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Identifying and testing drivers of consumers' attitude towards last-mile delivery modes

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Abstract
Many online businesses strive to optimize last-mile delivery cost by implementing delivery modes aimed at cutting costs through automation or collaboration. Convincing consumers to adopt cost-efficient last-mile delivery modes is imperative to successfully achieve this goal. Yet, evidence on consumers' attitude towards different delivery modes is scarce and causes of differences in attitude are currently not well understood. Based on qualitative interviews with e-food industry experts, we identify potential drivers of consumers' attitude towards last-mile delivery modes. We test these drivers experimentally, finding privacy concerns to fully mediate differences in attitude of in-home and in-garage delivery when compared to timed in-person delivery. In addition, we find evidence indicating the presence of privacy calculus in delivery mode choice. Next to reducing customer risk, providing added customer value could therefore be a viable approach to encourage consumer adoption of more cost-efficient last-mile delivery.

Keywords Last-mile delivery · Fulfilment cost · Consumer attitude · Adoption · Mixed-methods research · Electronic commerce

1 Introduction

A recent industry report investigating 500 online grocery retailers and consumer product companies found last mile delivery to be the biggest cost driver in the supply chain [1]. The report further revealed that online retailers typically subsidize an average of 20% of the last mile delivery cost because consumers are unwilling

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to pay fees that reflect the real cost of delivery. This showcases how reconciling high last-mile logistics cost and consumers' limited willingness to pay poses a decisive challenge in online retailing, that severely impacts firm profit. These issues are especially prevalent in e-food retailing, where new "quick commerce" providers have started to challenge incumbent e-grocers with delivery within minutes and tiny delivery fees [2].

According to recent research, online grocery shopping increased during the COVID-19 pandemic [3]. However, this uptick in online grocery shopping adoption has proven to be relatively short-lived, as many quickly returned to buying groceries in physical stores [3]. In fact, to date, the market share of online grocery shopping remains remarkably low [4]. This may be in part because online grocery retailing struggles to offer cheaper prices in comparison to physical retail [5], as is the case in other product categories. Lower prices in comparison to traditional channels have been shown to be a decisive driver of consumer adoption of online shopping in general [6], and market research indicates that this equally applies in the online grocery shopping context [7]. Considering this, the intensified competition by "quick commerce" retailers and the significant burden of high last-mile delivery cost pose a dire threat to online grocers. To ensure their long-term survival, online grocers are hence under mounting pressure to lower cost by increasing their last-mile distribution efficiency [8].

The success of reducing logistics cost by implementing new last-mile delivery modes greatly depends on their acceptance by consumers [9]. Yet, attitude towards the last-mile delivery mode and its drivers have been only selectively studied in the literature to date [10]. Recognizing the practical importance of this issue, our research aims to fill this void by identifying and testing drivers and underlying mechanisms of consumers' attitude towards different last-mile delivery modes. To this end, we first identify drivers of last-mile delivery mode attitudes in a qualitative study. Findings from our expert interviews suggest that differences in attitude regarding in-person delivery modes might be due to variating service quality and perceived working conditions. On the other hand, consumers' attitude pertaining to impersonal delivery may be influenced by convenience and privacy risk perceptions. We test these identified drivers experimentally, providing evidence for consumers' general preference towards in-person delivery. According to our findings, cost in personal delivery modes may be effectively streamlined through collaboration, since we found no differences in attitude between in-person delivery modes. In terms of impersonal delivery modes, automation can help to reduce cost, e.g., by eliminating the need for returning when recipients are not at home. However, our findings show in-home and in-garage delivery to be significantly less appealing than timed in-person delivery. We show that higher perceived privacy risk fully mediates this difference in attitude. In addition, our findings indicate the presence of privacy calculus, since the overall attitude and privacy risk of in-fridge delivery, the most invasive delivery mode, was found not significantly different compared to in-person delivery. E-grocers should therefore carefully manage privacy risk perceptions when implementing last-mile delivery modes that entail entering customers' private space.

2 Literature review

To enhance last-mile distribution efficiency, two archetypical strategies, collaboration and automation, have been extensively discussed in the literature [10, 11]. According to Cruijssen [12], "collaborative logistics describes the practice where companies work together to improve efficiency in their supply chains rather than operate in isolation and accept the inefficiency that frequently results." Previous research suggested collaboration to be an effective delivery cost reduction strategy. For instance, Gi and Spielvogel [8] argued that optimization of last-mile delivery processes is often achieved through collaboration with industry partners. Based on simulations, Serrano-Hernandez, de la Torre, Cadarso and Faulin [13] found significant reductions in driven distances and fulfillment speed for online food retailers who employ collaboration. Process automation is the second widely used cost-reduction strategy [14]. In the last mile, new promising modes of last-mile delivery have emerged, fueled by advances in automation technology and historically low interest rates that which decreased implementation barriers [14]. Today, the most sophisticated distribution solutions optimize delivery routes using real-time traffic data, while sensors monitor delivery conditions. In the near future, innovative delivery technologies such as autonomous vehicles, smart lockers, and drones may be implemented more widely, promising further cost-efficiency improvements [1].

Previous research has investigated novel and innovative delivery modes as they emerged [see, e.g., 15, 16]. For the sake of brevity, we limit our discussion to last-mile delivery modes considered in this research. Online grocery retailers (OGR) increasingly rely on delivering their customers' orders themselves. This typically takes the form of an employee of the OGR personally handing the delivery over to the customer. Arguably, the most common alternative to delivering orders with own personnel is relying on the services of established logistics providers, i.e., postal or parcel services such as UPS, FedEx or DHL. Crowd delivery has been pioneered by food delivery services such as UBER eats or Deliveroo and is particularly prevalent at "quick commerce" retailers who often use bike couriers for order fulfillment [2]. In this mode, a freelancing private individual assumes delivery duty using a privately owned mode of transport, such as a car or bicycle [17].

In recent years, numerous last mile delivery modes have appeared, which eliminate the need for the recipient to accept delivery. One example is a (lockable) smart box near the post box or door of the recipient, in which the delivery can be placed [18]. With the emergence of smart locks which allow limited access to service providers, new forms of delivery became possible [19]. For instance, in-home delivery allows the placing of a parcel inside a recipient's home. The delivery person authenticates themselves and receives one-time access via the smart lock, allowing delivery inside the recipient's home. In the same way, a parcel could also be delivered inside a recipient's garage (arguably, a less sensitive part of the home) or even directly into the fridge. Finally, OGR have trialed fulfilment through a range of autonomous vehicles such as drones or self-driving ground vehicles. Autonomous ground vehicles are small robots (pods) that typically drive

on sidewalks and deliver parcels to a recipient's doorstep or the nearest curb [16]. Table 1 summarizes the last mile delivery modes considered in this research and associated cost reduction strategies.

Extant research investigated last-mile delivery from the lenses of environmental sustainability, delivery service quality, and cost-efficiency improvement [10]. Some research also highlighted the challenges of last-mile delivery such as freight planning [20] and routing [21] which lead to the particularly high share of transportation costs incurred in the last-mile. In contrast, despite some emerging interest, consumers' attitude towards last-mile delivery modes have been generally neglected in academic literature. Among the few exceptions, a study investigating intention to use self-collection services, found compatibility with a consumer's lifestyle, a perceived relative advantage, and trialability of the service to increase usage intention [22]. The importance of delivery mode sustainability in consumers preference formation also received some attention. Buldeo Rai et al. [23] studied consumer preferences for traditional parcel delivery versus more sustainable alternatives (lockers, store pick-up, and pick-up points) in an omnichannel context. Their research demonstrated that consumers have a strong preference for free in-person delivery, with delivery fee being by far the most important determinant of consumer's choice. The authors further showed that consumers can be persuaded to adopt more sustainable delivery options through economic incentives (free delivery and returns). Ignat and Chankov [24] corroborated these findings in their study showing the relevance of sustainability information in delivery mode choice. The authors further argued that consumers consider trade-offs when deciding on a mode of delivery.

Recently, researchers have started to investigate differences in consumer preference between innovative and traditional last-mile delivery modes [15, 16]. Merkert et al. [15] focused on the influence of delivery speed, security, timing, and cost on delivery mode choice. In line with previous research, the authors found consumers to generally prefer cheap and fast in-person delivery, although delivery cost was identified as the dominating factor in delivery mode choice. Delivery by drone or to a parcel locker were found to be less appealing than in person delivery. Interestingly, price sensitivity was shown to be even more pronounced in the low-value parcel context. Similarly, Polydoropoulou et al. [16] compared in-person delivery to fulfillment by assisted ground automated vehicles (AVs), unassisted ground AVs (pods, robots), and drones. Their findings confirm previous results by showing a general preference towards personal delivery and a strong influence of delivery cost and speed on delivery mode choice.

We currently have no definitive explanation for the consistently shown differences in delivery mode appeal in previous research. Theory of planned behavior (TPB) posits attitude towards the behavior, subjective norm, and perceived behavioral control predict behavioral intentions, which in turn determines behavior [25, 26]. In the context of delivery drones, Ramadan et al. [9] drew on TPB to conceptually propose consumer attitude towards using delivery drones to be determined by perceptions of risk, functional benefit, and relational value. Building this line of reasoning, the appeal of last-mile delivery modes might be determined by factors and facets of customer value other than functional benefits. Indeed, in their qualitative study, Vakulenko et al. [27] proposed that the use of parcel lockers may result in functional,

Table 1 Overview of last-mile delivery modes and associated cost reduction strategies

Last-mile delivery mode	Description	Delivery cost reduction strategy
Delivery by e-grocer	In-person delivery to customer's door by an employee of the online retailer	Baseline scenario
Logistics provider	In-person delivery to customer's door by a logistics provider	Collaboration
Crowd delivery	In-person delivery to customer's door by a freelance contractor	Collaboration
Timed in-person	In-person delivery to customer's door within a customer-specified time window	Baseline scenario
Smart box	Delivery is placed inside a refrigerated smart locker at customer's door	Automation
In-home	Delivery is placed at the entry area inside customer's home using smart lock access (in a cooling bag)	Automation
In-garage	Delivery is placed inside customer's garage using smart lock access (in a cooling bag)	Automation
In-fridge	Delivery is placed inside customer's fridge using smart lock access	Automation
Autonomous ground vehicle	Delivery to customer's home within a customer-specified time window by an autonomous ground vehicle	Automation

social, emotional, and financial customer value, but might equally negatively impact such value.

In summary, prior research using choice experiments provided evidence that consumers generally prefer in-person delivery. At the same time, the scarce previous research showed the dominating influence of delivery fees on consumers last-mile delivery choice. Based on these findings, some authors suggested that consumer adoption of impersonal delivery modes must be enticed by reduced delivery fees [23], which is at odds with firms' cost-reduction motivation. In real-world settings, impersonal and autonomous delivery methods typically entail quicker and, at least in some cases, cheaper delivery for customers. And yet, innovative delivery modes were repeatedly found to be less appealing than traditional in-person delivery. This indicates the presence of hitherto unconsidered factors calling for closer examination. Furthermore, all identified prior studies only investigated a single or a few selected innovative delivery technologies. We are thus left with an incomplete picture of consumer attitudes across last-mile delivery modes [10]. Our research addresses these gaps by identifying novel drivers of delivery mode attitude in a qualitative study and subsequently testing newly identified factors in an experimental research framework.

3 Explorative study: identifying factors impacting consumers' attitude towards the last-mile delivery mode

Motivated by alleviating our currently limited understanding, we conducted an explorative, qualitative study to identify novel drivers of delivery mode attitude. In doing so, we wanted to assess overall feasibility, challenges, and success factors pertaining to last-mile delivery modes from a company perspective to bolster external validity and practical relevance of our research. In addition, we sought to identify reasons that might explain the observed differences in consumer preference. The results of our qualitative study provided a robust foundation for hypothesis development in our subsequent experimental study.

We conducted semi-structured qualitative interviews with executive-level informants from the food delivery and e-food industries. The interview guide[1] was structured in four thematic segments. In the introductory part, we aimed to establish rapport with our informants, by asking about their function and main responsibilities in daily business. We then inquired about prevalent customer expectations in the industry, and how retailers and service providers ought to react to these expectations in the future. The following part concentrated on the cost structures and main cost centers in online food retailers' distribution, potential for cost-reduction, and hurdles which hamper exploiting opportunities to lower cost. In the third part of our interviews, we asked the executives to evaluate four pre-identified last-mile distribution model archetypes. These archetypes comprised of traditional in-person delivery by a logistics provider, crowd delivery, Internet-of-Things-enabled (IoT) home delivery, and autonomous delivery vehicles. We provided vignettes, including a brief description

[1] The interview guide is available upon request from the corresponding author.

Table 2 Expert sample

Expert Alias	Industry	Position
E1	Food delivery	Former Chief Executive Officer
E2	E-grocer	Business Development Manager & Board Member
E3	E-grocer	Chief Executive Officer
E4	E-grocer	Entrepreneur & Investor (former Chief Executive Officer)
E5	Food logistics	Chief Executive Officer
E6	E-grocer	Change Management (former Chief Executive Officer)
E7	E-grocer	Chief Executive Officer

and a visualization of each archetypical mode. We then asked our experts about cost saving potential, challenges, and the practical feasibility of each delivery mode. The interviews concluded with a discussion on whether synergy effects might arise from combining two or more distribution modes.

Experts were selected based on theoretical sampling considerations. As our research is of particular concern to the e-food industry, we approached industry experts at national and international e-grocers, as well as from food logistics and food delivery industries. Moreover, since last-mile delivery configuration and the implementation of collaboration and automation-based cost reduction strategies are highly strategic decisions, we approached top-management and experts in comparable function when recruiting interviewees. As Table 2 shows, our final sample comprised seven top-management industry experts.

Interviews were conducted in October 2021 via video-conferencing software. Interviews lasted between 45 and 60 min, and all experts were provided with an interview guide in advance. The discussions were recorded with the expressed consent of the participants. We transcribed the corresponding audio files verbatim and in original language [28]. Following transcription, we invited our interview partners to check and validate the transcripts of their interviews. We did so to ensure rigor and content validity [29], ruling out drawing invalid conclusions due to transcription errors or misunderstanding. All in all, the interview transcripts covered 80 single-spaced pages.

We analyzed the interview transcripts using qualitative content analysis (QCA) [28]. QCA is an established method for summarizing textual material by identifying, describing, and categorizing embedded meaning linked to a focal research question [30]. In QCA, this is typically done by starting with establishing or extracting main thematic categories, to which relevant text passages are then assigned. After an initial first round of coding, thematic sub-categories are then developed inductively from the interview material [30]. Following Kuckartz [28], we divided the transcripts into main topics, deductively adopting the main categories of the interview guide. In an iterative approach, we coded the interviews in several rounds with an increasing level of abstraction. In total, this yielded 217 thematic sub-categories, summarizing relevant meaning embedded in the transcripts.

4 Summary of customer-related findings

We summarize the main findings of our exploratory study below. Since this research is focused on identifying and exploring determining factors and mechanisms of consumer attitudes towards last mile-delivery modes, we limit our discussion to the relevant findings.

The practical feasibility of sharing logistics capacities, traditionally through delivery by a postal service or a logistics provider, was universally accepted by experts (E3, E4, E7). Regarding customer-facing disadvantages and challenges, experts pointed towards a loss of customer touchpoint (E7), loss of control in the delivery process (E1), and loss of an opportunity for service differentiation (E3). As explained by E5: "The delivery personnel are the only humans visible to customers. They are crucial for customer satisfaction, product quality, and friendliness." According to E4, the handover at the customer's door is a moment of "making or breaking it", emphasizing the importance of trained delivery staff.

Given a dense store network, crowd delivery can enable retailers to deliver quickly to customers in store proximity, according to our experts (E3, E7). As E3 put it: "If I have a dense store network as we do in [country], I can deliver very fast, very reliably, and at low cost." However, experts identified a range of challenges, including working conditions and adequate wages (E1). According to E7, Uber-like models are more and more publicly criticized as they are perceived to create precarious working conditions, posing a reputational risk for the retailer (E5). In light of its downsides, our experts had opposing views on the practical feasibility of crowd delivery. According to the experts, the model might be best suited for less delicate products, such as beverages, and retailers with a small, standardized product assortment (E3, E5).

In the eyes of our experts, a key advantage of IoT-enabled delivery solutions is that customers would not be required to accept delivery (E3). From a service perspective, it might also provide additional customer value if the orders are directly placed inside the customer's home (E7) or fridge (E6, E7). Additionally, they may allow for the safe storage of orders, reducing the risk of theft, which might lead to an increased adoption of unattended delivery in environments with an elevated crime rate (E3, E7). Regarding challenges, experts pointed out that retailers would need to notify and provide assurance of on-time delivery, thereby respecting the customer's plans (E2, E4). In addition, this mode of delivery omits the human interaction at the door, which otherwise may be part of the shopping experience (E1). Experts furthermore agreed using smart reception boxes would result in a loss of convenience, as customers would have to carry heavy orders into their home themselves (E1, E6, E7). In-home delivery may be affected by privacy concerns, as the home may be considered a "sacred place" by consumers (E1). Consumers may hesitate allowing strangers entering their home, especially in crime-affected areas (E1). Against the backdrop of privacy and safety concerns, the feasibility of in-home delivery was seen to depend on customer acceptance, among other things (E7). To this end, experts proposed cameras allowing control of the delivery process to ease consumer concerns (E5, E6). In-garage

Table 3 Overview of factors influencing delivery mode attractiveness proposed by experts

Influencing factors	Experts' reasoning
Service quality	Control of the delivery process (E1, E5) Opportunity for service differentiation (E3) Delivery personnel as only humans visible to customers are crucial for customer satisfaction, product quality, and friendliness (E5) If the interaction with a delivery person is removed, the "charm of the person" gets lost (E2)
Working conditions	Rising public criticism for Uber-like models as they are perceived to create precarious working conditions, posing a reputational risk for the retailer (E5, E7)
Convenience	Higher convenience if customer attendance is not required (E3) Increased customer value if orders are directly placed inside customer homes (E6, E7) Lower convenience if unloading process must be carried out by the customer (E1, E3, E4, E6, E7)
Privacy concerns	Private home as "sacred place" for consumers (E1) Customer hesitation in allowing strangers to enter private homes, especially in crime-affected areas (E1)

delivery was seen to side-step this issue, as the garage may be considered to be a less sensitive space by customers as it is typically separate from the rest of the house (E4). Alternatively, in-home delivery might also be performed by a trusted person, such as a concierge (E1, E4). Lastly, in the mind of our experts, placing orders in the entrance area of customer homes would be less problematic than placing orders inside the refrigerator (E6, E7).

Overall, our experts expressed doubt about the feasibility of autonomous delivery fleets in the last mile, even in the near future (E5). Nevertheless, they maintained that some autonomous solutions, such as semi-automated delivery vans, will likely appear in the last mile over time (E7, E2). While autonomous ground vehicles were perceived interesting from a cost-perspective (E7), some experts saw them purely as a marketing tool to create attention for the company (E1, E5). The experts identified various drawbacks with autonomous delivery fleets in general. As with IoT-enabled solutions, cutting out the interaction with a delivery person also removes the "charm of the person" (E2). A further drawback concerns the unloading process, which would have to be carried out either by the customer, who must be physically present, or automated (E1, E3, E4, E7). For these reasons, the experts were skeptical about wide-spread adoption of autonomous delivery fleets until it enhances the consumer's shopping experience (E2, E6). Table 3 summarizes our findings regarding the factors proposed by the experts to influence delivery mode attractiveness, including their respective reasoning.

5 Testing drivers of attitude towards the last-mile delivery mode

Drawing on the insights generated in our explorative study, we proceeded to empirically test the nine last-mile delivery modes our informants deemed to be the most feasible. Based on expert assessment, we included two delivery modes that

may lower cost through collaboration (delivery by logistics provider and crowd delivery) and five modes that might offer cost benefits via automation (smart box delivery, in-home delivery, in-garage delivery, in-fridge delivery, autonomous ground vehicle delivery). We further included (in-person) delivery by the retailer and timed in-person delivery as experimental baseline scenarios, as those were deemed most typical by our experts. From the qualitative interviews, it emerged that attitudes towards collaborative and automation-based last-mile delivery modes are likely influenced by different factors. We therefore formulated and tested two separate conceptual models. Accordingly, following, we first develop the hypotheses for collaborative modes of last-mile fulfillment, and then turn our attention to automation-based modes.

5.1 Collaborative last-mile delivery modes

From a customer perspective, the form of collaboration determines the delivery person at their door, and with that all service characteristics of the handover process. When using a logistics provider, a neutral professional delivers the order to customers, while any individual may deliver the order in the crowd delivery approach. Overall, the experts had reservations regarding both modes due to numerous strategical and operational challenges, ranging from limited branding opportunities to loss of control over service quality. Previous research has shown that customers generally prefer in-person delivery [15, 16, 23]. However, to the best of our knowledge, no research has yet compared the attractiveness of delivery modes based on who is carrying out the delivery. Based on our expert input, we expect customers to perceive both modes less appealing than the non-collaborative alternative. In line with expert critical evaluation, we hypothesize the following:

H1: Delivery by a logistics provider is less appealing to customers than delivery by the e-grocer
H2: Crowd delivery is less appealing to customers than delivery by the e-grocer

According to the experts, both logistics provider and crowd delivery share the major disadvantage of losing direct customer contact and foregoing order handover as a touchpoint. On the other hand, the experts considered well-trained employees to be a critical success factor in last-mile delivery. According to previous research on customer contact, employee interaction greatly shapes service quality perception [31]. The experts consider the loss of control over service quality due to the reliance on company-external delivery personnel to be a significant disadvantage for both competing modes. We therefore expect customers to perceive the service quality of collaboration-based delivery modes inferior to direct delivery by the e-grocer, which in turn may lower consumer attitude.

H3: Perceived service quality is positively associated with delivery mode appeal

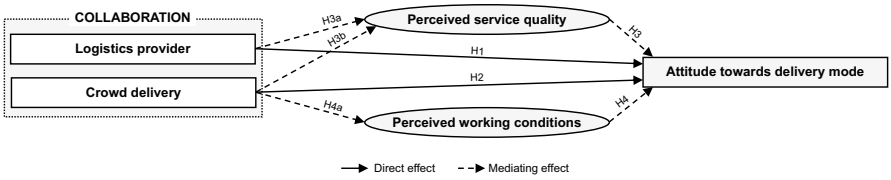


Fig. 1 Conceptual model for collaboration

H3a: Compared to delivery by the e-grocer, logistics provider has a perceived lower service quality
H3b: Compared to delivery by the e-grocer, crowd delivery has a perceived lower service quality

Our experts voiced concerns regarding reputational risks arising out of employment and working conditions of the independent delivery contractors in crowd-delivery. As this was correspondingly considered a major challenge, we expect the perception of working conditions to influence customer attitude. In fact, recent research, analyzing food delivery platforms in the gig economy, showed that controversial labor practices negatively affected intention to use and to recommend [32]. As crowd-delivery relies on the same or similar platforms for last-mile fulfillment, we hypothesize that:

H4: The worse the perceived working conditions, the lower delivery mode appeal
H4a: Compared to delivery by the e-grocer, crowd delivery is perceived to entail worse working conditions

Figure 1 visually summarizes the conceptual model for collaboration-based delivery mode attitude.

5.2 Automation-based last-mile delivery modes

According to the industry experts, successfully automating the last mile in practice strongly depends on the degree to which these technologies provide customer value. In general, the interviews highlight the mutual advantages of independence from customer presence in smart box deliveries and in-home deliveries (enabled by smart home locks). Qualitative research highlighted that failed delivery due to recipient absence regularly causes inconveniences for consumers [19]. Prior research, comparing drone and personal delivery, additionally found that delivery during a specific time window only became an attractive choice if recipients had no safe place where the delivery could be left [15]. These findings suggest that customers are likely to perceive impersonal delivery as being more attractive than personal delivery in a specified time slot. For in-home delivery, however, experts assume that the potential benefits are partly offset by privacy and safety concerns. This is underpinned by qualitative research indicating that security concerns are mainly responsible

for consumer hesitancy in adopting smart lock systems [19]. We hence expect the following:

H5: Smart box delivery is more appealing to customers than timed in-person delivery
H6: In-home delivery is less appealing to customers than timed in-person delivery

With the introduction of smart-lock technology, in-garage and in-fridge deliveries have emerged as promising new forms of in-home fulfillment. Both variants were also positively evaluated by our experts, whereby in-garage delivery was seen to be less critical than in-home delivery, and in-fridge delivery was considered more critical than in-home delivery. Based on their similarity to in-home delivery, and therefore their likewise exposure to privacy and safety challenges, we hypothesize in-garage and in-fridge delivery to be less appealing than timed in-person delivery.

H7: In-garage delivery is less appealing to customers than timed in-person delivery
H8: In-fridge delivery is less appealing to customers than timed in-person delivery

Regarding delivery by an autonomous vehicle, using drones was unanimously discarded as a feasible delivery mode in the foreseeable future. In contrast, employing (semi-) autonomous ground vehicles was perceived to be a more realistic scenario. In this context, the appeal of delivery by an automated delivery vehicle was discussed critically, particularly in reference to the unloading process, which (at present and in the near future) might require consumers to unload their delivery from the vehicle themselves. This requirement should decrease its appeal to customers in comparison to conventional in-person delivery.

H9: Autonomous ground vehicle delivery is less appealing to customers than in-person delivery

A core benefit of both smart box delivery and in-home delivery is that the presence of the customer is not required. Our experts suggested that the magnitude of this benefit may be influenced by the delivery region's crime level, which would negatively impact the consumer sense of security. On the other hand, not having to personally accept the delivery of an order might result in higher convenience for customers, according to the informants. Shopping convenience is defined as "a consumers' time and effort perceptions related to buying or using a service" [33]. In the retailing context, possession convenience has been conceptualized as the speed and ease with which consumers can obtain the desired products [34], which has been identified as a principal driver of convenience in online shopping [35]. Consequently, we expect that:

H10: Perceived possession convenience is positively associated with delivery mode appeal
H10a: Compared to timed in-person delivery, smart box delivery has a higher perceived possession convenience

H10b: Compared to timed in-person delivery, in-home delivery has a higher perceived possession convenience

Based on our informants' accounts, we expect customers to perceive in-garage delivery as less convenient than timed in-person delivery because of the physical distance of the garage to the home. We anticipate the opposite for in-fridge delivery because customers may gain value from being entirely relieved of unpacking and storing their order.

H10c: Compared to timed in-person delivery, in-garage delivery has lower perceived possession convenience
H10d: Compared to timed in-person delivery, in-fridge delivery has higher perceived possession convenience

Furthermore, we expect perceived possession convenience of autonomous ground vehicle delivery to be lower than for timed in-person delivery. This is due to the absence of delivery personnel, thus requiring customers to collect and unload the orders from the vehicle themselves. Customers would hence have to be present to accept their order, unless combined with some form of concierge service or novel unloading automation technology, which would counteract the cost-saving motivation of the e-grocer.

H10e: Compared to in-person delivery, autonomous ground vehicle delivery leads to lower perceived possession convenience

Specifically in regard to in-home delivery modes, the industry experts expected privacy concerns to negatively affect attitude, because those involve a delivery person to physically open and enter a customer's home. Prior qualitative research revealed that consumers have strong concerns regarding security-related aspects, such as theft, in smart-lock enabled last-mile delivery [19]. In e-service literature, privacy risk has been defined as the potential loss of control over personal information, which may be used fraudulently [36]. Perceived privacy risk can emerge from concerns regarding identity theft or the invasion of the private sphere [37], which corresponds to our experts who suggested that perceived privacy risk lowers the appeal of in-home, in-garage, and in-fridge delivery.

H11: Perceived privacy risk is negatively associated with delivery mode appeal
H11a: Compared to timed in-person delivery, in-home delivery has a higher perceived privacy risk
H11b: Compared to timed in-person delivery, in-garage delivery has a higher perceived privacy risk
H11c: Compared to timed in-person delivery, in-fridge delivery has a higher perceived privacy risk

Figure 2 visually summarizes our hypotheses regarding consumer attitudes to automated delivery modes.

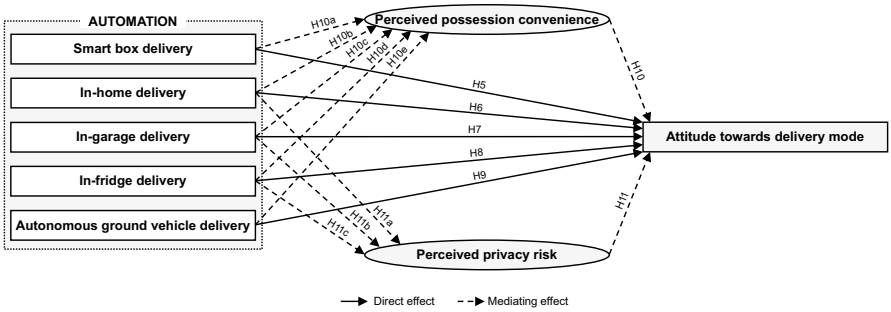


Fig. 2 Conceptual model for automation

5.3 Methodology

To investigate our hypotheses, we employed a between-subjects experimental design. In an online survey, participants were randomly assigned to one of nine conditions pertaining to different last-mile delivery modes. We displayed a visual and textual vignette stimulus[2] to participants, in which they were asked to imagine being a customer of a fictitious e-grocer expecting delivery of their order through the displayed delivery mode. After seeing the stimulus, we asked respondents to rate the overall appeal of the delivery mode, followed by questions regarding their perceptions of service quality and working conditions (collaboration), or possession convenience and privacy risk (automation). We also included an instructional manipulation check (attention check) to ensure that the respondents had read our stimuli and instructions carefully [38]. Finally, we obtained demographic information on the participants' gender, age, occupation, and previous experience in e-grocery shopping. Figure 3 provides a visual overview of our experimental study design.

We measured overall attitude towards the delivery mode using a star rating scale, ranging from one star (very unappealing) to five stars (very appealing), as star ratings have become customary, especially in online retailing [39]. All remaining constructs were measured using five-point Likert scales. To measure service quality, we adapted Mitropoulou and Tsoulfas [40] modified ten item SERVQUAL scale ($\alpha = 0.87$). For perceived working conditions, we adapted the seven-item scale ($\alpha = 0.90$) by Belanche et al. [32]. In the literature, possession convenience in online retailing settings has been measured using different scales. Following the approach of Duarte et al. [35], we combined and adopted scales by Beauchamp and Ponder [41] and Jiang et al. [42], discarding items unsuitable in the last mile delivery context. We thus removed items regarding assortment and communication, leaving four items pertaining to delivery speed, customer effort, delivery condition, and order completeness for each delivery mode. We initially obtained a value of $\alpha = 0.65$. By removing the item PPC1, α improved to 0.69, which we deemed borderline acceptable. Finally, perceived privacy risk was measured using the three-item scale ($\alpha = 0.92$) developed by Yoo, Yu and Jung [43].

[2] Refer to Appendix 2 for stimuli examples.

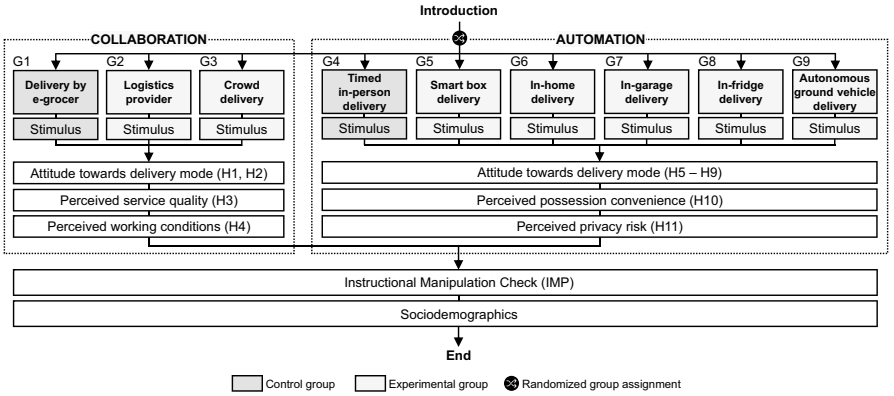


Fig. 3 Experimental study design

Our final sample comprised 384 respondents living in German-speaking Europe, after having excluded four participants from our dataset who did not pass the attention check. Group sizes were almost equal, with a total of 127 respondents for collaboration condition groups (N: G1 = 42, G2 = 43, G3 = 42), and an aggregate of 257 respondents in automation condition groups (N: G4 = 42, G5 = 44, G6 = 43, G7 = 43, G8 = 42, G9 = 43). Our final sample was balanced in terms of gender (46% female, 54% male) and had an average age of 31.3 years (SD = 10.6). Most of the survey respondents were furthermore either employed (46%) or in their studies (35%). The remaining respondents indicated that multiple answers applied (10%; e.g., working students), to be self-employed (5%), retired (2%), or other (3%). Most participants had little prior experience of e-grocery shopping. 34% had never ordered groceries online, 38% had only tried it (1–4 times), 1% were somewhat experienced (5–9 times), and 18% ordered groceries online at least occasionally (10 times or more). Running a MANOVA, we found no significant differences between the groups regarding these control variables ($F(8, 375) = 1.18$, $p = 0.22$).

6 Results

We began our analysis by inspecting the mean values and standard deviations of consumer attitude towards the delivery mode by group. As shown in Table 4, in-person delivery modes were generally deemed most appealing across all conditions. Interestingly, in-fridge delivery was also very appealing to consumers ($M = 4.07$, SD = 0.87), while delivery by an autonomous ground vehicle was deemed the least appealing delivery mode ($M = 2.49$, SD = 1.28).

We proceeded to assess whether differences in attitude were statically significant. Levene's test for homogeneity of variance was significant ($F(8, 375) = 4.44$, $p < 0.001$), signifying a violation of ANOVA assumptions. We therefore assessed group differences by performing a bootstrapped trimmed-means one-way ANOVA [44]. The robust ANOVA indicated significant differences in attitude between

Table 4 Means, standard deviation, minimum and maximum values of attitude towards the delivery mode

	Last-mile delivery mode	Attitude			
		M	SD	Min	Max
Collab	Delivery by e-grocer	3.76	1.05	1	5
	Logistics provider	3.98	0.74	2	5
	Crowd delivery	3.95	0.94	1	5
Automation	Timed in-person	4.21	0.75	3	5
	Smart box	3.93	0.97	1	5
	In-home	3.42	1.48	1	5
	In-garage	3.58	1.18	1	5
	In-fridge	4.07	0.87	1	5
	Autonomous ground vehicle	2.49	1.28	1	5

Table 5 Overview of fit-indices cut-off and model results

Fit indices	Recommended cut-off	Collaboration model	Automation model
Chi-square (fitted model)		283.977*** (df = 163)	69.976*** (df = 43)
Comparative Fit Index (CFI)	> 0.9	0.884	0.973
Tucker-Lewis Index (TLI)	> 0.9	0.865	0.957
RMSEA	< 0.1	0.076	0.049
SRMR	≤ 0.08	0.074	0.042

delivery modes ($F = 8.63$, $p < 0.001$). Subsequent robust post-hoc tests revealed significant differences between autonomous ground vehicle delivery and all other modes (all $p < 0.001$), as well as between in-person (the baseline condition) and in-home ($\Psi = 0.68$, $p = 0.039$), and in-garage ($\Psi = 0.61$, $p = 0.027$) delivery modes.

Following our descriptive analysis, we fitted two structural equation models (SEM) using maximum likelihood estimation to test our hypotheses. Structural equation modeling is a suitable approach when models include latent constructs, such as in our case [45]. Moreover, it allows for simultaneous testing of relationships between constructs, which is advantageous in our research context. We dummy-coded delivery modes as predictor variables in our models. Delivery by the e-grocer (G1) was used as the control group for the collaborative model, whereas timed in-person delivery (G4) provided the control group in the automation model. Path coefficients therefore represent the direction, strength, and significance of differences in attitude when compared with the corresponding baseline delivery mode.

We assessed model fit using well-established cut-off criteria [46]. The collaboration single-factor null model ($\chi^2 = 1229.95$, df = 189) and the automation baseline model ($\chi^2 = 1066.152$, df = 68) were both highly significant ($p < 0.001$). As shown in Table 5, chi-square values for the specified models were significantly lower than for null-models, indicating an overall better fit. Tucker-Lewis index (TLI) and comparative fit index (CFI) were borderline acceptable for the collaboration model and indicated a good fit for the automation model. Both models

Fig. 4 Standardized path coefficients collaboration model

Table 6 Collaboration model total effects

Total effect	Hypothesis	Estimate		SE	*p*	Conclusion
		Unstandardized	Standardized			
Logistics provider	H1 (−)	0.215	0.111	0.197	0.275	Rejected
Crowd delivery	H2 (−)	0.190	0.098	0.198	0.336	Rejected

further showed desirable (below 0.08) and outstanding (below 0.05) values for root mean square error of approximation (RMSEA). Finally, standardized root mean square residual (SRMR) was below the generally recommended cut-off of 0.08 for both models.

The model path coefficients from the collaboration model SEM analysis are presented in Fig. 4 and total effects in Table 6. Please refer to Appendix 3 for a table with the remaining SEM path estimates. No significant differences in attitude could be observed between cost-reducing in-person fulfillment modes and delivery by the e-grocer itself (H1, H2). The proposed mechanisms via service quality and working conditions were also found to be insignificant (H3a, H3b, H4, H4a). Perceived service quality did show significant influence on delivery mode attitude (H3).

Moving on to our automation model, total effects reveal in-home, in-garage, and autonomous ground vehicle delivery to be significantly less appealing than the in-person delivery baseline condition, supporting our hypotheses (H6, H7, H9). On the other hand, smart box and in-fridge delivery were not significantly less appealing than timed in-person delivery (H5, H8). The direction of the effect for smart box delivery was furthermore reversed to our hypothesis. Regarding perceived possession convenience, all modes except autonomous ground vehicle delivery (AGV; H10e) did not differ significantly from the baseline condition, and convenience did not impact delivery mode attitude (H10, H10a-d). In contrast, and in line with our hypothesis (H11), we found perceived privacy risk to have a strong negative impact on the attitude towards the delivery mode. In line with our hypotheses (H11a, H11b), in-home and in-garage delivery were perceived as having higher privacy risk. Although not hypothesized, we found AGV to also be associated with higher privacy risk, a somewhat surprising finding. Similarly unexpected was the insignificant link between in-fridge delivery and privacy risk (H11c). Since direct paths for in-home and in-garage delivery are insignificant in our model, perceived privacy risk fully mediates their lower appeal when compared with timed in-person delivery in our model. Similarly, although not hypothesized, the lower appeal of AGV can be partly attributed to perceived privacy risk (partial mediation) (Fig. 5; Table 7).

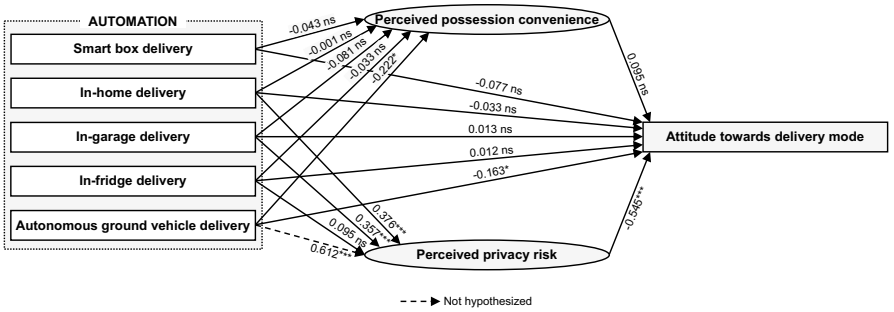


Fig. 5 Standardized path coefficients automation model

Table 7 Automation model total effects

Total Effect	Hypothesis	Estimate		SE	p	Conclusion
		Unstandardized	Standardized			
Smart box delivery	H5 (+)	−.282	−0.085	0.239	0.236	Rejected
In-home delivery	H6 (−)	−.796	−0.238	0.240	0.001	Supported
In-garage delivery	H7 (−)	−.633	−0.190	0.240	0.008	Supported
In-fridge delivery	H8 (−)	−.143	−0.042	0.241	0.554	Rejected
Autonomous ground vehicle delivery	H9 (−)	−1.726	−0.517	0.240	0.000	Supported

7 Discussion and Conclusion

E-Commerce firms, especially those with typically low order value, are keen to reduce last mile logistics costs. This is especially prevalent in the context of e-food, where low order value is met with inflated last-mile logistics costs as a result of special requirements such as ensuring an uninterrupted cold chain. Previous research has shown customers to be extremely price-sensitive when making (last mile) delivery mode choices [15, 16, 23]. For this reason, virtually all market players in the e-grocery industry currently subsidize shipping fees, sacrificing profitability [1]. This, along with aggressive market entrants, puts immense pressure on e-grocers to manage last-mile logistic costs. At the same time, the success of implementing cost-saving delivery alternatives primarily depends on consumer acceptance. In response to this challenge, our research identified and investigated a range of last-mile delivery modes which expert assessment deemed to be promising for cost-reduction purposes while also being feasible in the near future.

Our findings confirm previous findings showing the general preference of the consumer for in-person delivery [15, 16, 23]. The significant influence of service quality perception on (collaborative) delivery mode appeal also partly confirms our expert assessment of its relevance in the last mile. However, it surprisingly did not mediate differences in delivery mode attitude. This suggests that

consumers do not expect a lower quality of service from delivery by a logistics provider or a freelancing crowd worker. On the other hand, since service quality perception clearly impacted consumer attitude generally, service quality in the last mile should be monitored and managed carefully.

We are the first to show that for some delivery modes, namely in-home and in-garage delivery, differences in attitude can be attributed to elevated privacy risk. For these two modes, participants showed significantly higher privacy concerns, which reduced the appeal of these delivery modes. Privacy concerns may be addressed by using the camera feed of the smart-lock or by granting limited access to less sensitive areas of the home, such as the entrance hall. We further show that in-fridge delivery was unaffected by this relationship, indicating the presence of privacy calculus [47]. This might mean that consumers are willing to accept invasion of their private sphere if offered adequate customer value in return. This proposition is well in line with the previously suggested notion that consumers consider trade-offs when choosing the delivery mode [24]. Our findings firstly show that this also applies to consumer privacy.

Another intriguing finding was the irrelevance of possession convenience regarding delivery mode appeal. Convenience has been previously proposed to drive consumer adoption of alternative delivery modes [e.g., 48]. Our qualitative results corroborated this intuitive assumption, and yet we could not confirm it experimentally. Based on our experimental results, all automation-based delivery modes, except for AGV, were perceived as being equally convenient. This indicates that as long deliveries are placed near the home of the recipient, customers benefit from the same level of possession convenience. However, since we focused on possession convenience, we cannot rule out the influence of alternative dimensions of convenience on delivery mode appeal.

7.1 Implications for research

Reconciling the firm and consumer perspective, our research contributes to theoretical progress by identifying and investigating attitude drivers beyond functional determinants such as delivery fee and speed. This research is the first to investigate mechanisms underlying differences in delivery mode attitude, demonstrating the mediating effect of privacy risk perceptions. Furthermore, the empirical results of this research provide a first indicator of privacy calculus in home delivery. These results support the previously suggested notion of consumers considering trade-offs when choosing a delivery method [24]. Notably, our findings further indicate that providing additional customer value through last-mile delivery may entice consumers to accept regular delivery fees. Finally, this investigation extends prior research by considering a wider spectrum of different last-mile delivery modes.

7.2 Implications for online retailers

Online retailers may be particularly interested in our findings. Overall, and in contrast to our expectations, we found no significant differences in attitude between the different forms of in-person delivery. Based on this result, e-grocers can reduce cost by implementing alternative forms of in-person last-mile delivery, without sacrificing perceived service quality or risking backlash based on working condition perceptions. Regarding automation-based cost-saving opportunities, smart box delivery seems currently to be the way to go for e-grocers. Our evidence indicates that consumers perceive this form of delivery to be as appealing as timed in-person delivery. Moreover, our findings show that consumers may be persuaded to adopt more cost-efficient modes of delivery if offered additional customer value, thereby providing a viable alternative to monetary incentives. According to our research, in-fridge delivery appears to offer such additional customer value, although the current low adoption of smart locks positions such a value proposition somewhat further on the horizon. Finally, to successfully roll-out in-home and in-garage fulfillment, our findings indicate that e-grocers should consider and carefully manage the privacy risk perception of the consumers, for example by implementing strict behavioral rules or by providing a video feed of the delivery.

7.3 Limitations and avenues for future research

Certain aspects of our investigation offer opportunities for future research. This research aimed to pinpoint the underlying mechanism for consumers' strong preference for in-person delivery, despite the speed and cost benefits of the alternatives. At the same time, our study took an online retailer perspective, focusing on opportunities to improve last-mile cost-efficiency without risking adverse effects. We therefore did not manipulate functional factors such as delivery fee or speed, which future studies might find to be worth including. The large number of delivery modes in our study led to comparatively small group sizes within conditions. Hence, some of the insignificant effects in our models might be due to low statistical power, warranting further investigation. The composition of our sample represented another limitation. As our sample was comparatively young, it is conceivable that some of our findings are influenced by the age of our respondents. Future research might therefore replicate our findings with a more representative sample. Moreover, we focused our attention on near-to-home last mile delivery modes, since we undertook our research in the e-food context, in which order collection by consumers was deemed disproportionately unappealing. Future research in more suitable settings might hence augment our findings by including order pick-up and lockers.

Likewise, some of our findings call for further examination. One of our goals was to gauge the influence of convenience on consumer attitude, drawing on the construct of possession convenience. Contrary to expectation, we could not establish such a relationship. As our research only included a specific dimension of convenience, other dimensions of convenience may impact consumers' attitude towards

the delivery mode. Similarly, we did not find adverse effects of negatively perceived working conditions, contrary to recent evidence in the gig economy [32]. This might be due to the context of our study, which was conducted in German-speaking European countries with fairly pronounced labor rights. The culture in these countries is also relatively individualistic, which could provide an alternative explanation for our finding. It would be worthwhile to further investigate this relationship in environments with weak labor rights, as well as in more collectivist cultural settings.

Appendix 1: Survey scales

Attitude towards the delivery mode

Code	Item
DMA	How would you rate the appeal of this delivery method?

Perceived service quality (adapted from Mitropoulou and Tsoulfas 2021)

SERVQUAL	Code	Item
Tangibility	PSQ1	I believe the delivery person will have a neat appearance
Reliability	PSQ2	[…] the order will be delivered on time
	PSQ3	[…] the delivery person will have a sincere interest to solve my problems
Responsiveness	PSQ4	[…] the delivery person will be willing to help me
	PSQ5	[…] the delivery person will be available to respond to my customer requests
Assurance	PSQ6	[…] the delivery person's behaviour will promote my confidence
	PSQ7	[…] the delivery person will be consistently courteous with me
	PSQ8	[…] the delivery person will be knowledgeable to answer my questions
Empathy	PSQ9	[…] the delivery person will have my best interest at heart
	PSQ10	[…] the delivery person will understand my specific customer needs

Perceived working conditions (adapted from Belanche et al. 2021)

Code	Item
PWC1	I believe the Grocer Company/Delivery Company respects the rights of its employees/independent contractors
PWC2	[…] establishes safe and non-hazardous working conditions for the health of its employees/independent contractors
PWC3	[…] establishes decent working conditions
PWC4	[…] treats its employees/independent contractors fairly
PWC5	[…] offers adequate remuneration
PWC6	[…] develops, supports and trains its employees/independent contractors
PWC7	[…] communicates openly and honestly with its employees/independent contractors

Perceived possession convenience (adapted from [(1)] Beauchamp & Ponder, 2010; [(2)] Jiang et al. 2013)

Code	Item
PPC1[1]	I believe the delivery method will take a minimal amount of effort on my part to get what I want
PPC2[1]	[…] in this delivery method, the order is delivered in a timely fashion
PPC3[2]	[…] the delivery method ensures that goods are delivered undamaged
PPC4[2]	[…] the delivery method ensures that I receive all the items I ordered

Perceived Privacy Risk (adapted from Yoo et al. 2018)

Code	Item
PPR1	I believe the delivery method will cause me to lose control over my privacy
PPR2	[…] the delivery method will lead to a loss of privacy for me
PPR3	[…] the delivery method might not be used in a way that respects my privacy

Appendix 2: Exemplary stimuli

Scenario D: Timed in-person

Please put yourself in the following situation

You want to order groceries online. On an online grocer's website, you read that delivery will be made to your front door. You are asked to choose a suitable time slot in which to receive the order.

This illustration helps you to better imagine this delivery method.

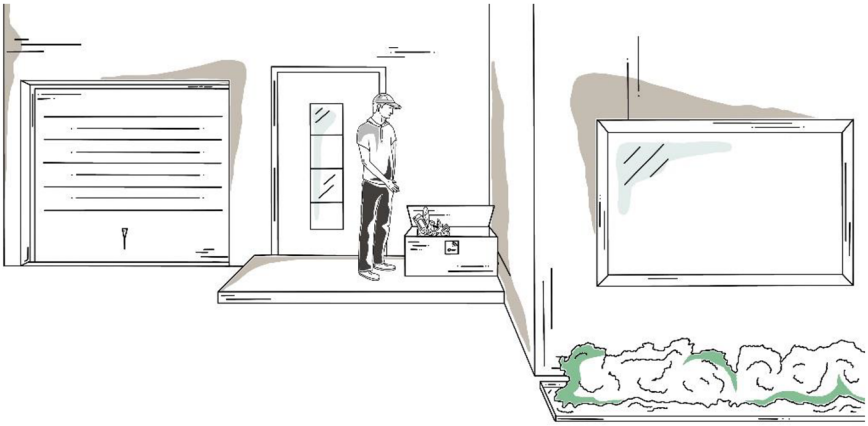
Scenario E: Smart box

Please put yourself in the following situation

You want to order groceries online. On an online grocer's website, you read that the delivery will be made into a smart delivery box, which is at the entrance of your

home. Only you and the delivery person can open this box, and your order remains refrigerated. This way, you do not have to be home at the time of delivery.

This illustration helps you to better imagine this delivery method.



Appendix 3: SEM Path Estimates

Collaboration model

Model Path	Hypothesis	Estimate		SE	p	Conclusion
		Unstandardized	Standardized			
Perceived service quality → delivery mode attitude	H3 (+)	0.698	0.328	0.261	0.008	Supported
Logistics provider → perceived service quality	H3a (−)	−0.154	−0.171	0.100	0.122	Rejected
Crowd delivery → perceived service quality	H3b (−)	−0.138	−0.152	0.100	0.166	Rejected
Perceived working conditions → delivery mode attitude	H4 (+)	−0.019	−0.016	0.132	0.888	Rejected
Crowd delivery → perceived working conditions	H4a (−)	−0.081	−0.050	0.175	0.643	Rejected
Automation model						
Model path	Hypothesis	Estimate		SE	p	Conclusion
		Unstandardized	Standardized			
Perceived possession convenience →Delivery mode attitude	H10 (+)	0.275	0.095	0.192	0.151	Rejected

Model path	Hypothesis	Estimate		SE	p	Conclusion
		Unstandardized	Standardized			
Smart box delivery → Perceived possession convenience	H10a (+)	−0.049	−0.043	0.108	0.652	Rejected
In-home delivery → Perceived possession convenience	H10b (+)	−0.001	−0.001	0.108	0.995	Rejected
In-garage delivery → Perceived possession convenience	H10c (−)	−0.093	−0.081	0.109	0.394	Rejected
In-fridge delivery → Perceived possession convenience	H10d (+)	−0.038	−0.033	0.109	0.729	Rejected
Autonomous ground vehicle delivery → Perceived possession convenience	H10e (−)	−0.254	−0.222	0.116	0.029	Supported
Perceived privacy risk → Delivery mode attitude	H11 (−)	−0.522	−0.545	0.068	0.000	Supported
In-home delivery → Perceived privacy risk	H11a (+)	1.311	0.376	0.240	0.000	Supported
In-garage delivery → Perceived privacy risk	H11b (+)	1.245	0.357	0.240	0.000	Supported
In-fridge delivery → Perceived privacy risk	H11c (+)	0.333	0.095	0.240	0.165	Rejected
Autonomous ground vehicle delivery → Perceived privacy risk	–	2.131	0.612	0.244	0.000	na

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Declarations

Competing interests The authors declare no competing interests.

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