

AUTONOMOUS VEHICLES IN URBAN LAST-MILE DELIVERY. A DELPHI-BASED ASSESSMENT OF ADOPTION PROSPECTS

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Purpose: This paper aims to assess the adoption prospects of autonomous vehicles in urban last-mile courier delivery.

Design/methodology/approach: A qualitative Delphi study was conducted. The Delphi research form included four future-oriented theses concerning the use of autonomous vehicles by courier companies. The factors supporting and hindering the implementation of the theses were identified on the basis of the literature review. The paper presents findings from the Delphi study. Expert assessments were synthesised using significance, favourability and barrier indicators derived from research.

Findings: The results indicate that experts perceive autonomous vehicles as a plausible future component of courier fleets, rather than a short-term replacement for all other last-mile delivery solutions. Experts assigned the strongest support to the development of autonomous vehicle technology, the possibility of co-financing purchases and the readiness of urban infrastructure. The main barriers were the cost of purchasing autonomous vehicles, legal uncertainty, limited service facilities, difficulties in obtaining spare parts and concerns about the safety of technological solutions.

Research limitations/implications: The study is based on a limited expert panel and presents exploratory findings. Future research should involve a larger and more diverse group of experts and allow comparison between stakeholder groups.

Practical implications: The findings can support courier companies, city authorities and policymakers in planning conditions for testing and implementing autonomous vehicles in urban logistics.

Social implications: The study points to the need to consider public acceptance, safety and environmental expectations when introducing autonomous delivery solutions in cities.

Originality/value: The paper contributes an expert-based Delphi assessment of autonomous vehicles in urban last-mile delivery and identifies factors that may shape their adoption.

Keywords: autonomous vehicles; last-mile delivery; urban logistics; Delphi method.

Category of the paper: Research paper.

1. Introduction

E-commerce has changed the organisation of retail distribution. It has increased the number of small, frequent and geographically dispersed deliveries to individual customers. This change has shifted part of retail competition from store accessibility and product availability to the quality of order fulfilment and delivery performance. In online retailing, physical distribution service quality includes such dimensions as delivery reliability, timeliness, product availability, information quality and returns handling. Therefore, in last-mile logistics, service quality is often assessed at the point where the parcel reaches the recipient. This makes the final delivery stage a source of market differentiation and customer value creation. At the same time, it creates operational pressure for retailers, logistics service providers and courier companies (Xing et al., 2010; Lim et al., 2018; Mangiaracina et al., 2019; Raźniewska et al., 2026).

Customers expect short delivery times, reliable information, flexible delivery options, convenient returns and, increasingly, low or no delivery charges. The popularity of next-day delivery and free delivery models increases the tension between customer convenience, operational efficiency and environmental sustainability. These expectations reduce the possibilities for shipment consolidation. They also increase the number of delivery trips in urban areas, particularly when home delivery is used as the dominant fulfilment model. As a result, the last mile has become one of the most demanding parts of the supply chain. It is costly, service-sensitive, difficult to standardise and strongly dependent on local demand density, urban form and customer behaviour (Visser et al., 2014; Allen et al., 2018; Buldeo Rai et al., 2019; Boysen et al., 2021; Olsson et al., 2019).

The pressure is particularly visible in cities. Urban areas concentrate demand for parcel delivery, but they also concentrate congestion, limited road space, curbside competition, noise and emissions. Freight transport is necessary for urban economic activity, but it also generates negative externalities that must be managed through transport policy, land-use planning and cooperation between public and private stakeholders. City logistics must therefore combine economic efficiency with quality of life and environmental objectives. This makes urban last-mile delivery not only a logistics problem, but also a matter of transport policy, spatial planning, environmental management and public acceptance (Dablanc et al., 2013; Savelsbergh, van Woensel, 2016; Viu-Roig, Alvarez-Palau, 2020; Kiba-Janiak et al., 2021; Wolniak, 2023).

The literature proposes different ways of improving last-mile delivery. These include parcel lockers, pickup and drop-off points, cargo bikes, electric vans, crowdsourcing, drones and autonomous delivery systems. Parcel lockers and other out-of-home delivery solutions are often discussed as ways to reduce failed deliveries, improve consolidation and limit the environmental burden of individual home deliveries. Green last-mile solutions are also increasingly analysed in relation to customer preferences and the willingness of e-commerce users to choose more sustainable delivery options when information about environmental

impacts is available. These solutions differ in terms of technological maturity, cost structure, infrastructure needs, environmental performance and social acceptance. They should not be treated as mutually exclusive. In many cities, future last-mile delivery will probably be based on a combination of several solutions adapted to local conditions (Iwan et al., 2016; Ranieri et al., 2018; Ignat, Chankov, 2020; Mucowska, 2021; Lauenstein, Schank, 2022).

Autonomous vehicles are one of the most discussed directions of change in urban delivery. In this paper, the term refers to ground-based driverless delivery solutions used in courier operations, including autonomous delivery vehicles and smaller autonomous delivery robots. Their potential is linked to lower dependence on human drivers, more flexible delivery models and better use of local distribution systems. Previous studies indicate that such solutions may reduce delivery time and operational costs in selected contexts. They may also limit some external effects of urban freight transport, especially when autonomous delivery is integrated with electric propulsion, local hubs or other low-emission delivery systems (Baum et al., 2019; Figliozzi, 2020; Chen et al., 2021; Engesser et al., 2023; Jennings, Figliozzi, 2019; Guzowski, Szpilko, 2025).

However, the implementation of autonomous vehicles in courier services remains uncertain. It depends on technological development, urban infrastructure, legal regulations, safety, public acceptance and investment capacity. In addition, autonomous delivery requires an operational ecosystem that includes charging facilities, remote supervision, maintenance services, data management, liability rules and procedures for interaction with pedestrians, cyclists and other road users. The literature also points to the limited number of real-world implementations and the early stage of empirical research on autonomous delivery systems. For this reason, adoption prospects should be assessed not only from a technical perspective, but also from an organisational, economic, legal, environmental and social perspective (Hoffmann, Prause, 2018; Kapser, Abdelrahman, 2020; Alverhed et al., 2024; Yuen et al., 2022; Koh et al., 2024).

Existing research discusses many operational and technological aspects of autonomous delivery, including routing, fleet configuration, customer acceptance, safety, environmental performance and regulatory conditions. At the same time, last-mile logistics research remains fragmented across several disciplines, including transport studies, logistics, operations research, sustainability research, consumer behaviour and urban policy. Less attention has been paid to expert assessments of how and under what conditions autonomous vehicles may become part of courier fleets in urban last-mile delivery. This research gap is important because decisions concerning autonomous delivery are made under uncertainty. The technology is developing, but its wider use depends on several interrelated factors that cannot be assessed only on the basis of current empirical data (Olsson et al., 2019; Engesser et al., 2023; Alverhed et al., 2024).

In such conditions, the Delphi method is useful as a qualitative expert method that supports the structured assessment of future developments when precise empirical data are limited. The method enables the collection and refinement of expert judgements through iterative rounds, controlled feedback and systematic analysis of opinions. It is therefore suitable for

studying emerging technologies and complex socio-technical systems, especially when future adoption depends on technological, market, regulatory and social factors. In this study, the Delphi method was used to assess supporting factors and barriers to the adoption of autonomous vehicles in urban last-mile delivery (Rowe, Wright, 1999; Landeta, 2006; Belton et al., 2019; Beiderbeck et al., 2021).

The purpose of this paper is to assess the adoption prospects of autonomous vehicles in urban last-mile courier delivery. The study focuses on the significance, probability and expected time horizon of selected future-oriented theses concerning autonomous vehicles in courier services. It also examines factors supporting and hindering their implementation. These factors were identified on the basis of the literature review and then assessed by experts in a Delphi study.

The study addresses the following research questions:

- RQ1: How do experts assess the significance, probability and expected time horizon of future theses concerning the use of autonomous vehicles in urban last-mile courier delivery?
- RQ2: Which factors are perceived as supporting the implementation of autonomous vehicles in courier companies' last-mile delivery operations?
- RQ3: Which barriers are perceived as limiting the implementation of autonomous vehicles in urban courier delivery?

The remainder of the paper is organised as follows. Section 2 presents the literature review and identifies factors supporting and hindering the adoption of autonomous vehicles in urban last-mile delivery. Section 3 describes the research methodology, with particular attention to the qualitative Delphi study. Section 4 presents the results from the Delphi study. Section 5 discusses the findings in relation to courier companies, city logistics and urban transport policy. The final section presents conclusions, limitations and directions for future research.

2. Literature review

E-commerce has changed the structure of urban freight flows. It has increased the number of small parcels delivered to dispersed recipients. It has also strengthened customer expectations concerning speed, flexibility and delivery visibility. As a result, last-mile delivery has become one of the most complex stages of the supply chain. It combines operational efficiency, customer service and urban transport constraints (Lim et al., 2018; Mangiaracina et al., 2019).

The last mile is especially difficult in cities. Urban areas concentrate demand for courier services, but they also suffer from congestion, limited curb space, noise and emissions. These effects are not only private costs borne by logistics operators. They are also external costs

borne by residents, local authorities and other road users (Ranieri et al., 2018; Viu-Roig, Alvarez-Palau, 2020). For this reason, last-mile delivery should be considered as part of city logistics. City logistics aims to improve freight distribution while reducing the negative effects of transport in urban areas (Savelsbergh, van Woensel, 2016).

The literature identifies several solutions that may improve the last-mile delivery process. These include parcel lockers, pickup and drop-off points, cargo bikes, electric vans, crowdsourcing, drones and autonomous delivery systems. These solutions differ in terms of cost, infrastructure needs, environmental effects and customer acceptance. They should not be treated as direct substitutes in every urban context. In many cases, the future of last-mile delivery will probably be based on a combination of several solutions adapted to city structure, delivery density and service requirements (Boysen et al., 2021; Ranieri et al., 2018).

Autonomous delivery solutions are one of the most discussed directions of change. They include autonomous delivery robots, road autonomous delivery vehicles and multi-tier systems combining conventional vehicles with smaller autonomous units. In this paper, the term autonomous vehicles refers to ground-based driverless delivery solutions used or potentially used in courier operations. Drones are treated only as a contextual example of autonomous delivery technology.

Autonomous vehicles may support last-mile delivery in several ways. They may reduce dependence on human drivers, improve fleet availability, enable contactless delivery and support more flexible routing. Studies on sidewalk autonomous delivery robots indicate that they may reduce delivery time and travel per package in selected operating conditions (Jennings, Figliozzi, 2019). Other studies show that truck-and-robot systems can improve delivery efficiency when routes, delivery density and robot availability are properly coordinated (Boysen et al., 2018; Ostermeier et al., 2022). However, these benefits are not automatic. They depend on the maturity of the technology, urban infrastructure and the ability to integrate autonomous vehicles into existing logistics networks.

The literature also shows that autonomous delivery systems remain at an early stage of implementation. Engesser et al. (2023) indicate that autonomous delivery solutions require further research on energy demand, legislation, safety, implementation strategy and cooperation between stakeholders. Alverhed et al. (2024) show that autonomous delivery robots may reduce costs, improve time use and reduce some externalities. At the same time, they point to infrastructure, regulation and social acceptance as key challenges.

These findings are important for courier companies. The courier sector competes through delivery speed, reliability, cost efficiency and service flexibility. Autonomous vehicles may therefore become a source of competitive advantage if they reduce operating costs or enable new delivery models. This leads to the first future-oriented Delphi thesis: Increased use of autonomous vehicles will result in increased competition among courier companies (T1).

The environmental dimension is also important. The European Green Deal and the Sustainable and Smart Mobility Strategy indicate the need to reduce greenhouse gas emissions from transport and move toward low-emission and zero-emission mobility (European Commission, 2019, 2020). EU regulations on CO₂ emission standards for new cars and vans also increase pressure on the road transport sector to decarbonise vehicle fleets (European Parliament and Council, 2023). In last-mile delivery, this supports the development of electric vans, cargo bikes and other low-emission solutions. Autonomous vehicles may be part of this transition if they are based on electric propulsion and if their life-cycle effects are favourable.

However, the literature does not indicate that autonomous vehicles are the only sustainable solution for last-mile delivery. Life-cycle studies show that environmental effects depend on the vehicle type, delivery system design, electricity mix, load factor and production impact (Figliozzi, 2020; Lemardelé et al., 2023; Temporelli et al., 2022). Therefore, the second thesis should be treated as a strong future scenario submitted to expert assessment, rather than as an established fact from the literature: Autonomous vehicles will become the only way to deliver courier shipments consistent with Green Deal policies (T2).

Urban policies may also influence the adoption of autonomous delivery. Cities may introduce low-emission zones, access restrictions, curbside management rules and safety requirements for vehicles operating in dense urban space. For autonomous delivery robots, regulations are particularly important because these vehicles may operate on sidewalks, shared spaces or local roads. Hoffmann and Prause (2018) show that autonomous delivery robots create legal questions concerning traffic rules, liability and compliance. Alverhed et al. (2024) also point out that the lack of clear regulation creates uncertainty for market actors. This supports the third future-oriented thesis: City regulations and transportation policies in large metropolitan areas will eliminate the remaining delivery options other than autonomous vehicles (T3).

At the same time, the most moderate scenario is that autonomous vehicles will not replace all other delivery solutions but will become one component of courier fleets. Such a scenario is consistent with the literature on hybrid last-mile systems. Autonomous vehicles can operate together with conventional vehicles, electric vans, cargo bikes, parcel lockers and pickup points. Their role may be limited to selected areas, delivery types or time windows. This leads to the fourth Delphi thesis: Autonomous vehicles will be part of courier companies' fleets (T4).

The scale and pace of autonomous vehicle adoption will depend on several conditions. On the basis of the literature review, ten supporting factors were identified. These factors were used to prepare the Delphi research form.

For the purposes of this study, supporting factors are understood as conditions that may facilitate the implementation, diffusion and long-term use of autonomous vehicles in urban last-mile delivery (Table 1). They refer both to external conditions, such as public policy, legal regulations, infrastructure readiness and environmental requirements, and to internal technological and market-related conditions, including technology maturity, safety, consumer

acceptance and energy efficiency. The identified factors therefore reflect the multidimensional nature of autonomous vehicle adoption, which depends not only on the availability of the technology itself, but also on the institutional, social, environmental and operational context in which it is introduced.

Table 1.

Supporting factors for the adoption of autonomous vehicles in urban last-mile delivery

Code	Supporting factor	Literature basis
S1	Possibility of co-financing the purchase	High initial investment costs may limit adoption. Public support can reduce entry barriers for companies introducing low-emission and autonomous delivery technologies (European Commission, 2020).
S2	Readiness of urban infrastructure	Autonomous delivery requires adapted urban infrastructure, safe operating space, charging facilities and integration with local transport systems (Alverhed et al., 2024; Engesser et al., 2023; Hoffmann, Prause, 2018).
S3	Development of autonomous vehicle technology	Technology maturity is a basic condition for reliable operation. This includes sensors, navigation, remote supervision, communication systems and route optimisation (Baum et al., 2019; Engesser et al., 2023; Jennings, Figliozzi, 2019).
S4	Level of acceptance of autonomous vehicles	Consumer acceptance depends on perceived usefulness, perceived risk, trust and social influence. These factors are crucial for autonomous delivery services (Kapser, Abdelrahman, 2020; Koh et al., 2024; Yuen et al., 2022).
S5	Ensuring safety	Safety concerns relate to pedestrians, traffic interactions, theft, cyber risks and service reliability. Safety is therefore a condition for public acceptance and regulatory approval (Koh et al., 2024; Hoffmann, Prause, 2018; Jennings, Figliozzi, 2019; Kapser, Abdelrahman, 2020).
S6	Legal and regulatory framework	Clear regulations can reduce uncertainty for courier companies and technology providers. They concern vehicle approval, liability, traffic rules and operating zones (Alverhed et al., 2024; Hoffmann, Prause, 2018).
S7	Compliance with the requirements of the Green Deal	EU climate and mobility policies support the shift toward low-emission transport. Autonomous vehicles may contribute to these goals if they are integrated into low-emission delivery systems (European Commission, 2019, 2020; European Parliament and Council, 2023).
S8	Ecological awareness and consumer pressure	Environmental expectations may influence companies' delivery strategies and customers' acceptance of greener solutions (Ranieri et al., 2018; Viu-Roig, Alvarez-Palau, 2020).
S9	Ecological safety related to the construction of an autonomous vehicle	The environmental value of autonomous vehicles depends not only on operation, but also on production, batteries, materials and end-of-life processes (Lemardelé et al., 2023; Temporelli et al., 2022).
S10	Progress in research and production of power systems for autonomous vehicles	Electric propulsion, battery range, charging systems and energy efficiency influence the feasibility of autonomous last-mile delivery (Figliozzi, 2020; Lemardelé et al., 2023; Temporelli et al., 2022).

Source: Authors' own elaboration based on the literature review.

In addition to factors that may support implementation, the literature also points to a set of barriers that can slow down or limit the adoption of autonomous vehicles in urban last-mile delivery (Table 2). These barriers concern economic, regulatory, technological, organisational and infrastructural constraints. They are particularly important because autonomous delivery systems are still at an early stage of market development, and their implementation requires not only investment in vehicles, but also the creation of a broader operational ecosystem, including maintenance facilities, legal frameworks, safety procedures and user acceptance. The barriers

identified in the literature were therefore included in the Delphi form as potential obstacles to the practical deployment of autonomous vehicles in courier and urban delivery services.

Table 2.

Barriers to the adoption of autonomous vehicles in urban last-mile delivery

Code	Barrier	Literature basis
B1	Costs of purchasing an autonomous vehicle	High capital expenditure may reduce the willingness of courier companies to introduce autonomous fleets, especially when the business model is still uncertain (Sindi, Woodman, 2020; Alverhed et al., 2024; Engesser et al., 2023).
B2	Autonomous vehicle parts disposal costs	Battery systems, electronic components and vehicle materials may create environmental and cost challenges at the end of the life cycle (Lemardelé et al., 2023; Temporelli et al., 2022).
B3	Costs of operating an autonomous vehicle	Operating costs include energy, maintenance, software, supervision, insurance and fleet management. They determine whether autonomous delivery is competitive with conventional delivery (Jennings, Figliozzi, 2019; Ostermeier et al., 2022; Sindi, Woodman, 2020).
B4	Legal barriers	Unclear rules on road or sidewalk access, liability and vehicle approval may slow down implementation (Alverhed et al., 2024; Hoffmann, Prause, 2018).
B5	Insufficient safety and security of technological solutions	Perceived risk, safety concerns and lack of trust may limit acceptance among consumers, pedestrians and public authorities (Kasper, Abdelrahman, 2020; Yuen et al., 2022).
B6	Lack of openness to innovation	New delivery technologies require acceptance by companies, consumers and local stakeholders. Resistance may arise when benefits are unclear or perceived risks are high (Kasper, Abdelrahman, 2020; Koh et al., 2024).
B7	Lack of specialised service points	Autonomous vehicle adoption requires a service ecosystem for repairs, diagnostics, software support and maintenance. This is linked to technology maturity and operational readiness (Alverhed et al., 2024; Engesser et al., 2023).
B8	Difficulty in getting spare parts	Limited availability of components may increase downtime and operational risk, especially at the early stage of market development (Sindi, Woodman, 2020).

Source: Authors' own elaboration based on the literature review.

The reviewed literature shows that autonomous vehicles may become an important element of urban last-mile delivery. Their adoption is not determined only by technical progress. It also depends on public policy, infrastructure, financial support, safety, social acceptance and environmental performance. These conditions justify the use of the Delphi method. Expert assessment is useful because autonomous delivery remains an emerging area, and many implementation conditions are still uncertain.

3. Methods

This study was designed as a qualitative Delphi study. The Delphi method was selected because the adoption of autonomous vehicles in urban last-mile courier delivery is still an emerging issue. In such areas, empirical data are limited, and expert judgement is important for assessing possible future developments. The method is useful when the research problem

requires structured expert assessment rather than statistical generalisation (Linstone, Turoff, 1975; Rowe, Wright, 1999; Okoli, Pawlowski, 2004; Landeta, 2006; Ejdys et al., 2023; Szpilko et al., 2025).

The study has an expert-based and qualitative character. The numerical indicators used in the paper serve only to organise and synthesise expert opinions. They are not treated as inferential statistics. The results should therefore be understood as a structured expert assessment of adoption prospects, supporting factors and barriers.

The research process consisted of five stages, following the logic used in Delphi-based studies of emerging technologies (Ejdys et al., 2025).

Table 3.
Stages of the Delphi research process

No.	Stage	Description
1.	Literature review	The literature review was used to formulate Delphi theses and identify factors supporting and hindering the adoption of autonomous vehicles in urban last-mile delivery.
2.	Preparation of the Delphi research form	A structured research form was prepared. It included four future-oriented theses, questions related to each thesis, and supporting factors and barriers.
3.	Expert selection and data collection	Experts were selected purposefully and recruited using snowball sampling. The research form was distributed to experts representing courier companies, business practice, academia and couriers.
4.	Expert assessment	Experts assessed the significance, probability, expected time horizon, supporting factors and barriers related to the four theses.
5.	Final analysis and reporting	Expert assessments were synthesised using significance, favourability and barrier indicators. The results were then interpreted in relation to the research questions.

Source: Authors' own elaboration.

The Delphi research form included four theses concerning the possible role of autonomous vehicles in courier companies' urban last-mile delivery operations:

- T1: Increased use of autonomous vehicles will result in increased competition among courier companies.
- T2: Autonomous vehicles will become the only way to deliver courier shipments consistent with Green Deal policies.
- T3: City regulations and transportation policies in large metropolitan areas will eliminate the remaining delivery options other than autonomous vehicles.
- T4: Autonomous vehicles will be part of courier companies' fleets.

For each thesis, the same set of research questions was used. Experts were asked to assess:

- 1. the significance of the thesis for the development of the courier market,
- 2. the expected time horizon and probability of the thesis being realised,
- 3. the extent to which selected factors support the implementation of the thesis,
- 4. the extent to which selected barriers hinder the implementation of the thesis.

The supporting factors and barriers were identified on the basis of the literature review. The Delphi research form included ten supporting factors: possibility of co-financing the purchase, readiness of urban infrastructure, development of autonomous vehicle technology,

level of acceptance of autonomous vehicles, ensuring safety, legal and regulatory framework, compliance with the requirements of the Green Deal, ecological awareness and consumer pressure, ecological safety related to the construction of an autonomous vehicle, and progress in research and production of power systems for autonomous vehicles. The form also included eight barriers: costs of purchasing an autonomous vehicle, autonomous vehicle parts disposal costs, costs of operating an autonomous vehicle, legal barriers, insufficient safety and security of technological solutions, lack of openness to innovation, lack of specialised service points, and difficulty in getting spare parts.

The selection of experts was purposeful. Expertise was understood as academic knowledge or practical experience related to courier services, last-mile delivery, urban logistics, transport technologies, business processes or the use of delivery services. The Delphi study was conducted in March and April 2025. The panel consisted of 6 representatives of courier companies (30%), 4 active couriers (20%), 5 academic researchers specialising in logistics and transport (25%), and 5 representatives of the broader logistics and business environment (25%). Five participants were aged 18-25. Age was not a selection criterion, and each of these participants was included on the basis of documented professional, operational or research experience relevant to last-mile delivery. Experts were recruited using the snowball sampling method. The recruitment covered Polish companies and Polish branches of international companies operating in courier services, logistics, e-commerce, transport, last-mile delivery and technology-related business services. The business experts had at least five years of professional experience in managerial, specialist or operational positions related to courier services, logistics, transport, urban delivery or business process management. Academic experts were selected on the basis of their research experience in logistics, management, transport or new technologies. The Delphi panel included representatives of courier companies, the wider business environment, academics and couriers. This composition made it possible to include both theoretical and practical perspectives on the implementation of autonomous vehicles. It also enabled the assessment of the analysed theses from strategic, operational and user-oriented perspectives.

The paper reports the results from the Delphi study. The research included 20 completed Delphi forms. The structure of the expert panel is presented in Table 4.

Table 4.
Characteristics of the Delphi panel

Category	Structure of the expert panel
Gender	Female – 55%; Male – 45%
Age	18-25 years – 25%; 26-35 years – 30%; 36-45 years – 25%; 46-55 years – 20%
Education	Secondary education – 20%; Bachelor's or engineering degree – 25%; Master's degree – 55%
Professional activity	Representatives of courier companies – 30%; Active couriers – 20%; Academic researchers specialising in logistics and transport – 25%; Representatives of the broader logistics and business environment – 25%

Source: Authors' own elaboration.

The assessment of the significance of each thesis was synthesised using the significance indicator WI . The indicator was adopted from foresight research using the Delphi method (Ejdys, 2013). It was calculated as follows:

$$WI = \frac{n_{VS} \cdot 100 + n_S \cdot 75 + n_{RS} \cdot 25 + n_{NS} \cdot 0}{n - n_{NO}} \quad (1)$$

where:

- n_{VS} – number of “very significant” answers,
- n_S – number of “significant” answers,
- n_{RS} – number of “rather significant” answers,
- n_{NS} – number of “not significant” answers,
- n_{NO} – number of “no opinion” answers,
- n – total number of answers.

The indicator takes values from 0 to 100. A higher value means that experts assigned greater significance to a given thesis.

The strength of supporting factors was calculated using the favourability indicator WF . The indicator was also based on the approach used in foresight Delphi research (Ejdys, 2013):

$$WF = \frac{n_{VGE} \cdot 100 + n_{GE} \cdot 75 + n_{ME} \cdot 50 + n_{LE} \cdot 25 + n_{VLE} \cdot 0}{n - n_{NO} - n_{NR}} \quad (2)$$

where:

- n_{VGE} – number of “to a very great extent” answers,
- n_{GE} – number of “to a great extent” answers,
- n_{ME} – number of “to a medium extent” answers,
- n_{LE} – number of “to a low extent” answers,
- n_{VLE} – number of “to a very low extent” answers,
- n_{NO} – number of “no opinion” answers,
- n_{NR} – number of “factor is not related to the thesis” answers,
- n – total number of answers.

The same logic was used to calculate the barrier indicator WB . In this case, the indicator measured the strength with which a given barrier hindered the implementation of a thesis. Values closer to 100 indicate a stronger barrier.

For the expected time horizon of implementation, experts selected one of the following periods: by the end of 2025, between 2025 and 2035, after 2035, or never. The probability of implementation was assessed in five ranges: 0-20%, 21-40%, 41-60%, 61-80%, and 81-100%.

The final analysis was based on the Delphi results. The findings were interpreted in relation to the research questions concerning the significance and probability of the theses, supporting factors and barriers to the implementation of autonomous vehicles in urban last-mile courier delivery.

4. Results

4.1. Significance of the theses

The expert assessment of the four future-oriented theses reveals a cautious approach to the adoption of autonomous vehicles in urban last-mile courier delivery. The highest significance was assigned to the thesis that autonomous vehicles will become part of courier companies' fleets. More radical theses, especially those assuming the full replacement of other delivery options, were assessed with greater restraint. The values of the significance indicator are presented in Table 5.

Table 5.
Significance indicators for the Delphi theses

Thesis	Thesis statement	Significance indicator
T1	Increased use of autonomous vehicles will result in increased competition among courier companies.	37.50
T2	Autonomous vehicles will become the only way to deliver courier shipments consistent with Green Deal policies.	28.75
T3	City regulations and transportation policies in large metropolitan areas will eliminate the remaining delivery options other than autonomous vehicles.	55.00
T4	Autonomous vehicles will be part of courier companies' fleets.	68.80

Source: Authors' own study based on the Delphi study.

The highest value was obtained for Thesis 4, which assumes that autonomous vehicles will become part of courier companies' fleets (68.80). This result indicates that experts considered fleet integration the most relevant scenario. The qualitative justifications show that this thesis was associated with operational efficiency, cost reduction and adaptation to future regulatory requirements. One expert stated that autonomous vehicles may "increase operational efficiency, reduce costs and allow companies to better adapt to new regulations and social expectations". Another expert indicated that the introduction of such vehicles would not be limited to transport processes, because "if autonomous vehicles become part of the fleet, this will affect the functioning of the whole company, its structure and employment".

At the same time, the experts' comments show that this scenario was not perceived as simple or unconditional. Some respondents referred to the practical tasks that still require human involvement. One expert asked: "Who will load it into the car?". Another noted that couriers deliver "100-120 parcels a day" and argued that, under current conditions, they may remain more effective than autonomous vehicles. A similar concern was expressed in the comment that autonomous vehicles may influence "jobs and social trust in individual companies". These statements explain why Thesis 4 received the highest assessment but should still be interpreted as a scenario of gradual fleet diversification rather than immediate automation of courier work.

Thesis 3 received the second highest significance indicator (55.00). Experts recognised the role of city regulations and transport policies in shaping delivery systems. Their comments suggest, however, that they did not expect a fast elimination of traditional delivery options. One expert wrote that “complete elimination of traditional forms of delivery is unlikely in the short term”, although urban policies such as low-emission zones or access restrictions may force courier companies to change their fleets. Another respondent stressed that “regulations may significantly limit many activities, especially in the case of small and medium-sized companies”. This points to the regulatory importance of the thesis, but also to its potential economic and organisational consequences.

The qualitative material also shows that experts were sceptical about the idea of creating a single dominant delivery technology. One respondent stated that “zero-emission vehicles, electric vehicles and cargo bikes already meet the requirements of large agglomerations” and added that “a monopoly of autonomous vehicles should not be created”. This comment is important because it shows that experts did not reject regulatory pressure, but they questioned the exclusiveness of autonomous vehicles as the only future urban delivery mode.

Thesis 1 received a lower significance indicator (37.50). The comments reveal two opposite interpretations of the relationship between autonomous vehicles and competition. Some experts perceived autonomous vehicles as a possible source of competitive advantage. One respondent stated that “the use of autonomous vehicles may significantly reduce operating costs, shorten delivery times and increase efficiency, which will create a competitive advantage”. Another expert indicated that courier companies “will try to use autonomous vehicles in the best possible way in order to gain stronger market support”.

However, the sceptical comments were more frequent and more operationally grounded. One expert wrote: “The vehicle will only be able to drive to the address by itself. The rest will still have to be done by the courier”. Another respondent referred to everyday delivery problems: “In most areas, people are not at home and ask for the parcel to be hidden. An autonomous vehicle will not do this for you”. A further comment stressed that “errors in address markings are very large” and that couriers often recognise an address only because a customer orders frequently. These opinions show that experts saw important limits to the competitive potential of autonomous vehicles. They did not perceive driving automation as equivalent to full automation of the courier service.

The lowest significance was assigned to Thesis 2 (28.75). This thesis assumed that autonomous vehicles would become the only delivery solution consistent with Green Deal policies. Experts’ comments suggest that the low assessment resulted mainly from the exclusive wording of the thesis. One respondent wrote that “there are also alternatives, such as cargo bikes, electric vans or public transport, which also meet the objectives of the Green Deal”. Another expert stated that “an electric car with a driver is equally harmless to the environment”. These opinions indicate that experts perceived environmental transformation in last-mile delivery as a broader process that may include several low-emission solutions.

Some comments also reflected doubts about the financial feasibility of Green Deal-oriented transformation in courier services. One expert stated that the courier sector “will not be able to bear this financially”. Another argued that the final form of implementation would depend on regulations and on research concerning the impact of autonomous vehicles on the environment, adding: “I do not think this will be the only form of courier services”. The assessment of Thesis 2 therefore suggests that experts recognise environmental pressure, but they do not treat autonomous vehicles as the only path toward sustainable last-mile delivery.

4.2. Expected time horizon and probability of implementation

The probability assessments complement the significance results. Experts did not expect the analysed theses to be implemented in the short term. The implementation horizon was usually shifted beyond 2035, especially for the thesis concerning the inclusion of autonomous vehicles in courier fleets. This confirms that autonomous vehicles were perceived as a future possibility rather than an immediate market change.

The most favourable probability assessment concerned Thesis 4. The results are presented in Figure 1.

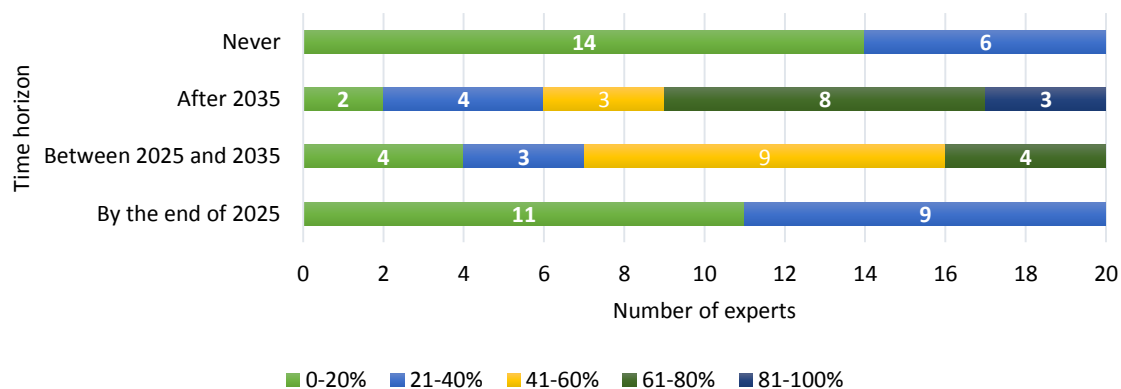


Figure 1. Probability and expected time horizon for Thesis 4. Autonomous vehicles will be part of courier companies’ fleets

Source: Authors’ own study based on the Delphi study.

For Thesis 4, more than half of the experts assessed the probability of implementation after 2035 in the range of 61-100% (55%). At the same time, most experts considered the “never” scenario unlikely, as 70% assigned it a probability of only 0-20%. This means that experts did not reject the future inclusion of autonomous vehicles in courier fleets. They located this process mainly in the long-term perspective.

The open-ended justifications explain this assessment. One expert wrote that “autonomous technology is already being tested by many logistics companies”. Another noted that current technological conditions do not yet allow courier companies to use autonomous vehicles on a wider scale, but “this may change in the more distant future, depending on the economic situation and regulations”. The same cautious optimism appears in the statement that

autonomous vehicles may be useful in selected contexts, for example in rural areas where the depot is far away, provided that the vehicle capacity is sufficient.

The sceptical arguments were also clear. One respondent stated that “no autonomy will replace a courier who can work despite various situations that will prevent an autonomous vehicle from completing the task”. Another argued that “a bicycle will be cheaper and faster”. These comments suggest that experts did not understand fleet adoption as full automation. They rather considered the possibility of using autonomous vehicles in specific delivery segments where their limitations can be controlled.

The assessment of Thesis 3 shows a stronger role of uncertainty. The results are presented in Figure 2.

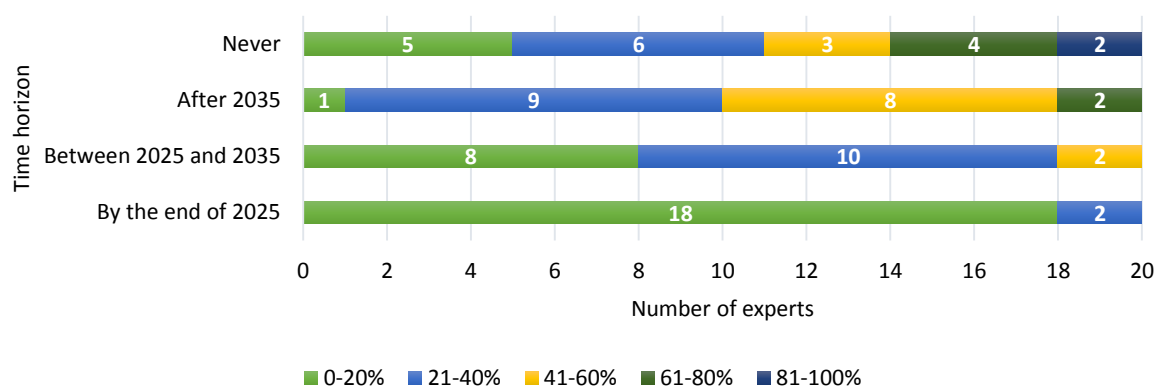


Figure 2. Probability and expected time horizon for Thesis 3. City regulations and transportation policies in large metropolitan areas will eliminate the remaining delivery options other than autonomous vehicles

Source: Authors' own study based on the Delphi study.

For Thesis 3, implementation by the end of 2025 was assessed as highly unlikely. Most experts assigned this time horizon a probability of 0-20% (90%). For the period after 2035, the opinions were more dispersed, and half of the experts assigned the thesis a probability of at least 41%. This indicates that the regulatory scenario was not rejected, but it was treated as uncertain and dependent on long-term policy development.

The qualitative comments confirm this interpretation. One expert wrote that “regulations and their implementation, as well as companies' adaptation to them, will take a long time”. Another respondent suggested that such regulations may never be implemented in this form, because “simpler emission-related solutions may be introduced more quickly”. A third expert stated briefly that “price will kill the market”. These comments point to two important limitations of the regulatory scenario: the slow pace of institutional change and the economic burden imposed on courier companies.

The probability assessment of Thesis 1 also indicates a long-term horizon. The results are presented in Figure 3.

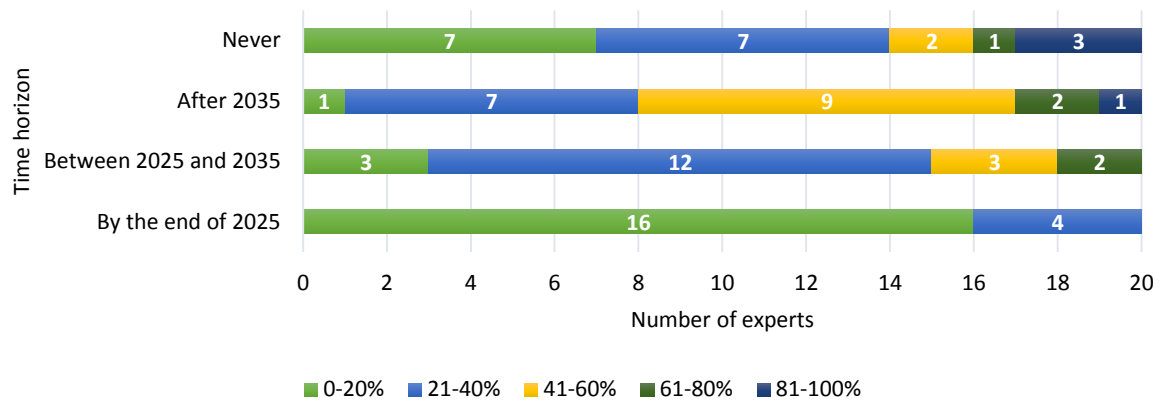


Figure 3. Probability and expected time horizon for Thesis 1. Increased use of autonomous vehicles will result in increased competition among courier companies.

Source: Authors' own study based on the Delphi study.

For Thesis 1, implementation by the end of 2025 was assessed as unlikely by most experts. The probability of implementation in this period was assessed at 0-20% by 80% of experts. In the period after 2035, 60% of experts assigned this thesis a probability of at least 41%. This means that experts perceived a possible future relationship between autonomous vehicles and competition, but they did not see it as an immediate effect.

The experts' comments show that this delay is linked mainly to technological, financial and organisational barriers. One respondent stated that "autonomous vehicles currently have too many weaknesses to be implemented in parcel distribution systems". Another expert noted that courier companies "are only beginning to switch to electric vehicles, so the full transition to autonomous vehicles will take more time". A more technical comment pointed out that autonomous transport requires the development of "AI, machine learning, neural networks and sensors that act as the driver's eyes". Another respondent assessed the probability as low because "driverless vehicles are currently prohibited in the EU". These justifications show that the experts associated the probability of Thesis 1 with the maturity of the whole innovation ecosystem, not only with the availability of vehicles.

Some comments also referred to the risk borne by courier companies. One expert wrote that "no company will bear the costs and responsibility for errors". Another indicated that the implementation of such innovations is unlikely in the near future because of the general economic situation and the lack of public signals that such solutions are ready for broad use. These opinions explain why the experts postponed the possible competitive effect of autonomous vehicles to a longer time horizon.

The most cautious probability assessment concerned Thesis 2. The results are presented in Figure 4.

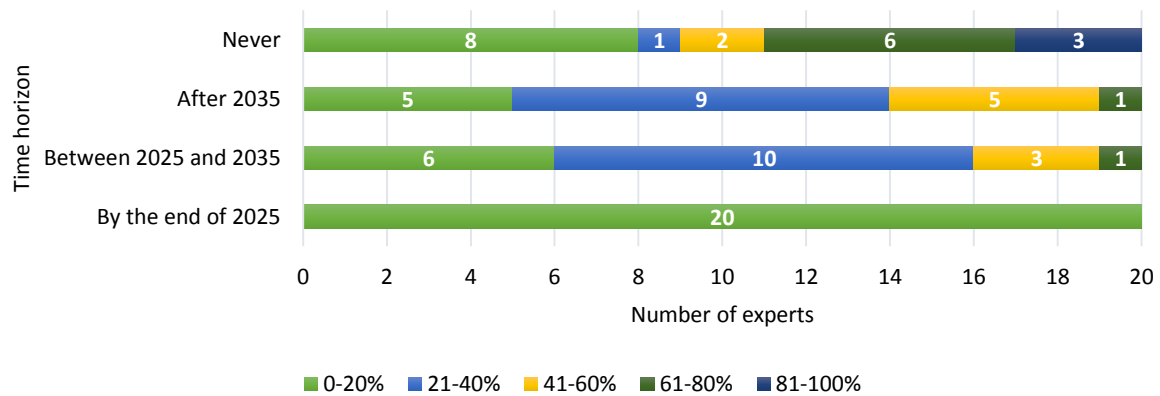


Figure 4. Probability and expected time horizon for Thesis 2. Autonomous vehicles will become the only way to deliver courier shipments consistent with Green Deal policies.

Source: Authors' own study based on the Delphi study.

For Thesis 2, all experts assessed the probability of implementation by the end of 2025 at only 0-20% (100%). For the period between 2025 and 2035, only 20% of experts assigned the thesis a probability of at least 41%. For the period after 2035, this share increased to 30%. This confirms that experts treated the Green Deal-related thesis as the least plausible of the four assessed scenarios.

The qualitative justifications show that the experts considered this thesis both too costly and too exclusive. One respondent wrote: "This is possible, but it requires huge investments". Another stated that "technical possibilities and the economic situation do not allow the introduction of such solutions in the near future". A further comment emphasised that regulations are not introduced quickly and require a long implementation period. Some experts were even more sceptical. One wrote: "I think this will never happen, although there will certainly be people who will try to implement such solutions in a few years". Another stated that "drones with small parcels will come sooner".

At the same time, not all comments were negative. One expert argued that courier companies are obliged to comply with Green Deal policy and that driverless vehicles could reduce delays, increase working hours, reduce human error in delivery and lower fuel costs. This opinion shows that the thesis had some support, but the dominant view was that autonomous vehicles are unlikely to become the only Green Deal-compliant delivery solution.

Overall, the probability assessments are coherent with the significance results. The most plausible scenario is the gradual inclusion of autonomous vehicles in courier fleets. The least plausible scenario is the exclusive use of autonomous vehicles as the only solution compatible with Green Deal policies. The qualitative comments add an important explanation. Experts saw technological potential, but they also pointed to the continued importance of human courier work, delivery flexibility, customer contact, address errors, financial capacity and regulatory readiness.

4.3. Supporting factors

The factors supporting the implementation of the theses were assessed using the favourability indicator. The values are shown in Table 6. The results indicate that the strength of individual factors differs depending on the content of the thesis.

Table 6.
Factors supporting the implementation of the theses

Code	Supporting factor	Thesis 1	Thesis 2	Thesis 3	Thesis 4
S1	Possibility of co-financing the purchase	68.75	78.75	71.25	86.25
S2	Readiness of urban infrastructure	61.25	65.00	81.25	83.75
S3	Development of autonomous vehicle technology	80.00	73.75	75.00	76.25
S4	Level of acceptance of autonomous vehicles	63.75	66.25	67.50	68.75
S5	Ensuring safety	68.75	67.50	76.32	69.74
S6	Legal and regulatory framework	65.00	76.39	83.75	69.74
S7	Compliance with the requirements of the Green Deal	37.50	88.16	44.74	44.74
S8	Ecological awareness and consumer pressure	40.00	57.89	54.17	42.11
S9	Ecological safety related to the construction of an autonomous vehicle	38.89	59.21	47.37	44.74
S10	Progress in research and production of power systems for autonomous vehicles	53.95	69.74	63.89	47.37

Source: Authors' own study based on the Delphi study.

For Thesis 1, the strongest supporting factor was the development of autonomous vehicle technology (80.00). This means that experts linked the possible competitive effect of autonomous vehicles mainly with technological progress. Co-financing and safety were also relevant conditions (68.75 for both factors).

For Thesis 2, the strongest supporting factor was compliance with Green Deal requirements (88.16). This result is consistent with the wording of the thesis. The scenario was also linked with co-financing (78.75), legal and regulatory framework (76.39) and technological development (73.75). This suggests that the Green Deal-related scenario depends on public policy, legal frameworks, financial support and the maturity of autonomous vehicle technology.

For Thesis 3, the highest value was obtained for legal and regulatory framework (83.75), followed by the readiness of urban infrastructure (81.25). This reflects the regulatory nature of the thesis. Experts considered that the influence of city policies on last-mile delivery would depend on the development of legal conditions and on the ability of cities to prepare infrastructure for autonomous delivery.

For Thesis 4, the strongest factor was the possibility of co-financing the purchase (86.25). Urban infrastructure readiness was also highly assessed (83.75), followed by technological development (76.25). This indicates that the adoption of autonomous vehicles by courier companies is conditioned mainly by financial accessibility, infrastructure readiness and technology maturity.

Comparison of the highest-rated supporting factors shows that the scenarios were associated with different enabling conditions. T1 was most strongly associated with the development of autonomous vehicle technology (80.00), T2 with compliance with Green Deal requirements

(88.16), T3 with the legal and regulatory framework (83.75) and urban infrastructure readiness (81.25), and T4 with the possibility of co-financing vehicle purchases (86.25). These results indicate that the dominant enabling condition varied by scenario.

Across the four theses, experts attached the greatest importance to practical implementation conditions. Co-financing, technological development and urban infrastructure were more consistently assessed as relevant than ecological awareness or ecological aspects of vehicle construction. Environmental factors were important mainly in relation to the Green Deal-related thesis. This confirms that the adoption of autonomous vehicles is perceived not only as an environmental issue, but also as a technological, economic, infrastructural and regulatory challenge.

4.4. Barriers to implementation

The barriers to the implementation of the theses were assessed using the barrier indicator. The values are shown in Table 7. The results indicate that financial, legal and operational barriers are the most important for the adoption of autonomous vehicles in urban last-mile courier delivery.

Table 7.
Barriers to the implementation of the theses

Code	Barrier	Thesis 1	Thesis 2	Thesis 3	Thesis 4
B1	Costs of purchasing an autonomous vehicle	73.75	71.25	72.50	85.00
B2	Autonomous vehicle parts disposal costs	56.25	56.25	53.75	62.50
B3	Costs of operating an autonomous vehicle	62.50	53.75	65.00	67.50
B4	Legal barriers	62.50	78.95	80.26	69.74
B5	Insufficient safety and security of technological solutions	51.25	65.79	69.74	65.79
B6	Lack of openness to innovation	53.75	57.89	60.53	61.84
B7	Lack of specialised service points	62.50	52.63	64.47	71.05
B8	Difficulty in getting spare parts	65.00	48.68	58.33	69.74

Source: Authors' own study based on the Delphi study.

The cost of purchasing an autonomous vehicle was the strongest barrier. It received the highest value in relation to Thesis 4 (85.00), but it was also highly assessed for Thesis 1 (73.75), Thesis 3 (72.50) and Thesis 2 (71.25). This shows that experts perceived the initial investment cost as a key limitation for courier companies.

Legal barriers were particularly important for Thesis 3 and Thesis 2. The highest value was obtained for the thesis concerning city regulations and transport policies (80.26), followed by the thesis related to Green Deal-compliant delivery (78.95). This result is coherent with the content of both theses. Autonomous vehicles require clear rules concerning approval for public use, liability, insurance, certification, operating zones and access to public space.

Operational barriers also received high assessments. Lack of specialised service points was particularly important for Thesis 4 (71.05). Difficulty in obtaining spare parts was also assessed as a relevant barrier for fleet adoption (69.74). These findings show that experts considered not

only the purchase of autonomous vehicles, but also their maintenance and operational continuity. The lack of service points and spare-part availability may increase vehicle downtime, disrupt route schedules and reduce the ability of courier operators to maintain promised delivery windows. Consequently, the adoption challenge is not limited to vehicle acquisition but also involves ensuring continuity of daily delivery operations.

The insufficient safety and security of technological solutions was assessed as a meaningful barrier, especially for Thesis 3 (69.74), Thesis 2 (65.79) and Thesis 4 (65.79). This indicates that safety, technical reliability and trust remain important conditions for broader adoption. These concerns may relate to road safety, cybersecurity, interaction with pedestrians and other road users, and the reliability of vehicle control systems.

These findings indicate that the implementation challenge is not limited to the acquisition of autonomous vehicles but extends to the continuity of courier operations. From the perspective of last-mile delivery processes, insufficient service infrastructure and difficulties in obtaining spare parts may increase vehicle downtime, reduce fleet availability and disrupt delivery schedules. As a result, the reliability and timeliness of courier services may be negatively affected, which is particularly important in urban logistics where delivery performance and customer expectations are critical operational factors.

The lack of openness to innovation received moderate values. It was not perceived as the strongest barrier, but it may slow down implementation when combined with high costs, unclear regulations and limited service infrastructure.

5. Discussion

The Delphi study indicates that the adoption of autonomous vehicles in urban last-mile courier delivery should be understood as an evolutionary process rather than a rapid technological substitution. Experts perceived autonomous vehicles primarily as a future component of courier fleets. They did not treat them as the only possible form of last-mile delivery. This finding is consistent with the literature on last-mile logistics, which increasingly presents urban delivery as a system of complementary solutions. Parcel lockers, pickup points, cargo bikes, electric vans, autonomous robots and other delivery models may coexist, depending on the density of demand, urban form, delivery time requirements and customer preferences (Boysen et al., 2021; Ranieri et al., 2018; Savelsbergh, van Woensel, 2016).

This interpretation is important because discussions on autonomous delivery are often technology-centred. The results of the Delphi study suggest a more conditional view. Autonomous vehicles may support courier companies, but their usefulness will depend on the specific operational context. In dense urban areas, their role may be different from that in suburban districts, campuses, logistics parks or controlled delivery zones. This is in line with

studies showing that the efficiency of autonomous delivery robots depends on route structure, delivery density, vehicle capacity, speed, range and integration with depots or micro-hubs (Jennings, Figliozzi, 2019; Ostermeier et al., 2022).

The findings also show that technological maturity alone is not sufficient for adoption. Experts linked the future use of autonomous vehicles with urban infrastructure, public support, legal conditions and operational readiness. This confirms the systemic character of autonomous last-mile delivery. Vehicles must be able to operate safely in public space, communicate with infrastructure, respond to changing traffic conditions and interact with pedestrians, cyclists and other road users. Previous reviews of autonomous delivery systems point to similar implementation conditions, especially infrastructure readiness, safety, stakeholder cooperation and regulatory clarity (Alverhed et al., 2024; Engesser et al., 2023).

The economic dimension is central to the interpretation of the results. Autonomous vehicles may reduce some operating costs in the long term, but their implementation requires high initial investment. For courier companies, the decision will not be based only on the purchase price. It will also depend on maintenance, software updates, supervision, insurance, spare parts, service availability and vehicle downtime. This explains why financial support was perceived as a relevant condition of adoption. Public co-financing may reduce the entry barrier at the testing stage, but it does not remove the need to demonstrate a viable business model.

The operational barriers identified by experts deserve particular attention. The lack of specialised service points and difficulties in obtaining spare parts show that autonomous delivery requires more than access to vehicles. It requires a service ecosystem. Courier companies operate under strong pressure of time, reliability and delivery continuity. If autonomous vehicles cannot be repaired quickly, or if their components are difficult to obtain, they may increase operational risk. This is especially relevant in courier services, where even short disruptions may affect service quality and customer satisfaction.

Legal and regulatory conditions also play a decisive role. Autonomous vehicles cannot be implemented at scale without clear rules on vehicle approval, liability, insurance, access to roads or sidewalks, operating zones and safety standards. This is particularly important in cities, where public space is shared by many users and where local authorities regulate mobility, parking, curb access and low-emission transport. The literature on autonomous delivery robots confirms that legal uncertainty remains one of the main barriers to wider implementation (Hoffmann, Prause, 2018; Sindi, Woodman, 2020).

The Green Deal-related findings should be interpreted with caution. Experts did not support a scenario in which autonomous vehicles become the only delivery solution consistent with environmental policy objectives. This does not mean that autonomous vehicles are irrelevant for sustainable logistics. Rather, it suggests that sustainability in last-mile delivery cannot be reduced to one technology. The environmental effect of autonomous vehicles depends on propulsion type, electricity sources, production processes, battery systems, load factors, routing and vehicle utilisation. Life-cycle studies show that low-emission delivery solutions should be

assessed across the whole delivery system, not only during the operational phase (Figliozi, 2020; Lemardelé et al., 2023; Temporelli et al., 2022).

The social dimension is also relevant. The implementation of autonomous delivery vehicles requires trust from customers, residents, city authorities and courier companies. Trust in technology depends on perceived usefulness, safety, reliability and risk. Ejdys (2017) emphasises that trust becomes particularly important when users depend on technologies whose operation they cannot fully control. This is applicable to autonomous delivery. Customers must trust that the vehicle will deliver the parcel safely, while city users must trust that it will behave predictably in shared urban space. Studies on the acceptance of autonomous delivery vehicles also confirm the importance of perceived risk, usefulness and trust (Kapsler, Abdelrahman, 2020; Yuen et al., 2022).

The removal of the human courier from the delivery process may create additional service challenges. Last-mile delivery is not only a transport task. It also includes communication with the recipient, reaction to wrong addresses, failed delivery attempts, access problems and unexpected customer behaviour. Autonomous vehicles may perform well in standardised conditions, but courier services often require flexibility. This means that autonomous vehicles may first be introduced in delivery contexts where uncertainty is lower and the delivery process can be better controlled.

The Delphi results therefore support a gradual adoption pathway. Autonomous vehicles may first appear in pilot projects, controlled areas and selected delivery segments. Their broader use will depend on the ability to integrate them with existing courier systems. A mixed model seems more realistic than full replacement. In such a model, autonomous vehicles may cooperate with conventional vans, electric vehicles, cargo bikes, parcel lockers and micro-hubs. From a managerial perspective, the results suggest that courier companies should not treat autonomous vehicles as an isolated innovation. They should assess them as part of fleet strategy, network design and service quality management. From a policy perspective, the findings point to the need for urban testing frameworks, clear legal rules and infrastructure adapted to new delivery technologies. Public support may be useful, but it should be connected with safety, environmental performance and organisational reliability.

6. Conclusions

The purpose of this paper was to assess the adoption prospects of autonomous vehicles in urban last-mile courier delivery. The study was based on a qualitative Delphi approach. It focused on expert assessments of four future-oriented theses, supporting factors and barriers. The findings show that experts perceive autonomous vehicles as a possible future component of courier companies' fleets. The highest significance indicator was obtained for the thesis that

autonomous vehicles will be part of courier companies' fleets. This result suggests a gradual and selective adoption path. It does not indicate that autonomous vehicles will replace all other last-mile delivery solutions in the short term. The results also show caution toward more radical scenarios. Experts were less convinced that autonomous vehicles will become the only delivery solution consistent with Green Deal policies. They were also cautious about the thesis that urban regulations will eliminate all other delivery options. The data support a cautious, long-term fleet-diversification scenario. In the short term, autonomous vehicles are more likely to complement than replace existing last-mile delivery solutions. This means that autonomous vehicles should be considered as one element of a broader transformation of urban last-mile delivery. This transformation may also include electric vans, cargo bikes, parcel lockers, pickup points and better delivery consolidation.

The most important supporting factors were the development of autonomous vehicle technology, the possibility of co-financing purchases and the readiness of urban infrastructure. These results indicate that adoption will depend not only on technological maturity. It will also depend on financial accessibility and the ability of cities to create suitable operating conditions. Public support may be important, especially at the stage of testing and early implementation.

The main barriers were the cost of purchasing autonomous vehicles, legal uncertainty, insufficient safety and security of technological solutions, lack of specialised service points and difficulty in obtaining spare parts. These barriers are practical and institutional. They show that courier companies need more than access to autonomous vehicles. They also need clear regulations, reliable maintenance systems, spare parts supply and safe operating rules in urban space.

The study has practical implications for courier companies, city authorities and policymakers. The recommendations presented below represent the authors' interpretation of the Delphi findings rather than direct statements made by the expert panel. Courier companies should assess autonomous vehicles as part of mixed fleet strategies rather than as a single replacement technology. City authorities should prepare conditions for safe testing, including infrastructure, public-space rules and cooperation with logistics operators. Policymakers should consider financial instruments that reduce entry barriers, but such support should be linked to safety, environmental performance and organisational reliability.

The study has several limitations. The Delphi panel was limited in size. The results should therefore be interpreted as an exploratory expert assessment, not as a statistically representative market forecast. The study did not directly measure substitution effects between delivery modes. The study presents findings from the Delphi study and does not include a formal measurement of consensus or stability of expert opinions. The use of indicators helped to organise expert assessments, but the qualitative character of the Delphi method remains central.

Future research should involve a larger and more diverse expert panel. It would be useful to compare the views of courier companies, technology providers, city authorities, researchers and users of delivery services. Further studies may also include additional Delphi rounds,

comparative research between cities or countries, and case studies of pilot implementations. Future research should also examine the economic feasibility, environmental effects and social acceptance of autonomous vehicles in urban last-mile delivery.

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