freight policies in emerging markets. *Transportation Research Part A: Policy and Practice, 132*, 329–348. https://doi.org/10.1016/j.tra.2019.11.017

Amaya, J., Delgado-Lindeman, M., Arellana, J., & Allen, J. (2021). Urban freight logistics: What do citizens perceive? *Transportation Research Part E: Logistics and Transportation Review, 152*, Article 102390. https://doi.org/10.1016/j.tre.2021.102390

Baker, J., Lovell, K., & Harris, N. (2006). How expert are the experts? An exploration of the concept of 'expert'within Delphi panel techniques. *Nurse researcher, 14*(1), 59–70. https://doi.org/10.7748/nr2006.10.14.1.59.c6010

Ballantyne, E. E. F., Lindholm, M., & Whiteing, A. (2013). A comparative study of urban freight transport planning: Addressing stakeholder needs. *Journal of Transport Geography, 32*, 93–101. https://doi.org/10.1016/j.jtrangeo.2013.08.013

Barratt, M. (2004). Understanding the meaning of collaboration in the supply chain. *Supply Chain Management: An International Journal, 9*, 30–42. https://doi.org/10.1108/13598540410517566

Beckers, J., Cardenas, I., Le Pira, M., & Zhang, J. (2023). Exploring logistics-as-a-service to integrate the consumer into urban freight. *Research in Transportation Economics, 101*, Article 101354. https://doi.org/10.1016/j.retrec.2023.101354

Berger, R. (2018). *Stronger together: Keep the wild west scenario at bay with cooperation – Urban logistics 2030 in Germany [WWW document]*.

Bergqvist, R., & Pruth, M. (2006). Public/private collaboration in logistics: An exploratory case study. *Supply Chain Forum: An International Journal, 7*, 106–116. https://doi.org/10.1080/16258312.2006.11517162

Bertolini, L. (2012). Integrating mobility and urban development agendas: A manifesto. *Disp - The Planning Review, 48*, 16–26. https://doi.org/10.1080/02513625.2012.702956

Biancolin, M., & Rotaris, L. (2024). Environmental impact of business-to-consumer e-commerce: Does it matter to consumers? *Research in Transportation Business & Management, 52*, Article 101087. https://doi.org/10.1016/j.rtbm.2023.101087

Bjørgen, A., Bråthen, S., Hansson, L., & Bjerkan, K. Y. (2024). The special issue on integrating e-commerce in urban mobility planning. *Research in Transportation Economics*. , Article 101439. https://doi.org/10.1016/j.retrec.2024.101439

Bjørgen, A., & Ryghaug, M. (2022). Integration of urban freight transport in city planning: Lesson learned. *Transportation Research Part D: Transport and Environment, 107*, Article 103310. https://doi.org/10.1016/j.trd.2022.103310

Bjørgen, A., Seter, H., Kristensen, T., & Pitera, K. (2019). The potential for coordinated logistics planning at the local level: A Norwegian in-depth study of public and private stakeholders. *Journal of Transport Geography, 76*, 34–41. https://doi.org/10.1016/j.jtrangeo.2019.02.010

Börjeson, L., Höjer, M., Dreborg, K. H., Ekvall, T., & Finnveden, G. (2006). Scenario types and techniques: Towards a user's guide. *Futures, 38*, 723–739. https://doi.org/10.1016/j.futures.2005.12.002

Bosona, T. (2020). Urban freight last mile logistics—Challenges and opportunities to improve sustainability: A literature review. *Sustainability, 12*, 1–20. https://doi.org/10.3390/su12218769

Browne, M., Allen, J., & Leonardi, J. (2011). Evaluating the use of an urban consolidation Centre and electric vehicles in Central London. *IATSS Research, 35*, 1–6. https://doi.org/10.1016/j.iatssr.2011.06.002

Browne, M., Allen, J., & Woodburn, A. (2007). The role of urban consolidation centres for different business sectors. In *World conference on transport research. Berkeley, USA*.

Brusselaers, N., Macharis, C., & Mommens, K. (2023). The health impact of freight transport-related air pollution on vulnerable population groups. *Environmental Pollution, 329*, Article 121555. https://doi.org/10.1016/j.envpol.2023.121555

Buijs, P., & Ozyavas, P. (2020). *Benchmarking & state-of-the-art. ULaaDS D3.1: Benchmarking business/operating models and best practices [WWW document]*.

Buldeo Rai, H., & Dablanc, L. (2023). Hunting for treasure: A systematic literature review on urban logistics and e-commerce data. *Transport Reviews, 43*(2), 204–233. https://doi.org/10.1080/01441647.2022.2082580

Cardenas, I., Borbon-Galvez, Y., Verlinden, T., van de Voorde, E., Vanelslander, T., & Dewulf, W. (2017). City logistics, urban goods distribution and last mile delivery and collection. *Competition and Regulation in Network Industries, 18*, 22–43. https://doi.org/10.1177/1783591717736505

Castillo, C., Viu-Roig, M., Nicolàs, M., & Alvarez-Palau, E. J. (2024). Tackling urban freight distribution: A public-private perspective. *Research in Transportation Business & Management, 53*, Article 101105. https://doi.org/10.1016/j.rtbm.2024.101105

Choubassi, C., Seedah, D. P. K., Jiang, N., & Walton, C. M. (2016). Economic analysis of cargo cycles for urban mail delivery. *Transportation Research Record: Journal of the Transportation Research Board, 2547*, 102–110. https://doi.org/10.3141/2547-14

CiViTAS. (2015). Policy note: Smart choices for cities. Making urban freight logistics more sustainable [WWW Document]. URL https://civitas.eu/sites/default/files/civ_pol-an5_urban_web.pdf (accessed 8.4.22).

Correia, D., Vagos, C., Marques, J. L., & Teixeira, L. (2024). Fulfilment of last-mile urban logistics for sustainable and inclusive smart cities: A case study conducted in Portugal. *International Journal of Logistics Research and Applications, 27*(6), 931–958 (Error! Hyperlink reference not valid).

Cruijssen, F., Cools, M., & Dullaert, W. (2007). Horizontal cooperation in logistics: Opportunities and impediments. *Transportation Research Part E: Logistics and Transportation Review, 43*, 129–142. https://doi.org/10.1016/j.tre.2005.09.007

Cushman, & Wakefield. (2017). Urban Logistics Space: the ultimate real estate challenge? [WWW Document]. URL https://www.cushmanwakefield.com/-/media/cw/emea/united-kingdom/insights/download-pdfs/2017-cushman-wakefield-urban-logistics-report.pdf (accessed 8.4.22).

Dablanc, L. (2007). Goods transport in large European cities: Difficult to organize, difficult to modernize. *Transportation Research Part A: Policy and Practice, 41*, 280–285. https://doi.org/10.1016/j.tra.2006.05.005

Dablanc, L. (2011). City distribution, a key element of the urban economy: Guidelines for practitioners. In C. Macharis, & S. Melo (Eds.), *City distribution and urban freight transport: Multiple perspectives* (pp. 13–36). Cheltenham, UK: Edward Elgar.

Dalmolen, S., Bastiaansen, H., Moonen, H., Hofman, W., Punter, M., & Cornelisse, E. (2018). Trust in a multi-tenant, logistics, data sharing infrastructure: Opportunities for blockchain technology. In *Proceedings 5th international physical internet conference (IPIC), Groningen 17-22 June 2018*.

DHL. (2018). Logistics Trend Radar, 5th edition [WWW Document]. URL https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/glo-core-logistics-trend-radar-5thedition.pdf (accessed 8.4.22).

Dreischerf, A. J., & Buijs, P. (2022). How urban consolidation Centres affect distribution networks: An empirical investigation from the perspective of suppliers. *Case Studies on Transport Policy, 10*(1), 518–528. https://doi.org/10.1016/j.cstp.2022.01.012

Dror, Y. (2006). Training for policymakers. In M. Moran, M. Rein, & R. E. Goodin (Eds.), *The 834 Oxford handbook of public policy* (pp. 80–108). Oxford University Press.

van Duin, R., Slabbekoorn, M., Tavasszy, L., & Quak, H. (2018). Identifying dominant stakeholder perspectives on urban freight policies: A Q-analysis on urban consolidation centres in the Netherlands. *Transport, 33*, 867–880. https://doi.org/10.3846/16484142.2017.1350996

ELTIS. (2016). Planning sustainable urban logistics [WWW Document]. URL https://www.eltis.org/resources/tools/planning-sustainable-urban-logistics (accessed 8.4.22).

European Commission. (2019). *Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 Setting CO2 Emission Performance Standards for New Heavy-Duty Vehicles and Amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC* (p. 198). official journal of the European Union, L. https://eur-lex.europa.eu/eli/reg/2019/1242/oj#d1e1921-202-1.

European Commission. (2020). Urban logistics as an on demand service - project description [WWW document]. https://cordis.europa.eu/project/id/861833.

European Commission. (2021a). *EU missions: 100 climate-neutral and smart cities. doi*. https://doi.org/10.2777/197915

European Commission. (2021b). Questions and Answers: European Urban Mobility Framework [WWW Document]. URL https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_6729 (accessed 8.4.22).

Fehling, C., & Saraceni, A. (2023). Technical and legal critical success factors: Feasibility of drones & AGV in the last-mile-delivery. *Research in Transportation Business & Management, 50*, Article 101029. https://doi.org/10.1016/j.rtbm.2023.101029

Ferrell, W., Ellis, K., Kaminsky, P., & Rainwater, C. (2020). Horizontal collaboration: Opportunities for improved logistics planning. *International Journal of Production Research, 58*(14), 4267–4284. https://doi.org/10.1080/00207543.2019.1651457

Figliozzi, M., Saenz, J., & Faulin, J. (2020). Minimization of urban freight distribution lifecycle CO2e emissions: Results from an optimization model and a real-world case study. *Transport Policy, 86*, 60–68. https://doi.org/10.1016/j.tranpol.2018.06.010

Figliozzi, M. A. (2020). Carbon emissions reductions in last mile and grocery deliveries utilizing air and ground autonomous vehicles. *Transportation Research Part D: Transport and Environment, 85*, Article 102443. https://doi.org/10.1016/j.trd.2020.102443

Fransoo, J. C., Cedillo-Campos, M. G., & Gámez-Pérez, K. M. (2022). Estimating the benefits of dedicated unloading bays by field experimentation. *Transportation Research Part A: Policy and Practice, 160*, 348–354. https://doi.org/10.1016/j.tra.2022.03.023

Gansterer, M., & Hartl, R. F. (2018). Collaborative vehicle routing: A survey. *European Journal of Operational Research, 268*, 1–12. https://doi.org/10.1016/j.ejor.2017.10.023

Gattringer, R., Wiener, M., & Strehl, F. (2017). The challenge of partner selection in collaborative foresight projects. *Technological Forecasting and Social Change, 120*, 298–310. https://doi.org/10.1016/j.techfore.2017.01.018

Gevaers, R., van de Voorde, E., & Vanelslander, T. (2011). Characteristics and typology of last-mile logistics from an innovation perspective in an urban context. In *City Distribution and Urban Freight Transport*. Edward Elgar Publishing. https://doi.org/10.4337/9780857932754.00009.

Gillström, H., & Björklund, M. (2024). Assessing the benefits of urban consolidation centres: An overview based on a systematic literature review. *Transport Reviews, 1-20*. https://doi.org/10.1080/01441647.2024.2348639

Gonzalez, J. N., Garrido, L., & Vassallo, J. M. (2023). Exploring stakeholders' perspectives to improve the sustainability of last mile logistics for e-commerce in urban areas. *Research in Transportation Business & Management, 49*, Article 101005. https://doi.org/10.1016/j.rtbm.2023.101005

von der Gracht, H. A., & Darkow, I. L. (2010). Scenarios for the logistics services industry: A Delphi-based analysis for 2025. *International Journal of Production Economics, 127*, 46–59. https://doi.org/10.1016/j.ijpe.2010.04.013

Gutierrez-Franco, E., Mejia-Argueta, C., & Rabelo, L. (2021). Data-driven methodology to support long-lasting logistics and decision making for urban last-mile operations. *Sustainability, 13*, 6230. https://doi.org/10.3390/su13116230

Haarstad, H., Rosales, R., & Shrestha, S. (2024). Freight logistics and the city. *Urban Studies, 61*(1), 3–19. https://doi.org/10.1177/00420980231177265

Hallowell, M. R. (2009). Techniques to minimize Bias when using the Delphi method to quantify construction safety and health risks. In *Construction research congress 2009* (pp. 1489–1498). Reston, VA: American Society of Civil Engineers. https://doi.org/10.1061/41020(339)151.

Heger, T., & Boman, M. (2015). Networked foresight-the case of EIT ICT labs. *Technological Forecasting and Social Change, 101*, 147–164. https://doi.org/10.1016/j.techfore.2014.02.002

Heger, T., & Rohrbeck, R. (2012). Strategic foresight for collaborative exploration of new business fields. *Technological Forecasting and Social Change, 79*, 819–831. https://doi.org/10.1016/j.techfore.2011.11.003

van der Heijden, K. (2005). *Scenarios: The art of strategic conversation* (2nd ed.). John Wiley & Sons Ltd.

Holguín-Veras, J., Amaya Leal, J., Sánchez-Diaz, I., Browne, M., & Wojtowicz, J. (2020a). State of the art and practice of urban freight management: Part I: Infrastructure, vehicle-related, and traffic operations. *Transportation Research Part A: Policy and Practice, 137*, 360–382. https://doi.org/10.1016/j.tra.2018.10.037

Holguín-Veras, J., Amaya Leal, J., Sanchez-Diaz, I., Browne, M., & Wojtowicz, J. (2020b). State of the art and practice of urban freight management part II: Financial approaches, logistics, and demand management. *Transportation Research Part A: Policy and Practice, 137*, 383–410. https://doi.org/10.1016/j.tra.2018.10.036

Holguín-Veras, J., & Sánchez-Díaz, I. (2016). Freight demand management and the potential of receiver-led consolidation programs. *Transportation Research Part A: Policy and Practice, 84*, 109–130. https://doi.org/10.1016/j.tra.2015.06.013

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*, 1277–1288. https://doi.org/10.1177/1049732305276687

Hu, W., Dong, J., Hwang, B. G., Ren, R., & Chen, Z. (2019). A scientometrics review on city logistics literature: Research trends, advanced theory and practice. *Sustainability, 11*, 1–27. https://doi.org/10.3390/su11102724

Hussler, C., Muller, P., & Rondé, P. (2011). Is diversity in Delphi panelist groups useful? Evidence from a French forecasting exercise on the future of nuclear energy. *Technological Forecasting and Social Change, 78*(9), 1642–1653. https://doi.org/10.1016/j.techfore.2011.07.008

ITF. (2021). *ITF transport outlook 2021. Paris*. https://doi.org/10.1787/16826a30-en

Janinhoff, L., Klein, R., Sailer, D., & Schoppa, J. M. (2024). Out-of-home delivery in last-mile logistics: A review. *Computers & Operations Research.* , Article 106686. https://doi.org/10.1016/j.cor.2024.106686

Janjevic, M., Knoppen, D., & Winkenbach, M. (2019). Integrated decision-making framework for urban freight logistics policy-making. *Transportation Research Part D: Transport and Environment, 72*, 333–357. https://doi.org/10.1016/j.trd.2019.05.006

Janjevic, M., & Ndiaye, A. (2017). Investigating the theoretical cost-relationships of urban consolidation centres for their users. *Transportation Research Part A: Policy and Practice, 102*, 98–118. https://doi.org/10.1016/j.tra.2016.10.027

Janjevic, M., & Winkenbach, M. (2020). Characterizing urban last-mile distribution strategies in mature and emerging e-commerce markets. *Transportation Research Part A: Policy and Practice, 133*, 164–196. https://doi.org/10.1016/j.tra.2020.01.003

Kaboli, S. A., & Tapio, P. (2018). How late-modern nomads imagine tomorrow? A causal layered analysis practice to explore the images of the future of young adults. *Futures, 96*, 32–43. https://doi.org/10.1016/j.futures.2017.11.004

Karakikes, I., & Nathanail, E. (2020). Using the Delphi method to evaluate the appropriateness of urban freight transport solutions. *Smart Cities, 3*, 1428–1447. https://doi.org/10.3390/smartcities3040068

Kiba-Janiak, M. (2017). Opportunities and threats for city logistics development from a local authority perspective. *Journal of Economics and Management, 28*, 23–39. https://doi.org/10.22367/jem.2017.28.02

Kim, W., & Wang, X. C. (2022). The adoption of alternative delivery locations in new York City: Who and how far? *Transportation Research Part A: Policy and Practice, 158*, 127–140. https://doi.org/10.1016/j.tra.2022.02.006

Kin, B., Buldeo Rai, H., Dablanc, L., & Quak, H. (2024). Integrating logistics into urban planning: Best practices from Paris and Rotterdam. *European Planning Studies, 32*(1), 24–44. https://doi.org/10.1080/09654313.2023.2242400

Knoppen, D., Janjevic, M., & Winkenbach, M. (2021). Prioritizing urban freight logistics policies: Pursuing cognitive consensus across multiple stakeholders. *Environmental Science & Policy, 125*, 231–240. https://doi.org/10.1016/j.envsci.2021.09.002

Lal, A., Renaldy, T., Breuning, L., Hamacher, T., & You, F. (2023). Electrifying light commercial vehicles for last-mile deliveries: Environmental and economic perspectives. *Journal of Cleaner Production, 416*, Article 137933. https://doi.org/10.1016/j.jclepro.2023.137933

Le Pira, M., Marcucci, E., Gatta, V., Ignaccolo, M., & Inturri, G. (2023). Participatory decision-support tools for stakeholder engagement in urban freight transport policy making. In *Handbook on City logistics and urban freight* (pp. 327–345). Edward Elgar Publishing.

Le Pira, M., Nascimento, C. D. O. L., Giuffrida, N., Tapia, R. J., Pilla, F., & Tavasszy, L. A. (2024). Innovations in last mile logistics: Towards inclusivity, resilience and sustainability. *Research in Transportation Economics.* , Article 101446. https://doi.org/10.1016/j.retrec.2024.101446

Lebeau, P., & Macharis, C. (2014). Freight transport in Brussels and its impact on road traffic? *Brussels Studies*. https://doi.org/10.4000/brussels.1239

Lebeau, P., Macharis, C., van Mierlo, J., & Janjevic, M. (2018). Improving policy support in city logistics: The contributions of a multi-actor multi-criteria analysis. *Case Studies on Transport Policy, 6*, 554–563. https://doi.org/10.1016/j.cstp.2018.07.003

Liimatainen, H., Kallionpää, E., Pöllänen, M., Stenholm, P., Tapio, P., & McKinnon, A. (2014). Decarbonizing road freight in the future — Detailed scenarios of the carbon emissions of Finnish road freight transport in 2030 using a Delphi method approach. *Technological Forecasting and Social Change, 81*, 177–191. https://doi.org/10.1016/j.techfore.2013.03.001

Lindholm, M., & Browne, M. (2013). Local authority cooperation with urban freight stakeholders: A comparison of partnership approaches. *European Journal of Transport and Infrastructure Research, 13*, 20–38. https://doi.org/10.18757/ejtir.2013.13.1.2986

Macioszek, E. (2018). First and last mile delivery – Problems and issues. In G. Sierpiński (Ed.), *Advanced solutions of transport Systems for Growing Mobility. TSTP 2017. Advances in intelligent systems and computing* (pp. 147–154). Cham: Springer. https://doi.org/10.1007/978-3-319-62316-0_12.

Mangiaracina, R., Perego, A., Seghezzi, A., & Tumino, A. (2019). Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: A literature review. *International Journal of Physical Distribution and Logistics Management, 49*, 901–920. https://doi.org/10.1108/IJPDLM-02-2019-0048

Maxner, T., Dalla Chiara, G., & Goodchild, A. (2024). The state of sustainable urban last-mile freight planning in the United States. *Journal of the American Planning Association, 1–14*. https://doi.org/10.1080/01944363.2024.2324096

McKinsey & Company. (2016). Parcel delivery: the future of last mile [WWW Document]. URL https://bdkep.de/files/bdkep-dateien/pdf/2016_the_future_of_last_mile.pdf (accessed 8.4.22).

McKinsey & Company. (2018). Fast forwarding last-mile delivery – Implications for the ecosystem [WWW document]. URL https://www.mckinsey.com/~/media/mckinsey/industries/travel%20logistics%20and%20infrastructure/our%20insights/technology%20delivered%20implications%20for%20cost%20customers%20and%20competition%20in%20the%20last%20mile%20ecosystem/fast-forwarding-last-mile-delivery-implications-for-the-ecosystem.pdf.

Melander, L., Dubois, A., Hedvall, K., & Lind, F. (2019). Future goods transport in Sweden 2050: Using a Delphi-based scenario analysis. *Technological Forecasting and Social Change, 138*, 178–189. https://doi.org/10.1016/j.techfore.2018.08.019

Mohammad, W. A. M., Nazih Diab, Y., Elomri, A., & Triki, C. (2023). Innovative solutions in last mile delivery: Concepts, practices, challenges, and future directions. *Supply Chain Forum: An International Journal, 24*(2), 151–169. https://doi.org/10.1080/16258312.2023.2173488

Mommens, K., Brusselaers, N., Van Lier, T., & Macharis, C. (2019). A dynamic approach to measure the impact of freight transport on air quality in cities. *Journal of Cleaner Production, 240*, Article 118192. https://doi.org/10.1016/j.jclepro.2019.118192

Muñuzuri, J., Larrañeta, J., Onieva, L., & Cortés, P. (2005). Solutions applicable by local administrations for urban logistics improvement. *Cities, 22*, 15–28. https://doi.org/10.1016/j.cities.2004.10.003

Neef, R., Verweij, S., Busscher, T., & Arts, J. (2020). A common ground? Constructing and exploring scenarios for infrastructure network-of-networks. *Futures, 124*, Article 102649. https://doi.org/10.1016/j.futures.2020.102649

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: An example, design considerations and applications. *Information & Management, 42*, 15–29. https://doi.org/10.1016/j.im.2003.11.002

Paddeu, D., Parkhurst, G., Rosenberg, G., Carhart, N., & Taylor, C. (2024). Promoting sustainable urban freight through stakeholder engagement to co-create decarbonisation pathways in the UK. *Research in Transportation Economics, 104*, Article 101424. https://doi.org/10.1016/j.retrec.2024.101424

Pan, S., Trentesaux, D., Ballot, E., & Huang, G. Q. (2019). Horizontal collaborative transport: Survey of solutions and practical implementation issues. *International Journal of Production Research, 57*(15–16), 5340–5361. https://doi.org/10.1080/00207543.2019.1574040

Patella, S. M., Grazieschi, G., Gatta, V., Marcucci, E., & Carrese, S. (2020). The adoption of green vehicles in last mile logistics: A systematic review. *Sustainability, 13*(1), 6 (Error! Hyperlink reference not valid).

Peppel, M., Ringbeck, J., & Spinler, S. (2022). How will last-mile delivery be shaped in 2040? A Delphi-based scenario study. *Technological Forecasting and Social Change, 177*, Article 121493. https://doi.org/10.1016/j.techfore.2022.121493

Przybylska, E., Kramarz, M., & Dohn, K. (2023). Analysis of stakeholder roles in balancing freight transport in the city logistics ecosystem. *Research in Transportation Business & Management, 49*, Article 101009 (Error! Hyperlink reference not valid).

PWC. (2019). Five forces shaping last-mile logistics. In *PwC CEE Transport & Logistics Trend Book 2019. [WWW Document]*. URL https://www.pwc.com/m1/en/industries/documents/transport-logistics-trendbook-2019-en.pdf (accessed 8.4.22).

Quak, H., & Kin, B. (2020). The impact of future delivery models in last-mile home deliveries. In *4th international conference green cities 2020 – Green logistics for greener cities, 3–5 June 2020, – online, Szczecin, Poland. Szczecin, Poland*.

Quak, H. J. (2012). Improving urban freight transport sustainability by carriers – Best practices from the Netherlands and the EU project CityLog. *Procedia - Social and Behavioral Sciences, 39*, 158–171. https://doi.org/10.1016/j.sbspro.2012.03.098

Ritchie, H. (2020). Cars, planes, trains: Where do CO2 emissions from transport come from? [WWW document]. https://ourworldindata.org/co2-emissions-from-transport.

Roberts, J. K., Pavlakis, A. E., & Richards, M. P. (2021). It's more complicated than it seems: Virtual qualitative research in the COVID-19 era. *International Journal of Qualitative Methods, 20*, 1–13. https://doi.org/10.1177/16094069211002959

Rubin, A. (2013). Hidden, inconsistent, and influential: Images of the future in changing times. *Futures, 45*, S38–S44. https://doi.org/10.1016/j.futures.2012.11.011

Russo, S. M., Voegl, J., & Hirsch, P. (2021). A multi-method approach to design urban logistics hubs for cooperative use. *Sustainable Cities and Society, 69*, Article 102847. https://doi.org/10.1016/j.scs.2021.102847

Saénz, M. J., Revilla, E., & Borrella, I. (2022). Digital transformation is challenging supply chain relationships. *Harvard Business Review*.

Savelsbergh, M., & van Woensel, T. (2016). City logistics: Challenges and opportunities. *Transportation Science, 50*, 579–590. https://doi.org/10.1287/trsc.2016.0675

Shrestha, S., & Haarstad, H. (2023). Do EU goals matter? Assessing the localization of sustainable urban logistics governance goals in Norwegian cities. *Cities, 137*, Article 104317. https://doi.org/10.1016/j.cities.2023.104317

Shrestha, S., Haarstad, H., & Rosales, R. (2024). Power in urban logistics: A comparative analysis of networks and policymaking in logistics sustainability governance. *Environmental Innovation and Societal Transitions, 51*, Article 100845. https://doi.org/10.1016/j.cities.2023.104317

Soosay, C. A., & Hyland, P. (2015). A decade of supply chain collaboration and directions for future research. *Supply Chain Management: An International Journal, 20*, 613–630. https://doi.org/10.1108/SCM-06-2015-0217

Tanco, M., & Escuder, M. (2021). A multi-perspective analysis for the better understanding of urban freight transport challenges and opportunities in Montevideo. *Case Studies on Transport Policy, 9*(2), 405–417. https://doi.org/10.1016/j.cstp.2020.11.005

Tapio, P., Paloniemi, R., Varho, V., & Vinnari, M. (2011). The unholy marriage? Integrating qualitative and quantitative information in Delphi processes. *Technological Forecasting and Social Change, 78*, 1616–1628. https://doi.org/10.1016/j.techfore.2011.03.016

Thoma, L., & Gruber, J. (2020). Drivers and barriers for the adoption of cargo cycles: An exploratory factor analysis. *Transportation Research Procedia, 46*, 197–203. https://doi.org/10.1016/j.trpro.2020.03.181

UPS. (2019). UPS Pulse of the online shopper - A customer experience study [WWW Document]. URL https://seattlegood.org/wp-content/uploads/2020/06/2019-Pulse-of-Online-Shopper.pdf (accessed 8.4.22).

Varho, V., & Tapio, P. (2013). Combining the qualitative and quantitative with the Q2 scenario technique - the case of transport and climate. *Technological Forecasting and Social Change, 80*, 611–630. https://doi.org/10.1016/j.techfore.2012.09.004

Wilson, M., Janjevic, M., & Winkenbach, M. (2022). Modeling a time-differentiated policy for management of loading bays in urban areas. *Research in Transportation Business & Management*. , Article 100773. https://doi.org/10.1016/j.rtbm.2021.100773

Witkowski, J., & Kiba-Janiak, M. (2014). The role of local governments in the development of City logistics. *Procedia - Social and Behavioral Sciences, 125*, 373–385. https://doi.org/10.1016/j.sbspro.2014.01.1481

World Economic Forum. (2020). *The future of the last-mile ecosystem*. Geneva: Transition Roadmaps for Public- and Private-Sector Players.

Yuen, K. F., Wang, X., Ma, F., & Wong, Y. D. (2019). The determinants of customers' intention to use smart lockers for last-mile deliveries. *Journal of Retailing and Consumer Services, 49*, 316–326. https://doi.org/10.1016/j.jretconser.2019.03.022