POLISH CONSUMERS' ATTITUDES TOWARD INNOVATIVE LAST-MILE DELIVERY TECHNOLOGIES IN THE CONTEXT OF LOGISTICS 4.0

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Abstract - The article analyzes Polish consumers' attitudes toward modern last-mile delivery technologies associated with Logistics 4.0, such as autonomous vehicles, drones, cargo bikes, and electric vehicles. Local e-commerce is dominated by parcel lockers and couriers. When choosing delivery methods, customers are primarily guided by convenience, price, and speed. Among new delivery technologies, electric delivery vans and cargo bikes are the most popular. In contrast, drones and ground robots face strong resistance stemming from a lack of trust, privacy concerns, theft, and architectural barriers. These findings hold significant practical value for the logistics sector.

Keywords - Last-Mile Delivery, Logistics 4.0, Consumer Attitudes

I. INTRODUCTION

The logistics sector is currently grappling with intense competition, e-commerce fast development and increasing consumer expectations, necessitating the development of innovative delivery methods (Cai et al., 2021; Araújo et al., 2020). Innovation is characterized as any concept, object or methodology that is perceived as novel by a person or an organization. In the context of logistics, service innovation encompasses a wide range of activities, from incremental improvements to more transformative changes, all aimed at creating significant value for a specific target audience (Wang et al., 2018).

In the e-commerce supply chain, the 'last mile' to the customer, defined as all logistics operations associated with delivering shipments to private households in urban areas (Boysen et al., 2021; Moroz and Półkowski, 2016), is probably one of the biggest challenges (Karli,Tanyaş, 2024; Asdecker, 2021). Companies face a trade-off between route efficiency and customer convenience, which leads to high costs, estimated to account for as much as 30% of total distribution costs (Felch et al., 2019; Said et al., 2023). In this context, logistics providers and e-commerce retailers continuously seek new ways to address these challenges. This dynamic and competitive environment has already resulted in the implementation of numerous promising innovations. Innovative solutions for last-mile delivery include self-collection of parcels via Automated Parcel Stations (APS) (e.g. Said et al., 2023, Kasper, 2019), drone deliveries (e. g. Said et al., 2023; Koh et al., 2023), electric freight vehicles (e.g. Lebeau et al., 2016), autonomous ground robots for freight transport (e.g. Kapser and Abdelrahman, 2020; Kasper, 2019) and cargo bike delivery (e.g. Philipsen et al., 2023; Zhang and Huang, 2024).

Unlike service innovations used upstreamin supply chains, both intra- and inter-organizational, last-mile logistics is clearly consumer-driven and relies heavily on end-users' behavior. Understanding how consumers perceive and respond to service innovations is crucial for designing solutions that truly meet their needs (Asdecker, 2019).

The research findings of Cai et al. (2021) and Said et al. (2023) suggest that the use of modern last mile delivery technologies is influenced by both rational factors (i.e., expected efficiency, expected workload, enabling conditions, and attitude) and irrational factors (e.g., habits). Research by Wang et al. (2018) indicates that the most important factor in innovation adoption is consumer attitude. Therefore, logistics service managers should introduce new solutions when customers are psychologically ready for them, while actively monitoring and shaping their attitudes. It is crucial that the innovation is perceived as clearly superior to existing services, which can be achieved by highlighting its unique benefits. It is also crucial to tailor services to consumers' lifestyles, needs, and circumstances to increase a sense of compatibility. Furthermore, individual customer innovativeness influences adoption, so logistics operators should offer services with varying levels of innovation, tailored to diverse consumer profiles.

It should be noted that this dimension of consumer behavior remains relatively underexplored in the Polish scientific literature, constituting a significant gap in the existing research on last-mile logistics. This study attempts to fill this gap by analyzing end-user behavior in the context of adopting innovative last-mile delivery solutions in the realities of Logistics 4.0. The main objective of this study is to identify and characterize Polish consumers' attitudes toward selected last-mile delivery technologies within

the framework of Logistics 4.0, including autonomous delivery vehicles, drones, cargo bikes and zero-emission electric vehicles. The practical objective is to formulate recommendations that can be used by companies and organizations involved in the production, sales, marketing and commercialization of selected last-mile delivery technologies.

Seven hypotheses were proposed:H1: Polish consumers most often choose parcel lockers for last-mile delivery; H2: Polish consumers have mixed feelings about autonomous delivery methods—while they generally express curiosity and openness, concerns about safety and a lack of trust prevail; H3: Most consumers say they are willing to try new delivery methods if they were available in their area; H4: Among Polish consumers, price is the dominant factor in choosing a last-mile delivery method, ahead of delivery speed and convenience of pickup; H5: Polish consumers have a more negative attitude toward drone delivery than toward autonomous ground robots; H6: Polish consumers view cargo bikes positively as a delivery method, but the main barriers are concerns about delivery times and size restrictions.

The paper is divided into the following sections. The first is dedicated to the Literature review, the second to the methodology and data collection and thethird to the empirical results and discussion. Finally, the conclusion provides a summary and indicates applications of the work, further research directions and limitations.

II. CONSUMER ATTITUDES TOWARD SELECTED INNOVATIVE LAST-MILE DELIVERY TECHNOLOGIES - LITERATURE REVIEW

Drones

The survey results conducted by Merkert et al. (2022) suggest that all other things being equal, Australian consumers prefer delivery by mail carrier over drone delivery. However, drone deliveries could become competitive and capture a significant market share if they meet expectations for faster and cheaper delivery. They also note, that both drone and mail carrier deliveries lose their appeal compared to parcel lockers when there is no safe place to leave a package at the recipient’s residence, which underscores the importance of situational context and infrastructure on the recipient’s end in last-mile deliveries.

Said et al. (2023), on the other hand, note that consumers tend to have a positive attitude toward drone delivery, especially when prices are low and delivery times are short. The main barrier is concern about the safety of shipments, particularly those that are valuable or fragile. At the same time, the requirement that the recipient be present is viewed positively, as a guarantee of safe receipt.

It is worth noting that the results of a study conducted by Koh et al. (2023) suggest that perceived usefulness, attitudeand perceived privacy threats directly influence consumers’ behavioral intentions toward drones. Furthermore, perceived ease of use, task characteristics, technology characteristics, task-technology fit and privacy concerns indirectly influence consumers’ behavioral intentions.

In a study conducted among 174 Greek respondents, Filiopoulou et al. (2022) demonstrated that Greek consumers are highly skeptical of drone deliveries, primarily due to a lack of trust in the safety of this technology (only 5.2% consider it safe). The average acceptance of this solution is low (2.77/5.0), and it faces particular resistance among island residents, where as many as 71.43% of respondents express strong opposition. As a result, despite their innovative nature, drones are losing out to traditional couriers, remaining an option that Greeks view with concern and skepticism.

Autonomous delivery vehicles

Autonomous delivery vehicles (ADVs) are believed to have the potential to revolutionize last-mile delivery in a more sustainable and customer-focused way (Kapser and Abdelrahman, 2020; Kasper, 2019). Consumer attitudes toward autonomous vehicles in general are complex and often ambivalent. On the one hand, they recognize the functional benefits; on the other, they express concerns regarding loss of control, safety, and privacy (Bagloee et al., 2016; Hörl et al., 2016; Neumann, 2018; Noussia, 2020; Luo, 2023; Litman, 2024).

A study conducted by Kapser and Abdelrahman (2020) among 501 German respondents on the acceptance of ADV indicates that price sensitivity is the strongest predictor of behavioral intention (i.e., user acceptance), followed by performance expectations, hedonic motivation, perceived risk, social influence, and enabling conditions, while no effect on expected effort was observed.

Said et al. (2023) note that, in the case of ADV, acceptance depends mainly on convenience and security, and less on price and delivery time. The requirement for the recipient to be present is viewed negatively, although this effect diminishes with flexible delivery windows. Older adults show lower acceptance, while those who are better educated and more open to technology show higher acceptance. Concerns about improper handling of packages by automated systems also remain a significant barrier.

Pani et al. (2020), in a study of 483 respondents in Portland, found that the implementation of

autonomous vehicles (AVs) is seen as crucial for the decarbonization of urban logistics. There is significant variation in willingness to pay extra for robot-delivered goods. Determinants include demographic factors (age, gender, income), psychological factors, and location-based factors (acceptance of the technology depends on building density and distance from stores).

It is worth noting that Karli and Tanyaş (2024), based on a discrete choice experiment conducted among 480 consumers in Istanbul, demonstrated that price and delivery time play a decisive role in the choice of last-mile delivery methods, while the technology used—including drones and autonomous robots—does not significantly influence the decisions of consumers choosing home delivery. The authors point out that a positive attitude toward innovative delivery technologies does not automatically translate into a willingness to actually use them, which indicates a clear gap between consumers' stated attitudes and their behavioral intentions.

Electric cargo bikes

The use of electric cargo bikes (ECBs) can be a solution that enables zero-emission and sustainable mobility, while also relieving pressure on city centers, which often struggle with air pollution, noise, traffic congestion, and a shortage of parking spaces caused by traditional cars (Philipsen et al., 2023, Llorca and Moeckel, 2021; Tegeltija et al., 2020).

Bang et al. (2025), in a study examining the acceptance of cargo bikes among 600 respondents in South Korea, found that the main barriers to adopting this technology were concerns about road safety, adverse weather conditions, and regulatory uncertainty. Well-developed cycling infrastructure and institutional support significantly increased willingness to use this form of delivery.

Gruber et al. (2013) found that German respondents' overall expectations regarding the adoption of electric cargo bikes appear to be positive. Electric cargo bikes seem to be compatible with the organization of a courier's work. However, electric range and purchase price are still seen as key issues.

Research shows that Polish customers are increasingly paying attention to the carbon footprint of their shipments and choosing more eco-friendly options, however, their willingness to pay more for eco-friendly delivery remains low (Cudziło, 2024).

Based on a survey of 2,030 residents in five European capitals (London, Paris, Rome, Dublin, and Warsaw) Zhang and Huang (2024) found that consumers in all of the cities surveyed strongly support the introduction of cargo bike deliveries as an eco-friendly alternative to traditional delivery vans. Although priorities regarding sustainable development varied from city to city, residents of Warsaw and Rome emphasized reducing CO_2 emissions, while in London and Dublin reducing traffic congestion was a higher priority. Road safety proved to be a universally important criterion across all locations (Zhang and Huang, 2024).

Electric freight vehicles

A study conducted by Bainy (2024) involving 80 respondents from the Kollam district in Kerala revealed a positive attitude toward electric vehicles. The main barriers were cost, a lack of variety in modelsand charging issues. Overcoming these barriers through technological advancements will lead to a more environmentally friendly environment.

Niteemoh et al. (2025), in their study of the factors influencing consumers' intentions regarding the use of deliveries made by electric vehicles, demonstrated that three groups of variables play a key role: the environmental messaging used by providers, the availability of services, and their affordability. The results indicate that while consumers recognize the environmental potential of electric vehicles in last-mile logistics, including reduced CO_2 emissions, their actual willingness to choose this delivery method remains limited, mainly due to insufficient infrastructure availability and a lack of transparency in how logistics operators communicate the environmental benefits. The authors emphasize that consumers' mere declaration of eco-friendly attitudes does not automatically translate into choosing more sustainable delivery options.

Raźniewska, Wronka, and Gulc (2026), in their study of Polish e-consumers' willingness to use courier services provided by electric vehicles, demonstrated that the growing interest in electric fleets among courier operators aligns with e-consumers' stated willingness. However, the results point to important caveats: consumers' technological optimism influences adoption intentions only indirectly, while innovation and consumer trust have a weaker-than-expected impact on the willingness to use eco-friendly last-mile delivery services.

III. RESEARCH METHODOLOGY

In order to achieve the objectives and verify the hypotheses, the method used in the research process was a diagnostic survey using a questionnaire technique. The survey used the technique of CAWI (Computer Assisted Web Interview) - a computer-assisted interview. Direct quantitative research covered individual consumers over 18 years of age.The questionnaire consisted of a short introduction, instructions for the respondents, ten relevant questions, and a metric to characterize respondents (Table 1). The questions focused on

assessing public readiness, consumer anxieties, and the perceived value of eco-friendly/automated delivery innovations compared to traditional shipping habits.In the next section of this work each question is presented in detail, and the results are discussed. The research was conducted in April 2026 and covered the entire area of Poland. 306 correctly completed questionnaires were returned. The choice of the research method, the selection of the sample, as well as the method of analyzing the collected information was determined by the objectives and scopes of direct research.

Variable	Characteristics
GENDER	Women – 51%, men – 49%
AGE	18–24 years – 14.4%, 25–34 years – 23.2%, 35–44 years – 24.5%, 45–54 years – 14.4 %, 60–64 years – 15%, > 65 years – 8.5%
RESIDENCE	City – 67.3%, rural – 32.7%
EDUCATION	Higher – 36.6%, secondary – 45.4%, vocational – 14.10%, lower secondary 0.7%, primary 3.3%
ASSESSMENT OF INCOME SITUATION	Very good – 6.9%, good – 41.8%, average – 45.4%, bad –3.3%, very bad – 2.6%
DRIVER PROFILE	Frequent car driving as a driver – 67.3% No frequent driving as a driver – 32.7%

Table 1.Characteristics of the research sample
Source: Own elaboration.

IV. RESULTS AND DISCUSSION

Research has shown that Polish consumers most often choose parcel lockers (automated parcelstations, APS). As many as 81% of respondents used this delivery method in the past year. Home delivery by courier came in second (65.4%), followed by click-and-collect locations (42.2%). Traditional postal services were chosen by less than 1% of respondents, confirming their marginal role in Polish e-commerce. The dominance of parcel lockers reflects the success of the InPost network and is consistent with the findings of Said et al. (2023) and Kasper (2019), who identify APS as one of the innovative methods of parcel delivery.

The most important criteria for choosing a delivery method turned out to be: convenience of pickup (62.7% rated it 'very important'), price (60.1%), and delivery speed (60.1%). Together, these form the triad of consumers' most important expectations (table 2). Technological modernity and environmental friendliness received low ratings (16.0% and 17.0% of respondents, respectively, rated them as 'very important'), which has significant implications for the adoption of innovative logistics solutions. The results are partially consistent with those of Karliand Tanyaş (2024) and Said et al. (2023).

Category	**1 Not very important**	**2**	**3 Moderately important**	**4**	**5 Very important**
Shipping cost	**17 (5,6%)**	**5 (1,6%)**	**37 (12,1%)**	**63 (20,6%)**	**184 (60,1%)**
Delivery speed	**3 (1,0%)**	**7 (2,3%)**	**36 (11,8%)**	**76 (24,8%)**	**184 (60,1%)**
Convenience of pickup	**6 (2,0%)**	**4 (1,3%)**	**37 (12,1%)**	**67 (21,9%)**	**192 (62,7%)**
Environmental friendliness	**56 (18,3%)**	**30 (9,8%)**	**80 (26,1%)**	**88 (28,8%)**	**52 (17,0%)**
Safety	**14 (4,6%)**	**3 (1,0%)**	**35 (11,4%)**	**107 (35,0%)**	**147 (48,0%)**
Modernity	**56 (18,3%)**	**37 (12,1%)**	**94 (30,7%)**	**70 (22,9%)**	**49 (16,0%)**

Table 2. The most important criteria for choosing a delivery method.
Source: Own elaboration.

Respondents were also asked about their familiarity with selected innovative delivery methods. Electric delivery vehicles enjoyed the highest recognition. Only 32.4% of respondents reported having no

knowledge of them, while 7.5% had already used them. Cargo bikes ranked in the middle: over half of respondents (58.9%) had encountered them or heard of them, though only 3.3% had direct experience with them. Drones turned out to be the least familiar technology: 57.5% of respondents had no knowledge of them.

The low level of familiarity with drones may explain the high percentage of neutral responses to questions about respondents' attitudes toward selected innovative delivery methods. These stood out with the highest proportion of 'no opinion' responses (46.1%). Electric delivery vehicles received the highest ratings. Over 50% of respondents expressed a positive or somewhat positive attitude. Cargo bikes were close behind (43.1% positive ratings). Autonomous ground robots sparked the most skepticism: nearly 41% of respondents expressed a negative attitude.

The hierarchy of acceptance was aligned with general attitudes. Electric delivery vehicles received the highest willingness to use (57.2% of affirmative responses), while cargo bikes came in second (46.4%). In the case of drones, 31.7% of respondents chose the 'I don't know' option, indicating indecision rather than rejection. Autonomous ground robots received the lowest willingness to use (24.5% yes/somewhat yes), with 44.5% of responses being 'somewhat no' or 'no' (Figure 1).

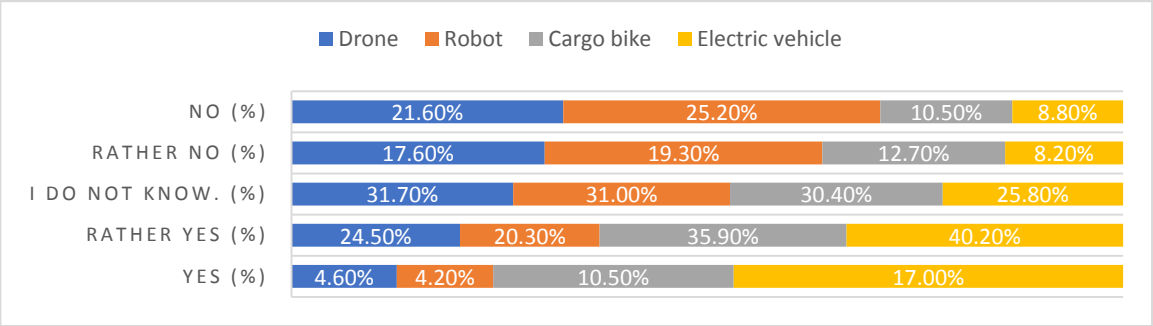

Figure 1. Readiness to use selected delivery methods
Source: Own elaboration.

The main barrier to the adoption of drone delivery was a general lack of trust in the technology (23.5% of respondents), followed by the risk of damage to the shipment (16.3%) and concerns about privacy and surveillance (15.7%). 19.0% of respondents did not report any concerns; they represent a potential pool of early adopters. Three thematic areas emerged from the open-ended responses: infrastructure barriers and lack of awareness, physical and logistical constraints (primarily the inability to deliver to the doorstep in multi-family apartment buildings), as well as concerns regarding safety and social aspects. These findings are consistent with the findings of Filiopoulou et al. (2022) regarding Greek consumers and the research by Koh et al. (2023), who emphasize that behavioral intentions toward drones are directly influenced by perceived usefulness, attitude, and privacy concerns. In turn, the predominant concern regarding the adoption of autonomous ground robots was the risk of theft or vandalism (27.8%), followed by a lack of trust in autonomous systems (24.8%) and safety risks to pedestrians (17.0%). Open-ended responses also revealed the 'last-floor' problem: the inability of robots to access upper floors of multi-family buildings, which is consistent with the findings of Pani et al. (2020). It is worth noting that Karli and Tanyaş's (2024) observation regarding the gap between stated attitudes and actual purchasing intentions particularly well describes the Polish results for ADV: even respondents with positive attitudes rarely stated a willingness to use this form of delivery.

The study found that cargo bikes enjoyed the highest level of unconditional acceptance, with as many as 24.2% of respondents reporting no concerns whatsoever, a finding consistent with the results of Gruber et al. (2013), which indicated generally positive expectations regarding electric cargo bikes among European respondents. The main barrier was concern about shipment safety (30.4%), followed by size restrictions (26.8%) and reliability in adverse weather conditions (16.3%). The results are largely consistent with the findings of Bang et al. (2025).

It should be noted that as many as 72.5% of respondents expressed indifference or explicitly prioritized other criteria over environmental considerations when choosing a delivery method, which is consistent with Cudziło's (2024) research. Among those with a positive attitude, 27.1% would prefer EV delivery only if the price were the same, and only 5.6% would choose it regardless of the price difference. The findings of Raźniewska, Wronka, and Gulc (2026) regarding the Polish market support this interpretation: the growing interest in electric fleets among courier operators aligns with consumers' stated willingness to adopt them, but technological optimism has only an indirect effect on adoption intentions.

V. SUMMARY

The main objective of this study was to identify and characterize Polish consumers' attitudes toward selected last-mile delivery technologies within the framework of Logistics 4.0, including autonomous delivery vehicles, drones, cargo bikes and zero-emission electric vehicles. It was shown that the Polish e-commerce market is dominated by parcel lockers and couriers, with convenience, price, and speed being the key factors in consumer choice, while environmental considerations play a marginal role. Among logistics innovations, electric vehicles and cargo bikes, which raise the fewest concerns, enjoy the highest levels of acceptance. On the other hand, drones and ground robots are met with the most skepticism due to a lack of trust, privacy concerns, theft, and architectural barriers (such as the inability to access upper floors of apartment buildings).

This research provided a lot of practical information that can be used in the business environment. Firstly, the key to successfully implementing drones and robots lies in building trust through pilot tests and safety guarantees, rather than just financial incentives. Additionally, the issue of deliveries to high-rise buildings should be addressed through designated drop-off zones or hybrid systems (autonomous transport and traditional courier service). It should be noted that cargo bikes are a technology ready for immediate implementation in cities due to their high level of acceptance; operators should clearly communicate safety issues regarding packages.

Future research should focus on analyzing the perspective of logistics operators, taking into account Polish legal and infrastructure barriers.

Among the limitations of the research are the convenience sampling method, the selected databases, as well as the limited nature of the survey questionnaire.

H1: Polish consumers most often choose parcel lockers for last-mile delivery.	Supported
H2: Polish consumers have mixed feelings about autonomous delivery methods—while they generally express curiosity and openness, concerns about safety and a lack of trust prevail.	Supported
H3: Most consumers say they are willing to try new delivery methods if they were available in their area.	Rejected. Most consumers say they are willing to try new delivery methods only when it comes to electric delivery vehicles.
H4: Among Polish consumers, price is the dominant factor in choosing a last-mile delivery method, ahead of delivery speed and convenience of pickup.	Rejected. The dominant factor is the convenience of pickup (62.7%).
H5: Polish consumers have a more negative attitude toward drone delivery than toward autonomous ground robots.	Rejected. The results indicate that respondents have more negative attitude toward autonomous ground robots than toward drones.
H6: Polish consumers view cargo bikes positively as a delivery method, but the main barriers are concerns about delivery times and size restrictions.	Partially supported. The results partially confirm the hypothesis: size restrictions were confirmed, but the biggest barrier turned out to be shipment security, not delivery time.

Table 3. Results of the verification of research hypotheses

Source: Own elaboration.

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