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Public transportation-based crowd-shipping initiatives: Are users willing to participate? Why not?

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ABSTRACT

An emerging stream of Crowd-Shipping (CS) solutions focuses on existing momentum in Public Transportation (PT) to ship viable delivery packages by PT passengers. Few studies have explored the package delivery acceptance behavior of passengers engaged in PT-based CS initiatives while passengers' behavioral intention to participate (i.e., engage) is not studied. It is requisite that newly introduced CS platforms explore their potential crowdshippers' behavior on intention to participate and set efficient marketing strategies. Given survey data collected from 2208 PT passengers in Sydney metropolitan area, this study explores the intention of PT passengers as crowd-shippers to participate in PT-based CS initiatives, as well as prohibiting factors in way of participation. Accordingly, a binominal logit model is developed whereby the variables impacting the intention to participate are identified. Then, using an inductive thematic analysis, 917 reasons (text responses) for not participating are scrutinized, and the prohibiting factors are identified and categorized. Considering demographic and socio-economic characteristics of the respondents, the study reveals to what degree passengers with different characteristics are sensitive to prohibiting factors. This research provides several practical insights that can assist in successfully defining, launching, and advertising a new PT-based CS initiative. As a key finding, it is observed that women, full-time employees, elderly, retirees, and low-income PT passengers hardly participate, while the youth, individuals with a positive attitude towards sustainable freight initiatives, and those who experienced working with parcel lockers would participate with a higher probability. Moreover, it is observed that factors relating to time availability/flexibility and physical health condition/importance of passengers are much more important than the compensation level for passengers to accept to participate in PT-based CS initiatives.

1. Introduction

The e-commerce industry has grown rapidly in recent years. Working-from-home is becoming a new norm and online shopping and home deliveries are dominating retail markets (Vonage, 2021; Beck and Hensher, 2022). Global e-commerce sale has soared from $1.3 billion in 2014 to $4.3 billion in 2020 and is estimated to grow to $6.4 billion by 2024 (U.S. Department of Commerce, 2022). As part of this growth, customers' expectations for quick, free, and flexible delivery services are changing rapidly.

Given the emerging changes in retail markets, several innovative freight last-mile delivery initiatives have been launched in recent years, among which initiatives based on the concept of crowd logistics have gained great attention (Mohri et al., 2022; Carbone et al.,

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2017). Crowd logistics is a type of crowdsourcing in which outsourcing logistics services is the subject of debate. Crowd-Shipping (CS) is a segment of crowd logistics in which only freight shipping services are outsourced to crowds, called crowdshippers. Crowdshippers are occasional carriers who conduct the whole or a part of a freight delivery task from its origin to its destination or between some intermediate points.

For many years, both industry and academia have mainly focused on CS by occasional drivers. In the industry, e-retailers and couriers have introduced many CS platforms such as Amazon Prime, Walmart Spark Delivery, DHL MyWays, Deliveroo, UberEATS, DoorDash, and PiggyBee (Alnaggar et al., 2021). In academia, many studies have been conducted to advance planning for CS by occasional drivers in terms of behavioral, design, and evaluation aspects (Le et al., 2019; Mohri et al., 2023a). From the sustainability perspective, although CS initiatives can reduce van or truck dedicated trips for package delivery, relying on occasional drivers as crowd-shippers in the CS initiatives may not be ideal as it induces additional car traffic. Evidence shows that these initiatives might induce traffic demand in transportation systems since many drivers may adopt it as a secondary job, or new immigrants in developed countries find it a ready-to-hire job option (The New York Times, 2020). Considering this shortcoming, a new, yet emerging stream of CS research focuses on CS using PT passengers (Marcucci et al., 2017; Serafini et al., 2018; Gatta et al., 2019a; Gatta et al., 2019b; Fessler et al., 2022). Green CS is the terminology used for PT-based CS, as such services may not generate dedicated trips for package delivery (Gatta et al., 2019a) or even if they do, the capacity utilization and revenue in the PT systems will be improved.

As expected, initial research work in the scope of PT-based CS has concentrated on the behavioral reactions of PT passengers to these sustainable CS initiatives because such behavioral studies can justify conducting subsequent design and evaluation studies.

In ride-sharing, ride-sourcing, or CS systems, there are typically two consecutive behavioral stages that users (i.e., riders or crowdshippers) go through. As shown in Fig. 1, the first stage involves users showing their intention or willingness to participate in the system by registering. This participation does not guarantee the acceptance of CS delivery tasks; it merely reflects users' initial willingness to encounter such tasks, which in turn contributes to increasing the supply of potential task performers in ride-sharing or CS initiatives. However, during this initial stage, users often do not have a clear understanding of the tasks and their specific details. They possess a basic understanding of the system's workings and its benefits, which they acquire through diverse channels such as social media, word of mouth, outdoor ads, print media, and broadcast media. The second stage occurs after a user has successfully registered and is now considered a participant in the system. In this stage, users are presented with actual tasks and the associated details. Here, users face a crucial decision point: they must choose whether to accept or reject the tasks offered to them. This decision is based on a more concrete understanding of what the tasks entail and the potential benefits or drawbacks.

This study focuses primarily on the first stage, where users express their intention or willingness to participate in the system. We aim to shed light on two critical aspects:

Probability of Participation: One of the research objectives is to examine the probability of intention to participate in the system using a binomial logit model, developed based on survey data collected from the Sydney metropolitan area in 2022. Results of the model can estimate the initial attractiveness of the initiative for PT passengers and be used in approximating the expected number of registered crowd-shippers.

Prohibiting Factors for Non-Participation: Additionally, this research delves into the factors that may deter certain users from participating in the system. These factors could include concerns about safety, lack of trust, or perceptions of inconvenience. By pinpointing these barriers, we can provide insights into how to address them and encourage broader user engagement. The survey data includes the reasons for passengers rejecting the initiative, collected through an open-ended question in the survey. Using an inductive thematic analysis, nearly 917 text responses on the rejection reasons are investigated, coded, and categorized into nine major categories of prohibiting factors. Moreover, assessing the demographic and socio-economic characteristics of the categories' members, the sensitivity degree of respondents with different characteristics to the prohibiting factors are revealed. Therefore, CS platform managers can design an optimal marketing strategy to maximize the expected participation rates by strengthening motivational factors for their platform that can be either common for all passengers or customized for different sociodemographic groups.[1]

2. Literature review

In pursuit of the net-zero emission target for city logistics, as outlined in the Paris Agreement, researchers are actively investigating various sustainable urban freight systems. One of the promising systems is crowdsourced delivery involving PT passengers (CS by PT passengers). In this CS system, package movements are outsourced to PT passengers who are travelling in the PT system for their own purposes. In this section, the literature on CS and CS by PT passengers are reviewed and the contributions of the paper are highlighted.

It is worth noting that CS by PT passengers can also represent an innovative integration of passenger and freight solutions, sometimes referred to as cargo hitching or co-modality (Antoniou et al., 2023). While traditional cargo hitching solutions primarily concentrate on sharing spare capacity in public transportation (PT) vehicles for freight movement and utilizing PT infrastructure (including lines and stations) for freight operations (Machado et al., 2023; Zhu et al., 2023; Hatzenbühler et al., 2023), CS by PT passengers include a different approach. In CS by PT passengers, it is the "users" of PT services that are leveraged as contributors to the movement of goods. This solution proves particularly sustainable when incorporates PT links with high volumes of PT trips (Mohri et al., 2023a). This is in contrast with existing integration of passengers and freight which are typically more suitable for underutilized service with spare capacities inside PT vehicles or at stations. Accordingly, cargo hitching applications may be more suitable in

[1] It is worth mentioning that advertising services through social media can be individually customized by exploring individual likes, dislikes, hobbies, and so on.

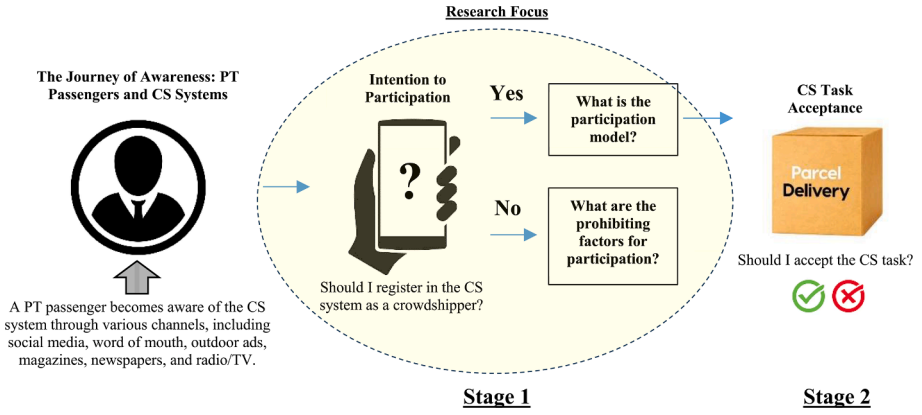


Fig. 1. Research scope.

suburban and rural areas in which PT system is in operation below capacity (Cavallaro and Nocera, 2023). Given these structural differences, this section focuses specifically on reviewing literature related to CS, aiming to position the contributions of the current paper within the broader CS literature. Interested readers to other solutions around integration of passengers and freight can refer to a special issue recently published in 2023 (Antoniou et al., 2023).

Early studies on CS date back to the period 2014 to 2016; hence, it is a newly emerging research subject in academic literature (Rougès and Montreuil, 2014; Archetti et al., 2016; Chen et al., 2016). However, the subject has been well appreciated by researchers and a remarkable uptake in the number of research and review papers on this subject has been observed in recent years (Carbone et al., 2017; Le et al., 2019; Alnaggar et al., 2021; Gläser et al., 2021; Mohri et al., 2023a). While early publications clearly highlighted the importance of bringing environmental benefits in CS initiatives (Rougès and Montreuil, 2014), this is mainly overshadowed by the monetary gains for stakeholders (retailers, CS platform, and crowd-shippers).

This section reviews the literature concerning eco-friendly CS systems. Consequently, the review encompasses papers that address not only the environmental dimension but also the economic aspects of sustainability. There are 17 papers focusing on achieving environmental gains in CS initiatives. Our observations show there are three different approaches for meeting eco-friendly goals in CS initiatives.

Approach 1: Eco-friendly objectives: A group of researchers consider environmental objectives such as minimizing total CO_2 emissions when designing a CS system (Rai et al., 2018; Gatta et al., 2019b; Ballare and Lin, 2020; Simoni et al., 2020).

Approach 2: Eco-friendly transportation modes: Some studies suggest recruiting crowds traveling on eco-friendly modes such as bikes (Kafle et al., 2017; Binetti et al., 2019; Lin et al., 2020; Wicaksono et al., 2021) or PT (Marcucci et al., 2017; Serafini et al., 2018; Gatta et al., 2019a; Gatta et al., 2019b; Simoni et al., 2020; Giuffrida et al., 2021; Fessler et al., 2022).

Approach 3: Detour minimization: Some studies employ existing mobilities with a minimum detour for CS trips. Also, the issue that a CS system should not induce additional traffic (e.g., vehicle trips) is of concern (Chen et al., 2016; Allahviranloo and Baghestani, 2019; Yildiz and Savelsbergh, 2019).

Although adopting Approaches 1 or 3 can reduce the environmental impacts produced from CS initiatives by occasional drivers (i.e., crowd-shippers traveling by unsustainable modes); as long as the reliance is on occasional drivers, sustainability of the initiative may be compromised. Nevertheless, the industry seems to be reluctant to launch CS initiatives by eco-friendly transportation modes (Approach 2) since there have been only a few real-world implementations, primarily in the food retail industry, that have been developed in comparison to CS by occasional drivers. Companies like UberEATs and DoorDash have successfully implemented CS systems by cyclists although the delivery cyclists are dedicated riders officially employed by the companies as casual workers. Therefore, they generate induced cycling demand in the networks. These food delivery CS systems mainly operate well in dense population areas of mega cities, where a substantial amount of demand for delivery lies within a small spatial area (Dötterl et al., 2020). Chronobee is a PT-based CS platform, mainly designed for outsourcing interregional freight movements to passengers (Chronobee, 2022).

In terms of measuring the efficiency of PT-based CS systems, Simoni et al. (2020) performed a dynamic traffic simulation-based analysis to explore the effect of package delivery by occasional drivers and PT passengers on reducing air pollution, greenhouse emissions, and traffic delays. By considering the city centre of Rome, Italy, as the case study, their results show that CS by PT passengers is more beneficial than by occasional drivers from both an environmental and congestion perspective. Moreover, considering the level of matched demand of 50 %, nearly 35 % reduction is achieved in air pollution, greenhouse emissions, and traffic delays. Giuffrida et al. (2021) explored the spatial feasibility of outsourcing freight deliveries to university students who commute in the network with PT services and other active modes of transportation. A case study from the city of Catania, Italy, is used where the university campuses are in different zones of the city. Some spatial considerations for matching deliveries with student movements are regarded including the origin–destination (OD) flows of students' movements, the proximity of delivery points to students' home addresses, and main transportation modes for student trips to/from university campus. By assuming a maximum walking distance equal to 500 m for package delivery by students, the authors found potential locations where their deliveries could be outsourced to the

students.

Although CS by PT passengers can have significant environmental benefits, without a large volume of passengers as crowd-shippers, the benefits would not be attained. Hence, a group of studies focuses on the behavioral side of the initiative. Studies such as Serafini et al. (2018) and Gatta et al., (2019a) used survey data to develop discrete choice models to explore the conditions under which commuters on the metro network would accept delivery CS tasks as part of their daily travel. Such PT-based CS systems predominantly utilize intermediary points such as parcel lockers to facilitate the process of package pick up and drop off, which might have different inevitable implications on the behavior and preferences of PT passengers. In this regard, by applying a multinomial logit model to the survey data, these studies observed that PT passengers are more sensitive to the location of lockers (preference for lockers inside stations) as compared to compensation rates (1–3€/delivery). Also, contrary to students who display the largest marginal utility, older and high-income passengers are reluctant to accept CS tasks.

Marcucci et al. (2017) investigated the conditions under which students in Rome would be willing to act as crowd-shippers in CS systems. By surveying nearly 190 students, they showed that most of the students are unfamiliar with CS, while 87 % of them would be willing to act as a crowd-shipper. The participation of students as crowdshipper would be decreased to 55 % and 40 %, if the package is large and the reward is less than 5€, respectively. Also, the maximum acceptable detour distance was around 1.5 km for carless students. Moreover, 57 % of students acting as crowd-shippers are unwilling to be tracked. Fessler et al., (2022) explored how PT passengers in the Greater Copenhagen Area accepted some CS tasks having different weights, sizes, incentives, and detours. A CS system in which passengers pick up and drop off packages only from lockers inside PT stations is proposed. Therefore, this CS plan can mitigate deliveries to city centers by vans with packages outsourced to PT passengers to move towards lockers in city centers. Using survey data and applying a mixed logit model, results show youth, students, and employed and self-employed individuals show the highest willingness to accept CS tasks. Findings also show the marginal disutility of time spent retrieving and dropping off packages at ADPs is higher for elderly (aged +60) and individuals with higher income (i.e., earning more than 50,000 DKK/month), while it is lower for individuals with short-term education (i.e., below 2 years education after high school). The authors also observed that increasing compensation increases the willingness to accept while increasing the number, size, and weight of packages decreases the willingness.

In addressing the challenges and barriers of implementing an initiative, researchers often employ a mixed-methods research approach, which combines quantitative and qualitative methodologies (Creswell, 1999). This multifaceted approach involves collecting responses from stakeholders through surveys and interviews, enabling a comprehensive exploration of the challenges at hand. Subsequently, qualitative analysis techniques, such as thematic analysis, are applied to the collected data to identify and categorize the main challenge themes. In the field of city logistics, some studies have employed this approach (Lindholm and Behrends, 2012; Anosike et al., 2023; Kassai et al., 2020; Sista and De Giovanni, 2021; Alharbi et al., 2022).

Lindholm and Behrends (2012) employed thematic analysis to explore the difficulties in making city freight transport more eco-friendly and to examine how cities around the Baltic Sea plan for it. They conducted detailed interviews with people from the government and businesses and studied documents to find important topics. Their findings showed that city freight transport is crucial for the competitiveness of the region, but it's also harming urban sustainability. The way cities are designed makes it hard for freight operations to run smoothly, and surprisingly, both city authorities and transport companies often overlook these problems. Anosike et al. (2023) investigated the challenges of introducing electric vehicles in last-mile parcel delivery operations from both academic literature and the perspectives of parcel carriers. The research involved conducting semi-structured interviews with two prominent parcel carriers in the UK, followed by a thematic analysis to identify key challenges. These challenges revolved around aspects such as operations, infrastructure, battery technology, and the cost components associated with electric vehicles.

Kassai et al. (2020) examined the potential of autonomous self-driving trucks for delivery services, focusing on the courier, express, and parcel sectors. They conducted semi-structured interviews with industry experts and used thematic analysis. The findings reveal parcel delivery companies' interest in innovative solutions like autonomous vans for business-to-consumer (B2C) deliveries, but they also highlight barriers to implementation, including legislative hurdles, technological challenges, workforce adjustments, and the management of evolving customer expectations. Sista and De Giovanni (2021) studied the common issue of smart city logistics projects failing to scale up and aim to identify key success factors related to their scalability. To achieve this, the researchers conducted a qualitative case study using the SMOOTh project in Gothenburg, Sweden, which involves multiple companies like Volvo Group and DHL. They conducted semi-structured interviews with seven project stakeholders and employed thematic analysis to identify four categories of success factors: business model, technical, stakeholder, and regulatory. Alharbi et al. (2022) investigated the use of CS to tackle last-mile delivery challenges in Saudi Arabia. The research involved semi-structured interviews with a range of stakeholders aimed at identifying the challenges associated with CS. Through doing thematic analysis, the study pinpointed four main obstacles impeding the effective implementation of CS: legislative constraints, availability of crowdshippers, trust issues, and cultural factors.

2.1. Contributions

Previous behavioral studies in the field of CS have primarily concentrated on modeling the acceptance behavior of crowdshippers regarding package delivery. Notable works by Marcucci et al. (2017), Punel et al. (2018), and Le and Ukkusuri (2019) have delved into the participation issues associated with CS involving occasional drivers. In all three studies, the choice questions employed fixed and deterministic attribute levels. However, a crucial aspect is that, prior to engaging in CS systems, users often lack a clear understanding of the tasks and their specific details. Consequently, modeling willingness to participate based on choice questions with exact attribute levels may lead to estimation errors. In this study, a departure from this approach is taken, as attribute levels are presented in broad ranges rather than exact values. These ranges encompass additional variations that may occur in the attribute levels defined for CS

tasks.

While the intention to participate problem has been investigated for CS involving occasional drivers, there has been a gap in exploring this aspect for PT-based CS initiatives. As depicted in Table 1, existing behavioral studies on PT-based CS have primarily focused on the acceptance problem related to CS tasks (Serafini et al., 2018; Fessler et al., 2022; Mohri et al., 2024). These studies in the PT-based CS literature typically involve PT passengers facilitating locker-to-locker deliveries, contrasting with the approach taken in this study, which considers PT passengers for locker-to-home (package receiver's location) deliveries, specifically addressing the last mile. As illustrated in Fig. 2, the existing PT-based CS studies involve passengers transferring packages solely between two lockers, rather than delivering them to the actual destinations. The substitution of receivers' delivery addresses (such as homes) with locker facilities has the potential to influence the participation rate of PT passengers in the CS system. In locker-to-home CS systems, crowdshippers would encounter significant detours and interactions with package receivers. Therefore, this study aims to enhance the modeling of the intention to participate in PT-based CS systems by incorporating the substitution of receivers' homes with locker facilities.

Regarding every new service, participants have implicit concerns that could be beyond the capability of service providers in advance to include them. Qualitative research techniques are an appropriate tool for recognizing their concerns. To the best of our knowledge, this study is the first to study the concerns of PT passengers refusing to participate in PT-based CS systems and identify the main prohibiting factors for participation. By conducting an inductive thematic analysis on the data collected, categories of prohibiting factors are identified which can significantly aid service providers in ways of successfully defining, launching, and advertising their services.

3. Survey data

Sydney has an area of 12.4 thousand square meters and is home to nearly 5.4 million people, according to the estimated population in June 2021 (Australian Bureau of Statistics, 2022). The PT system in Sydney includes train, bus, metro, light rail, and ferry whereby nearly 30 % of total passenger trips are made by PT modes. Train and bus are the dominant PT modes in Sydney, where on average 53 % (420 million passenger trips) and 41 % (324 million passenger trips) of annual PT passenger trips (before COVID-19) were made by train and bus, respectively (TfNSW, 2022). The train system consists of 8 lines and 170 stations, while the bus system has more than 600 routes and 4.2 thousand stops. Given the dense and attractive PT system, Sydney can be a viable option to launch PT-based CS initiatives.

To explore the intention of Sydney PT passengers to participate in the proposed PT-based CS initiative, an online survey was conducted in February 2022. The survey asked respondents to provide information of their preferences for city logistics initiatives including the PT-based CS initiative. Two pilot studies were also conducted to improve the research quality and make it realistic and workable. The first pilot targeted 12 professionals in areas of statistical analyses and freight last-mile logistics. The second pilot was conducted through Qualtrics and targeted 10 % of the sample size for Sydney. After revising the survey based on the feedback received from both pilot studies, the survey was finalized and launched. Two specific questions were included to explore the intention to participate, as shown in Fig. 3.

In the realm of experimental design for choice modeling, there is a prevalent emphasis on achieving a high level of resemblance between the experiment and the real-world context that unfolds after implementation. This alignment with the post-implementation scenario is sought to enhance the generalizability and practicality of the experiment's results (Haghani et al., 2021). As depicted in Fig. 1, in crowd-based systems such as ride-sourcing or CS systems, occasional service providers (e.g., crowdshippers in CS systems) often lack a comprehensive understanding of the tasks and their precise details. They possess a rudimentary grasp of the system's operations, with information presented in broad ranges rather than exact values. Consequently, the first question (Q1) is formulated to present attribute quantities, like incentives or parcel delivery weights, in varying ranges that align with the fluctuations observed in CS delivery tasks. This approach fosters similarity between the experiment and the post-implementation scenario.

The first question (Q1) was posed to all respondents who use PT at least once a month. It defines the key parameters for the CS tasks,

Table 1
Review Table.

Reference	Crowdshipper	CS Task	Behavioral problem	DC method	Attributes type
Miller et al. (2017)	Occasional driver	Without lockers	Acceptance	Mixed logit	Deterministic
Devari et al. (2017)	Occasional driver[a]	Without lockers	Acceptance	Binary logit	Deterministic
Marcucci et al. (2017)	General[b]	Without lockers	Participation	No DC model	Deterministic
Punel et al. (2018)	Occasional driver	Without lockers	Participation	Binary logit	Deterministic
Serafini et al. (2018)	PT passenger	Locker to locker	Acceptance	MNL[c]	Deterministic
Le and Ukkusuri (2019)	Occasional driver	Without lockers	Participation	Binary logit	Deterministic
Gatta et al., (2019a)	PT passenger	Locker to locker	Acceptance	MNL	Deterministic
Wicaksono et al. (2021)	Cyclist	Without lockers	Acceptance	MNL	Deterministic
Fessler et al., (2022)	PT passenger	Locker to locker	Acceptance	Mixed logit	Deterministic
Mohri et al., (2024)	PT passenger	Locker-to-home	Acceptance	LC model	Deterministic
Current study	PT passenger	Locker-to-home	Participation	Binary logit	Stochastic

[a] Friends of package receivers in social platforms.
[b] Students traveling by any mode.
[c] Multinomial Logit (MNL).

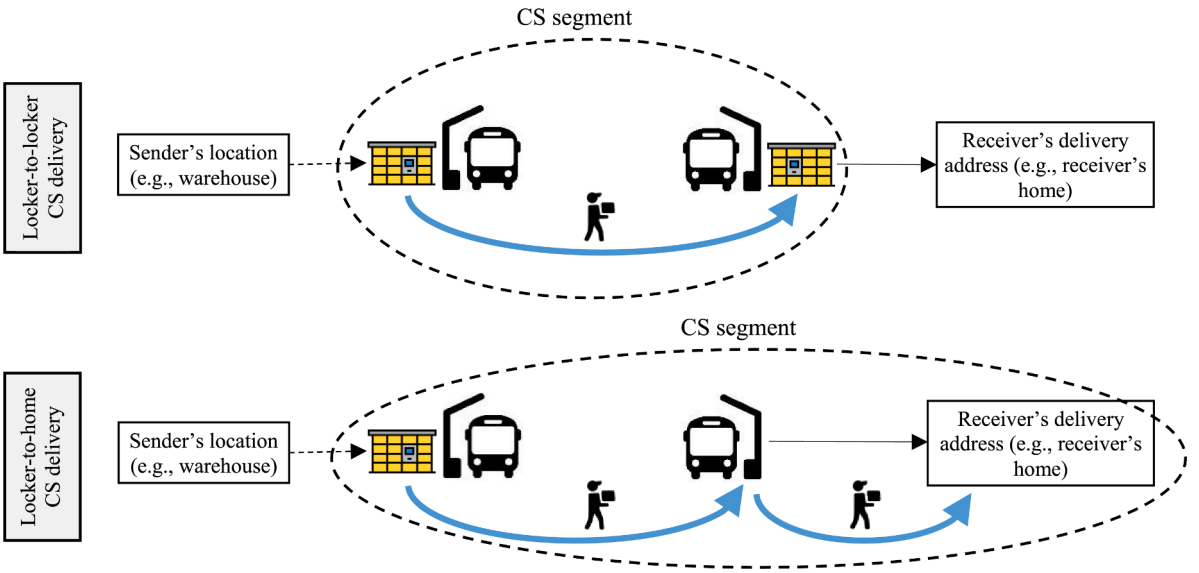


Fig. 2. Delivery segments outsourced to crowd-shippers.

Crowd-shipping by public transport passengers

Note: *Imagine, as part of a sustainable government-sponsored freight initiative program, you are offered a small parcel delivery task (i.e., 1 to 3kg) at your public transport station, near work or home location. You will be given a parcel, at your origin station locker, and you are asked to deliver it to an address close to your final destination within a short walking distance (i.e., 200 to 600 meters).*

Q1: Would you be interested to participate in the above program, and deliver parcels in return for a monetary incentive (e.g., 3-8 AUD per delivery)?

Yes ◯ ◯ No

(If the answer is No:)
Q2: Please explain why you are **not** interested to participate in the above program?
(You can select multiple reasons or write your own reason)

- ◯ I rarely use public transport services
- ◯ I do not need the incentive
- ◯ I cannot carry additional items/weight
- ◯ I do not have time
- ◯ Other reasons *Please explain*

Fig. 3. Questions for exploring the intention to participate.

including the range of incentive values, parcel weight, and delivery detour. These parameters were determined through a comprehensive review of prior research (Gatta et al., 2019a; Fessler et al., 2022), analysis of delivery costs in Australia (Fair Work Ombudsman, 2023; Sendle, 2022), and consultation with 12 industry experts specializing in statistics and last-mile logistics. Parcel weights in the CS initiative were suggested to fall between 1 kg and 3 kg, in consideration of the fact that over 90 % of global package deliveries are under 3 kg (Statistica, 2022). For delivery detours, a range of 200 m–600 m was proposed, based on a study of walking distances to PT stations in Sydney that shows walking distance to bus/train stations follows a triangular distribution with a mean of around 400/600 m (Daniels and Mulley, 2013). To make the CS initiative appealing to PT passengers, a minimum hourly pay rate higher than the national minimum wage of 23 AUD (Fair Work Ombudsman, 2023) was set. This ensures that even the least attractive CS task, involving a 3 kg parcel and a 600-meter detour, meets or exceeds the national hourly wage. Given an average walking speed of 5 km/h, the minimum incentive was determined to be above 3 AUD. To make it attractive for carriers, the maximum incentive was set at 8 AUD, aligning with the average delivery fees charged by carriers in Australia for small packages (8–12 AUD) (Sendle, 2022). This balance aims to meet carrier expectations while keeping CS tasks economically attractive.

Once the response for Q1 was "No", a follow-up question, Q2, was asked to determine the reason for rejecting the participation decision. This is an open-ended question in which respondents were allowed to either choose one (or more) reasons in a multiple-choice menu or write their own reasons.

The survey was distributed in March 2022 through the Qualtrics platform. The sample was aimed to be representative of Sydney's population in terms of age, gender, and level of income, and only included respondents older than 18. Through this survey, 2208 valid responses were collected. The demographic details of the collected sample and Sydney's population are summarized in Table 2, which shows that the collected sample is well representative of the population.

Data shows 1589 of 2208 respondents travel by PT services at least once a month, hence, 1589 responses were collected from Q1 where 952 responded "Yes", as shown in Fig. 4(a). It shows that 60 % of the total population in Sydney traveling at least monthly by PT services intend to participate in the PT-based CS initiative which can lead to an appropriate participation rate. On another side, 637 respondents (40 %) were unwilling to participate and provided their reasons by answering Q2. Fig. 4(b) shows the frequency of the selected reasons by the respondents. Since Q2 was a multiple-response open-ended question, there are more than 637 reasons (917 reasons) for rejecting the participation decision.

Fig. 4(b) shows that the most and least frequent reasons are "I do not have enough time" and "I do not need the incentive", respectively. Also, the second most frequent reason (i.e., rarely using PT services) has a similar frequency to the first reason. It is interesting that 147 respondents (17 %) provided other reasons, motivating the research to conduct qualitative analysis to extract prohibiting factors and categorize them.

In addition to Q2, respondents who agreed to participate are asked to declare on which trips they prefer to serve as a crowdshipper. The alternatives were (1) home to work, (2) work to home, (3) both, and (4) all trips. Fig. 5 demonstrates which trips PT passengers prefer to carry packages on. Results show only 34 % of passengers might accept carrying CS packages along all their trips. Accordingly,

Table 2
Observed factors.

Attribute	Frequency	Breakdown	Census 2016	Attribute	Frequency	Breakdown	Census 2016
Demographic factors				**Socio-economic factors**			
Gender				***Sustainability role***			
Male	1061	48.05 %	51.1 %	Yes	1688	76.45 %	–
Female	1147	51.95 %	49.90 %	No	520	23.55 %	–
Age				***Annual income***			
18–30	476	41.56 %	42.61 %	Less than $30,000	484	27.92 %	29.50 %
31–40	464	30.01 %	31.09 %	$30,000 to $60,000	526	21.82 %	22.10 %
41–50	460	8.83 %	10.00 %	$60,000 to $90,000	511	23.14 %	22.60 %
51–60	369	8.71 %	7.28 %	$90,000 to $120,000	373	13.89 %	23.50 %
61–70	253	6.46 %	5.22 %	More than $120,000	314	12.22 %	
71 and older	186	4.42 %	3.80 %	**E-shopping activity-related factors**			
Employment status				***Delivery volume***			
Full time employee	1157	52.40 %	51.20 %	Under 5 items/year	244	11.05 %	–
Part time employee	396	17.93 %	38.6 %	5–10 items/year	456	20.65 %	–
Retired	348	15.76 %		11–20 items/year	534	24.18 %	–
Disabled	39	1.77 %		More than 20 items/year	974	44.11 %	–
Student full time	89	4.03 %	–	***Parcel locker experience***			
Unemployed	179	8.11 %	5.90 %	Yes	514	23.28 %	–
Dwelling type				No	1694	76.72 %	–
				Parcel locker preference			
Stand-alone house	1341	60.73 %	66.40 %	Yes	1433	64.90 %	–
Apartment	727	32.93 %	32.10 %	No	775	35.10 %	–
Other	140	6.34 %	3.50 %	**PT mobility-related factors**			
Household size							
1	341	15.44 %	16.00 %	PT trip frequency per month	2 trips (min)		–
2	701	31.75 %	36.60 %	(Continuous variable)	34 trips (max)		
3 or 4	934	42.30 %	47.40 %		12 trips (average)		
5 or more	232	10.51 %					

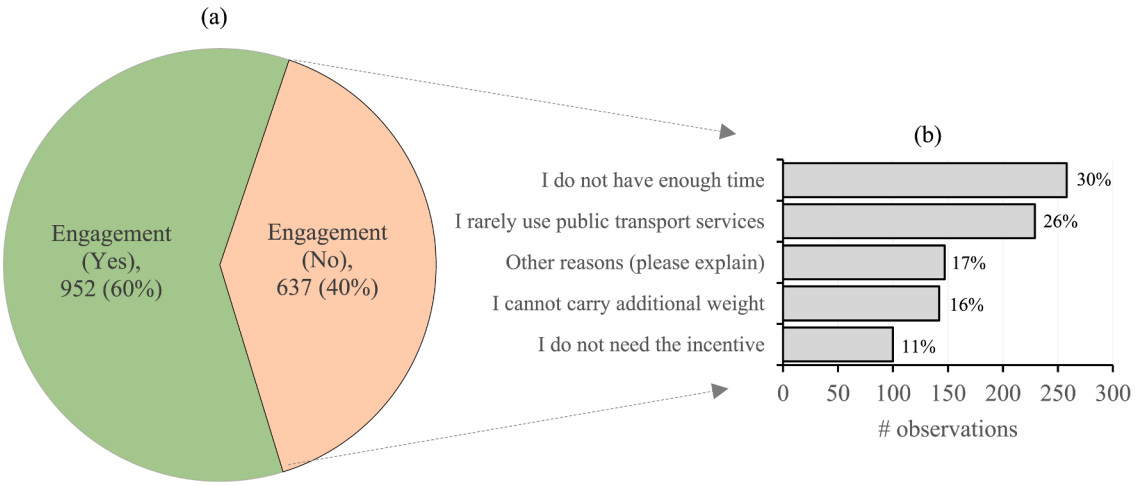


Fig. 4. Questions for exploring reasons for rejecting the participation decision.

29 % and 10 % of passengers would act as crowdshipper while travelling only from work to home and home to work, respectively. It can indicate a higher potential of outsourcing packages to passengers during afternoon and evening periods when passengers are returning from their workplaces to homes.

4. Method

In order to model the intention of PT passengers to participate in the PT-based CS initiative, this research relies on discrete choice models based on random utility maximization (Train, 2009). The participation question, Q1, has a "yes"/or "no" response; hence, there are two alternatives. The binominal logit model was selected to represent the probabilities of the alternatives. Accordingly, $U_{n,i}$ is the utility of choosing alternative i for individual n which has two parts: the representative (or systematic) utility ($V_{n,i}$) and the random utility ($\varepsilon_{n,i}$). The $V_{n,i}$ includes the observed factors ($\beta_{k,n}$, k is the index of factors) affecting the systematic utility, while $\varepsilon_{n,i}$ represents the random part of the utility, including factors that cannot be captured in the model, or measurement errors. In binominal logit one utility function can represent the choice model ($U_{n,i=yes} - U_{n,i=no}$), as shown by Equation (3). Assuming that the error term follows an independent and identically distributed (iid) extreme value distribution for all i, the probability of accepting the initiative can be calculated by Equation (4). Moreover, the probability of rejecting the initiative is $1 - P_n(i = yes)$.

$$U_{n,i} = V_{n,i} + \varepsilon_{n,i} \tag{1}$$

$$V_{n,i} = \alpha + \sum_{k \in K} \beta_{k,n} x_{k,n,i} \tag{2}$$

$$U_{n,i=yes} - U_{n,i=no} = \alpha' + \sum_{k \in K} \beta'_{k,n} x_{k,n} + \varepsilon'_{n,i} \tag{3}$$

$$P_n(i = yes) = \frac{1}{1 + e^{-(U_{n,i=yes} - U_{n,i=no})}} \tag{4}$$

$$P_n(i = no) = 1 - P_n(i = yes) \tag{5}$$

To build the binominal logit model on the 1589 collected responses for Q1, the software Stata version 15 was used (StataCorp, 2017). Several factors observed in the survey were grouped as follows: ***Demographics*** (age, gender, dwelling type, employment status, and household size), ***socio-economic*** (income and sustainability role[2]), ***e-shopping activity-related*** (delivery volume, parcel locker experience[3] and acceptance[4]), and ***PT mobility-related factors*** (PT trip frequency per month). In Table 2, different levels of the factors, as well as their frequencies in the sample, are presented.

[2] Sustainability role: It is a binary variable indicating whether the respondent is willing to play a role in achieving sustainability in urban freight systems (e.g., accept higher delivery cost, accept longer delivery time, and accept parcel locker or office post delivery if they contribute to reducing air pollution, congestion, and road accidents. Additional information on how the variable was constructed can be found in Appendix A.

[3] Parcel locker experience: It is a binary variable indicating whether the respondent had any parcel locker experience.

[4] Parcel locker acceptance: It is a binary variable indicating whether the respondent accepts using parcel lockers.

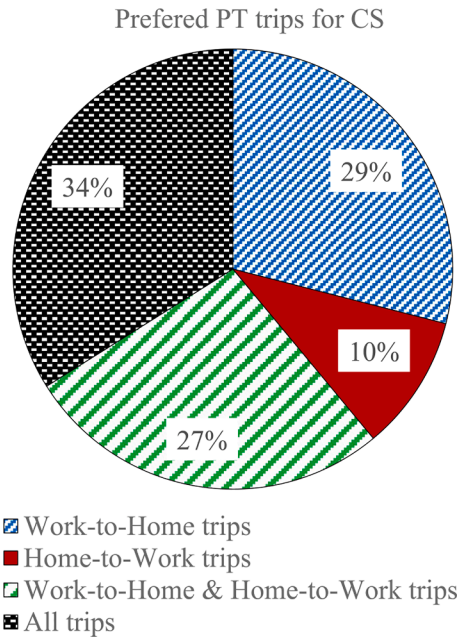


Fig. 5. Preferred PT trips for participation in CS delivery.

4.1. Inductive thematic analysis

Survey-based quantitative research has emerged recently to investigate the participation and acceptance behavior of crowdshippers in CS initiatives (Marcucci et al., 2017; Serafini et al., 2018; Gatta et al., 2019a; Gatta et al., 2019b; Fessler et al., 2022; Devari et al., 2017; Miller et al., 2017; Le and Ukkusuri, 2019; Punel et al., 2018). However, there is no qualitative research of crowdshippers behavior in the literature while conducting qualitative research in city logistics literature is essential (e.g., Kester et al., 2018; Vakulenko et al., 2018). Accordingly, a lack of in-depth understanding of the intention of potential crowdshippers to participate in CS initiatives motivates research in qualitative analyses.

The inductive qualitative data analyses (i.e., inductive thematic analyses) (Rahman et al., 2021) generate theories from the survey data by processing the text responses, coding text responses with inherent meanings, and categorizing the codes into meaningful units of information called categories or themes (Thomas, 2003; Nowell et al., 2017). The resulting themes built on the raw data can show the perspectives of different research participants and generate unanticipated insights (Braun and Clarke, 2006). This process begins with the extraction of text responses from the survey dataset. In our approach, we employed NVIVO 12 software, a widely used tool in qualitative research, to assist in this initial step. NVIVO 12 aids in extracting and organizing text responses efficiently. Once the text responses are extracted, the software facilitates the creation of preliminary categories or themes based on inherent meanings found within the text. However, it's important to note that this initial categorization is not the final step. To ensure the accuracy, coherence, and semantic relevance of the generated categories, the modeler carefully reviews and revises the segmentation and categorization produced by the software. This crucial phase involves a close examination of the extracted content to verify that it aligns with the research objectives and captures the nuances and subtleties in the responses.

5. Results

This section is organized into three subsections as follows. In Section 5.1, the results of the intention of PT passengers to participate in the proposed CS initiative are shown. In Section 5.2, the results of conducting the inductive thematic analysis on reasons for rejecting the participation decision are presented and the main prohibiting factors are recognized. The sensitivity of different socio-demographic groups to the prohibiting factors are identified and described in Section 5.3.

5.1. Modelling the intention to participate

Using the observed factors, illustrated in Table 2, several explanatory variables are defined by which the binominal logit model is developed. To find the best representative model, various combinations of variables are used iteratively. The decision to include variables in the final model is made based on the sign and z-statistic of the variables as well as their impacts on the model's goodness-of-fit. Overall, the best model is shown in Table 3, where except for one variable ("Large household size"), all the variables are significant at the 95 % confidence level. Moreover, the Pseudo R^2 value is 0.234 which is indicative of a relatively good model fit.

The binomial logit model developed suggests the intention to participate in PT-based CS initiatives is affected by several factors. In

Table 3
The binominal logit model representing the intention to participate.

Variable name (units)	Units	Parameters estimated	Z (P > |Z|)	95 % confidence interval
Female (yes: 1, no: 0)	1,0	−0.418**	−4.28 (0.000)	−0.610 to −0.227
Young adults (yes: 1, no: 0)	1,0	0.268**	2.60 (0.027)	0.066 to 0.470
Senior adults (yes: 1, no: 0)	1,0	−0.403**	−2.27 (0.030)	−0.751 to −0.055
High-income (yes: 1, no: 0)	1,0	−0.347**	−2.62 (0.014)	−0.607 to −0.870
Full-time employee (yes: 1, no: 0)	1,0	−0.230**	−1.89 (0.037)	−0.469 to 0.008
Retired (yes: 1, no: 0)	1,0	−0.527**	−2.71 (0.030)	−0.907 to −0.146
Large household size (yes: 1, no: 0)	1,0	0.165	1.67 (0.137)	−0.290 to 0.360
PT trip frequency per month	Continuous	−0.012**	−3.20 (0.000)	−0.201 to −0.004
Sustainable role (yes: 1, no: 0)	1,0	0.537**	3.95 (0.000)	0.270 to 0.804
Locker preference (yes: 1, no: 0)	1,0	0.793**	6.80 (0.000)	0.565 to 1.021
Locker experience (yes: 1, no: 0)	1,0	0.514**	4.41 (0.000)	0.286 to 0.742
Medium-volume delivery (yes: 1, no: 0)	1,0	−0.990**	−5.71 (0.000)	−1.328 to −0.650
High-volume delivery (yes: 1, no: 0)	1,0	−1.007**	−5.55 (0.002)	−1.363 to −0.652
Constant		0.486*0	2.03 (0.082)	0.016 to 0.956
Model fit statistics				
Number of observations	1589			
Log-likelihood at zero betas	−1623.37			
Log-likelihood at convergence	−1283.91			
Pseudo R^2	0.234			
Variable definition:				
Female: Women				
Young adults: Individuals aged less than 40				
Middle-aged adults: Individuals aged between 40 and 60				
Senior adults: Individuals aged more than 60				
Low income: Individuals with an income less than 30 k AUD per year				
Medium income: Individuals with an income between 30 k AUD to 90 k AUD per year				
High income: Individuals with an income more than 90 k AUD per year				
Full-time employee: Individuals working full time				
Part-time employee: Individuals working part time				
Unemployed: Unemployed individuals				
Retired: Individuals who are retired				
Disable: Individuals with disability				
Small household size: Individuals living in households with maximum 2 members				
Medium household size: Individuals living in households with 3 or 4 members				
Large household size: Individuals living in households more than 4 members				
PT trip frequency per month: An average number of PT trips per month				
Sustainable role: Individuals supporting sustainable urban freight initiatives				
Locker preference: Individuals not having an opposition to contact with parcel locker facilities				
Locker experience: Individuals having has working experience with parcel lockers				
Low-volume delivery: Individuals having less than 5 deliveries per year				
Medium-volume delivery: Individuals having between 5 and 20 deliveries per year				
High-volume delivery: Individuals having more than 20 deliveries per year				
Apartment dwellers: Individuals living in an apartment				
House residents: Individuals living in a house				

particular, women, senior adults, low-income individuals, full-time employees, retired, and individuals with high PT trip frequency, and medium or high number of deliveries per month are less likely to participate in this initiative. Conversely, individuals who are young, living in large households, caring for sustainability in urban delivery systems, and have had experience with parcel lockers (or preference) would be more likely to participate in this type of CS initiative.

The observation that women are more reluctant to participate in comparison to males can be attributed to their attitude towards risk, considering that women are statistically more likely to be risk averse (Jianakoplos and Bernasek, 1998), and carrying unknown packages and delivering to unknown receivers may be perceived as relatively risky task. Also, young adults as compared to seniors or retired individuals might be in better physical health and ability required for delivering packages, which may explain the signs of coefficients for young and senior adults. Full-time employees might not have enough time, or high-income individuals might not need the compensation. It is also interesting that the participation of individuals with frequent deliveries per month is less likely. This can be attributed to the fact that those on the receiving end of crowd-shipped packages may not feel comfortable receiving their packages from random individuals. While this observation may indicate the necessity for a separate line of research to uncover receiver behavior, this is out of the scope of this paper.

Moreover, frequent PT passengers may be less likely to participate in CS, as the negative sign indicates the coefficient associated with PT trip frequency per month. This might indicate that regular PT passengers (most of which may have full-time jobs) may not like to (e.g., daily) be burdened with CS tasks. Utilizing parcel locker services may pose a challenge for individuals who lack prior experience or are hesitant to give it a try; hence, it is observed that having experience or a positive attitude to contact the facilities can be associated with higher intention to participate. Since the initiative can contribute to achieving sustainability in urban freight systems, individuals feeling a sense of responsibility in this regard would participate more than others.

Although the parameter estimates are statistically significant and meaningful, calculating their elasticities can demonstrate the magnitude of their influence on the dependent variable. Hence, Table 4 shows the elasticities of the explanatory variables in the model. Results show that elasticity estimates for medium- and high-volume delivery, which are two discrete variables, are substantially large and negative. The finding implies that as the delivery volume for an individual transitions from low to medium and subsequently from medium to high, there is a significant decline in the individual's willingness to participate in the CS initiative. Additional discrete variables, including being retired, female and senior adult, similarly exhibit notably substantial negative effects on the utility associated with the intention to participate. Consequently, being retired, female, or a senior adult is indicative of a greater reduction in participation in the CS initiative. Conversely, possessing prior experience with parcel lockers, coupled with a strong inclination to contribute to sustainability efforts, yields the most significant positive effects on utility. Thus, having hands-on experience with parcel lockers or holding a favorable attitude towards sustainability and a willingness to actively contribute to its realization enhances individuals' intentions to participate in the CS system. At the next level, being young or living in a large household can also improve the chances of participation.

While the binomial logit model serves as an intention-to-participate model and lacks alternative-specific attributes, it is still feasible to provide a rough estimate of the willingness to work (WTW) among PT passengers by considering the expected values of weight and detour attributes related to CS tasks. According to our findings in Q1 (Fig. 3), PT passengers tend to expect an incentive of approximately 5.5 AUD for a parcel delivery with a weight of 2 kg, and an additional detour of about 400 m. Given the observed 60 % participation rate (Fig. 4), we can estimate the WTW with respect to weight and detour attributes to be roughly 1.65 AUD per kilogram and 0.825 AUD per 100 m, respectively. These estimates closely align with the WTW values reported in Mohri et al. (2024), who utilized a multinomial logit model to address the CS task acceptance problem using the same dataset. In their study, Mohri et al. (2024) reported WTW values associated with weight and detour as 1.15 AUD per kilogram and 1.09 AUD per 100 m, respectively.

In the following sections, respondents' reasons for rejecting the participation decision are investigated, to discover the underlying prohibiting factors for not participating in the initiative.

5.2. Results of the inductive thematic analysis

The main prohibiting factors for participation in the CS initiative are discussed in this section. A total of 917 text segments were extracted from the 637 reasons for rejection declared by respondents. As illustrated in Fig. 4(b), 17 % of the provided reasons fall into the "other reasons" category, where respondents have articulated specific reasons. Conversely, the remaining text segments are aligned with the top four choices indicated in Q2 (Fig. 3), corresponding to the selections made by respondents. Given that Q2 allowed for multiple answers, respondents had the flexibility to choose multiple reasons and also provide additional, context-specific explanations. Through the analysis of reasons for rejecting participation, it has been noticed that some PT passengers specifically cited some aspects of convenience as a factor influencing their rejection of participation. The term "convenience" pertains to the quality of being user-friendly, efficient, and aligned with one's preferences and needs and it encompasses various aspects, including accessibility, simplicity, comfort, safety, security, time-saving, and reliability. Among these convenience-related aspects, those with higher frequencies of observation were classified into distinct prohibiting categories. These categories include "time," "social/labor aspects," "safety and security," "responsibility," and "physical/mental ability".

However, some responses didn't specify the particular aspects of inconvenience and simply mentioned "convenience" in a general sense as the reason for declining participation. Additionally, few responses highlighted other inconvenience factors, like congestion within the PT system. Therefore, reasons related to inconvenience that had a low probability or were mentioned in a general manner are grouped under "additional convenience aspects." Ultimately, the inductive thematic analysis resulted in categorizing reasons for declining participation into nine primary categories: (1) Time, (2) physical/mental ability, (3) compensation, (4) responsibility, (5) safety and security, (6) social/labor aspects, (7) additional convenience aspects, (8) infrequent PT passengers, and (9) lack of interest. Fig. 6 shows the share of each of the categories from total text segments.

Table 4
Direct elasticities of choice.

Variable name (units)	Variable type	Elasticity/Semi-elasticity*	Z (P > |Z|)
Female (yes: 1, no: 0)	Discrete	−0.198	−4.28 (0.000)
Young adults (yes: 1, no: 0)	Discrete	0.126	2.63 (0.009)
Senior adults Old (yes: 1, no: 0)	Discrete	−0.204	−2.14 (0.032)
High-income (yes: 1, no: 0)	Discrete	−0.165	−2.61 (0.009)
Employed full-time (yes: 1, no: 0)	Discrete	−0.110	−1.89 (0.059)
Retired (yes: 1, no: 0)	Discrete	−0.251	−2.70 (0.007)
Large household size (yes: 1, no: 0)	Discrete	0.079	1.66 (0.096)
PT trip frequency	Continuous	−0.104	−3.19 (0.001)
Sustainable role (yes: 1, no: 0)	Discrete	0.265	3.92 (0.000)
Locker preference (yes: 1, no: 0)	Discrete	0.378	6.67 (0.000)
Locker experience (yes: 1, no: 0)	Discrete	0.245	4.41 (0.000)
Medium-volume delivery (yes: 1, no: 0)	Discrete	−0.471	−5.63 (0.000)
High-volume delivery (yes: 1, no: 0)	Discrete	−0.480	−5.48 (0.000)

*For continuous variables elasticity and for dummy and integer variables semi-elasticity should be computed (Greene and Hensher, 2010).

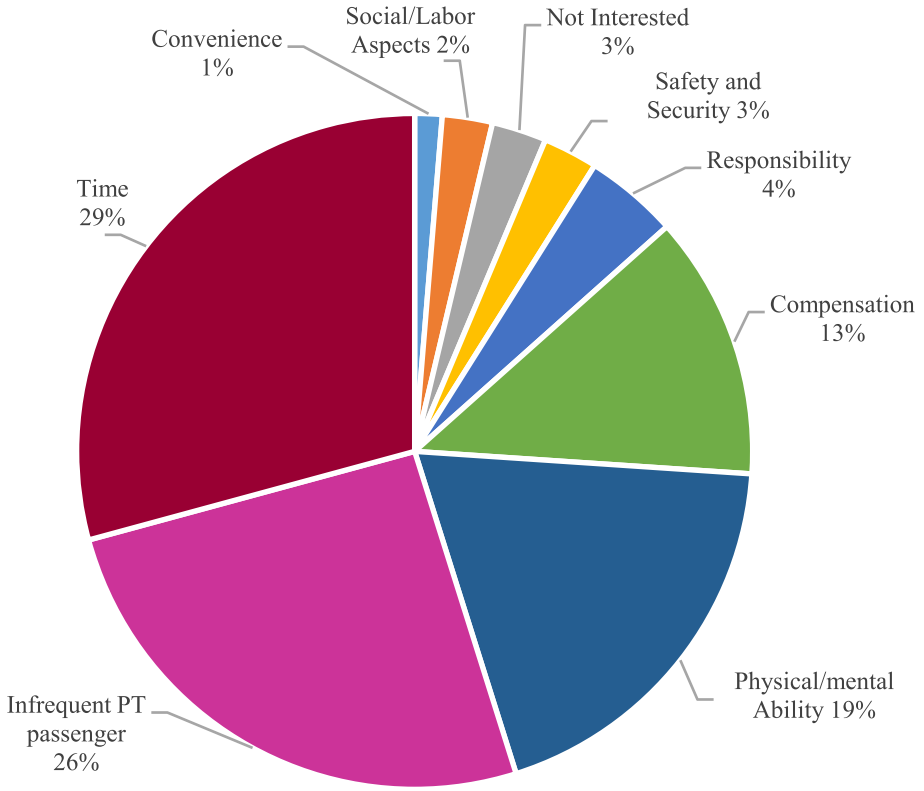


Fig. 6. Prohibiting factors and their shares.

5.2.1. Time

As shown in Fig. 6, time-related factors are the most frequent reasons hindering passengers' intention to participate in the initiative with a 29 % contribution. The respondents brought up multiple time-related prohibiting factors relating to lack of time, uncertainty in time schedule, and concerns over spending too much time dealing with the package's receiver. Some examples are presented: Lack of time: "*It's a great idea in theory, I'm just too time poor to do something like this - maybe if it was for a neighbour but wouldn't have time to go out of my way*", "*At the moment my work and personal life are full! I am not 100 % sure I could commit to this properly at the moment. Sorry!*", or "*If I am on public transport it is usually to get somewhere at a set time, and I am likely to be in a rush*". Uncertainty in time schedule: "*My schedule can change*" or "*Can't commit on a regular basis*". Concerns over spending too much time dealing with package receiver: "*Concern that I may have to deal with recipients. And I didn't have time*".

5.2.2. Infrequent PT passenger

Infrequent travel by PT services may be less motivated to participate in the initiative. Although, the respondents were those travelling at least monthly, the frequency of their trips within a month can affect their participation decision. As shown in Fig. 7, 91 % of those refused to participate had less than 3PT trips per month while based on total survey data only 47 % of respondents making PT trips less than 3 times per month. Moreover, a further 5 % has 4 to 7PT trips per month.

It's reasonable to posit that PT passengers with low PT trip frequency may not perceive CS initiatives as financially rewarding, leading them to decline participation. Interestingly, the binary logit model's results indicate a negative relation between PT trip frequency and participation in CS initiatives. This suggests that individuals with medium PT travel frequency (neither too high nor too low) constitute the most promising demographic for participation. This aligns with the corresponding pie chart in Fig. 7, which illustrates the frequency of PT trips among engaged respondents. This observation bears significance for companies seeking to establish PT-based CS systems. They should take into account that passengers taking fewer than three, or even seven, PT trips per month, as well as those with high trip frequencies (over 15 trips per month), are less likely to participate compared to PT passengers who usually travel two to three times per week.

5.2.3. Physical/mental ability

Nearly 19 % of the prohibiting factors were around physical and mental health problems of respondents, where physical problems are more frequent than mental health problems. Physical health problems are mainly related to mobility restrictions of respondents; however, some might avoid participating just because of high importance of maintaining their physical health. Some examples are as follows: Mobility restrictions: "*I have a walking disability*", "*I travel by public transport and use a walker so I can't carry much weight with*

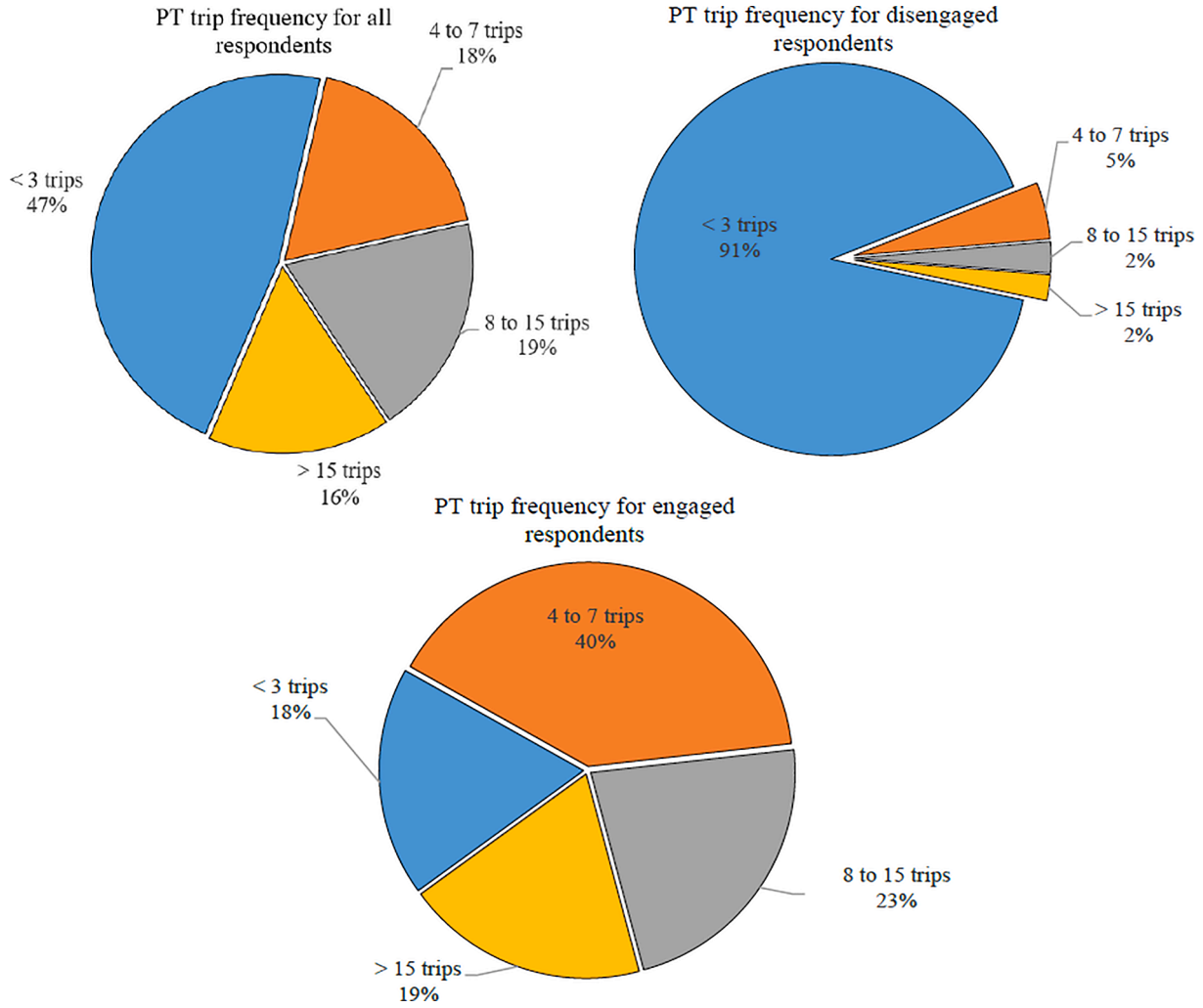


Fig. 7. PT trip frequency among respondents.

me", "*I have joint issues*", "*My disability prevents me* ", or "*probably difficult in a wheelchair*". Physical health importance: "*My health is very important. I cannot carry any package*", "*It is too heavy and may endanger my health*". Mental health problems: "*I might not be able to find the delivery address, I have terrible sense of direction*" or "*People are annoying*".

5.2.4. Compensation

With 13 %, compensation-related reasons are the fourth most important prohibiting factors. Some respondents highlighted that the suggested compensations for the tasks are not enough and less than their time value. Hence, their participation is conditional on the offered compensations over CS tasks. Here are some relevant responses to the prohibiting factor: "*Not enough money offered*", "*It isn't worth the time*", "*Because it's incentive is under minimum wage*", "*Not enough pay. That's slave wages*", "*the incentive is not worth it if I deliver by public transportation*", or "*The incentive does not justify the costs of transport*".

5.2.5. Responsibility

Responsibility is one of the major concerns of passengers when considering participation in this initiative, with 118 text segments indicating responsibility issues. Respondents believe the initiative might entail three types of responsibility. The first type is when the package receiver is not at home. Some respondents pointed out their concern about leaving the package at the door; "*I envisage the possibility that I would be responsible should the parcel go missing if the recipient isn't at home when I leave it*", "*I would be concerned delivering to someone's home if it went missing I would be responsible*", or "*What happens if someone steals the parcel after delivery or there is no one to accept delivery…Can you leave it on the doorstep or do you have to keep coming back to get the delivery signed off*".

The second type is when package receivers are not happy with the delivery services or don't receive the package, etc. Respondents show concern about cases when the product in the package is damaged before being pick-up. Here are some examples: "*What if the parcel is damaged prior to pick up and I am not aware, who is responsible*", "*I wouldn't want the responsibility of caring for the parcel. What if*

there is damage?", "*Would not want to be responsible if recipients of parcels had an issue with the delivery. There are too many ways consumers could dispute method of delivery*", "*What if you made the delivery and the other person denied receiving the delivery, too risky*", "*Liability for false claim of failed delivery*", "*All I can see are difficulties involving claims of the parcel not being delivered*", or "*I am concerned about the responsibility of carrying the parcel and being blamed or accused of losing it/not delivering it*".

The third type is when the crowdshipper may be responsible for receiver identification, information and privacy. Some respondents mentioned, "*I do not want to be responsible for someone else's package. That is a privacy issue, and I might be liable*" or "*Responsibility of recipient identification*".

5.2.6. Safety and security

Nearly 3 % of the text segments refer to some potential safety and security risk for crowdshippers. They have elaborated on details of the risk from four different perspectives: (1) receiver anonymity: they believe it is risky to interact with unknown individuals; (2) product anonymity: it might be an unsafe or illegal product that they are carrying; (3) dogs: the risk of dog attacks when they enter a property or the back garden. Some examples for the perspectives are as follows: Receiver anonymity: *"I don't know what type of person I am delivering to. Safety comes first"* or *"I'm female and delivering to a private address may be unsafe";* Product anonymity*: "I'm not comfortable delivering parcels that contain unknown items";* Dogs: "*scared of dogs; looks suspicious if I enter properties"* or *"I wouldn't feel safe dropping off items in case there were dogs"*.

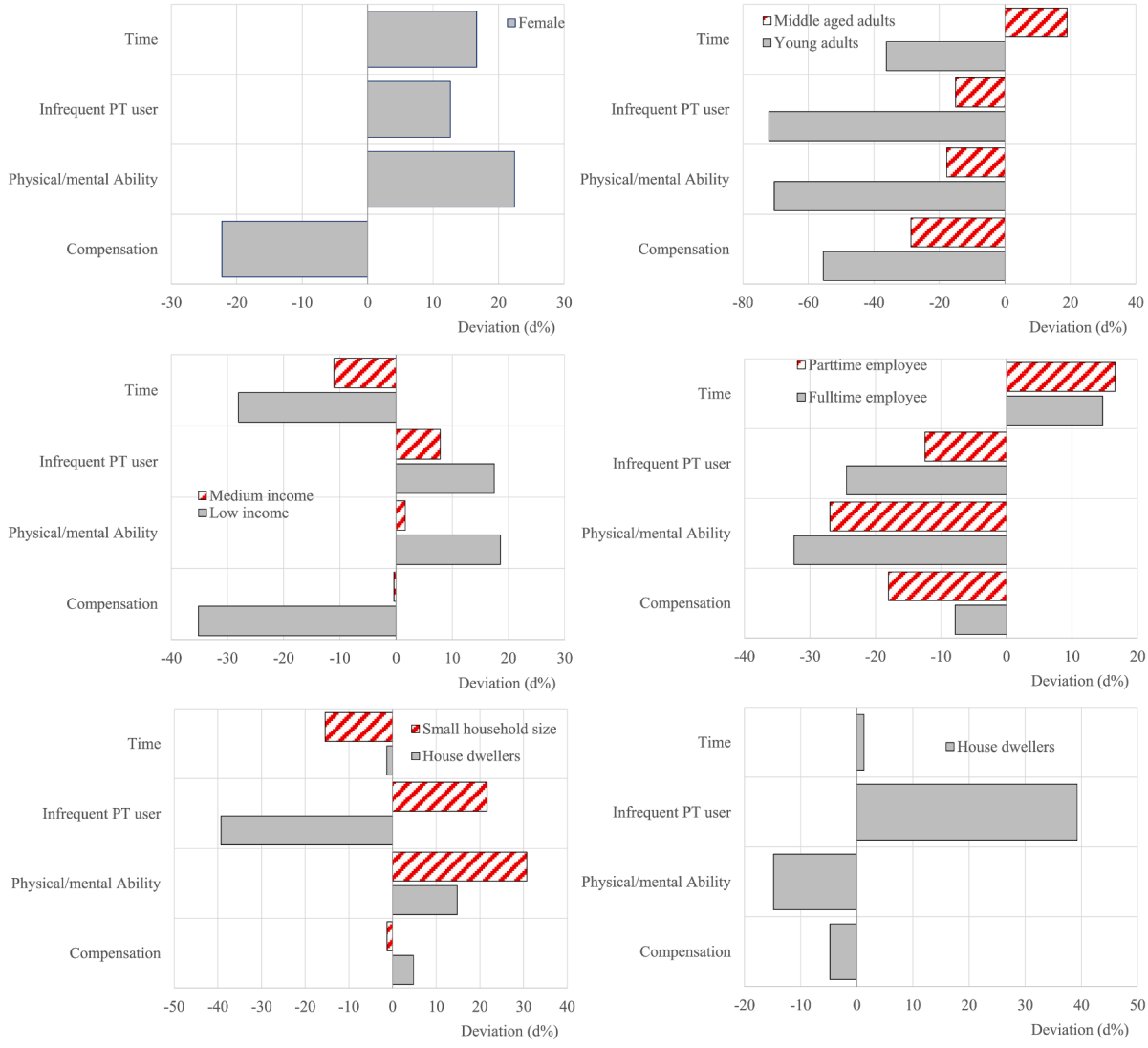


Fig. 8. Degree of sensitivity to prohibiting factors from survey respondents with different attributes.

5.2.7. Social/labor aspects

It is very interesting that some respondents refuse to participate because of social/labor aspects of the business. Some believe CS initiatives threaten jobs since some drivers in freight delivery sector might lose their jobs with the emergence and expansion of CS systems. Here are some examples: "*It's not my job. This takes jobs away from people who are delivery workers. A lot of which actually enjoy their jobs. I'm sick of this obsession of taking away unskilled jobs. Some people and families depend on these jobs*", "*Sounds too much like Amazon Flex (dodgy casualisation in lieu of supporting workers)*", or "*It will put delivery drivers out of a job*".

Although respondents were only asked to declare why they reject participating in the CS initiative as a crowdshipper, some responded that they would not like to be package receivers in a CS system, if/once this system becomes popular. This observation emphasizes the importance of exploring the intention of package receivers to participate in CS initiatives as well, which is left unaddressed in the literature (Marcucci et al., 2017; Devari et al., 2017). Some of the relevant text segments to this concern are as follows: "*I wouldn't want to do it because I would not want to have some random member of the public delivering a parcel to me*" or "*I wouldn't want to participate because if that was my parcel, I wouldn't want the risk of the parcel being stolen by another civilian. I trust myself to deliver someone else's parcels, but I guess the program would go both ways and I value the security I have through the standard postal delivery services*".

5.2.8. Additional convenience aspects

Some respondents believe inconveniences arise from participating in the initiative. The represented inconvenience can occur either at the pick-up point to the PT destination stop or from the PT destination stop to the package receiver's destination. Regarding the former, respondents highlighted that they want to relax during their PT trips or sometimes PT is so crowded; hence, carrying a package makes it difficult to ride. When walking from a PT destination stop to the package receiver's destination, the detour as well as approaching buildings with centralized security systems can cause additional inconvenience for crowdshippers. Some relevant examples are: "*Usually use public transport if I'm going out on occasion. "I don't want to be delivering a package when I'm relaxing*", "*I would not want to carry anything extra on public transport*", "*Too crowded on public transport*", "*I couldn't be bothered to go out of my way*", or "*Difficulty in delivering to secure apartments or office buildings*".

5.2.9. Not interesting

Only 1 % of those rejecting participation in the CS initiative highlighted that the idea is not interesting or naive (e.g., "*Not interested in this proposal*" or "*I think it is a silly idea*"). Some respondents compared this initiative with other city logistics initiatives such as parcel locker delivery (e.g., "*I believe we have enough options for parcel delivery collections. Quite happy with the local PO lockers*").

5.3. Prohibiting factors at a micro level

In this section, the contribution of different prohibiting factors is investigated for different sociodemographic groups. Respondents are grouped based on demographic and socio-economic factors (gender, age, income and household size). Sociodemographic factors have different attribute levels as shown in Table 3 (comment box). For example, gender has two attributes (male and female) and income has three attributes (low, medium, and high). To identify the contribution of prohibiting factors (a) for every attribute (s), the probability of observing the attribute in total responses ($P(s)$) is compared with the probability of observing the attribute in the total responses given rejecting the participation choice by prohibiting factor a ($P(s|a)$). Accordingly, $P(s|a) - P(s)$ shows the deviation between the probabilities. In cases where the deviation is a large positive/negative percentage, it is concluded that people with attribute s are high-sensitive/low-sensitive to prohibiting factor a. Fig. 8 shows the deviations for different attributes and the prohibiting factors with the highest observed frequency as depicted in 4. Recognizing the importance of robustness in our analysis, we have taken into account the limitations posed by small sample sizes, particularly in cases where prohibiting factors exhibited low observed percentages. Consequently, through the application of the sample size formula, we have retained only those categories of prohibiting factors for which the observed frequency exceeded the ideal sample size, as determined by the formula, at a 90 % confidence level and with a 5 % margin of error. These selected categories will undergo further analysis. This decision ensures that our analysis maintains its robustness by focusing on factors with more substantial representation within the dataset, thereby enhancing the reliability and validity of our findings.

As shown in Fig. 8, the investigated attributes belong to six sociodemographic factors (gender, age, income, employment status, household size, and dwelling type). The most and least significant prohibiting factors for people with specific demographic and socio-economic profiles are identified and discussed below.

- ***Female:*** The primary considerations for female respondents when declining participation in the proposed PT-based CS initiative revolve around their physical health and time availability. Curiously, compensation appears to be of lesser concern to them. Consequently, it is advisable for CS managers to emphasize the non-demanding nature of CS tasks, assuring passengers that they are lightweight and manageable in size, which should alleviate concerns related to physical health. Furthermore, by ensuring that CS tasks can be accommodated at various times throughout the day, CS managers can help alleviate worries regarding time availability, especially for those with busy schedules. These two factors hold greater significance for female respondents than compensation and should be prioritized to enhance the platform's supply of female participants (crowdshippers).
- ***Young adults:*** Younger respondents are less sensitive to all the prohibiting factors particularly the impact of CS tasks on their physical health. Hence, it is not recommended that CS managers advertise their initiative differently for them.

- ***Middle-aged adults:*** Except for "time", middle-aged respondents are less sensitive to other prohibiting factors. Hence, CS managers should take into consideration the time-related factors of their CS initiatives if they plan to effectively absorb middle-aged adults as crowdshippers in their systems.
- ***Low-income vs. medium-income individuals:*** Medium-income individuals are neutral to the entire set of prohibiting factors. In contrast, low-income individuals are less sensitive to compensation and time. However, physical health aspects are fairly important for them. Therefore, addressing and promoting the alleviation of concerns about potential threats to physical health should be a key focus when reaching out to low-income individuals regarding the initiative.
- ***Full-time vs. part-time employee:*** Results show full-time employees are actually interested in the initiative; however, they are more sensitive to physical health aspects. However, part-time employees are less sensitive to many of the prohibiting factors except for time, which still has neutral sensitivity (less than +20 %).
- ***Small vs. medium household size:*** Individuals living in small and medium households have opposite sensitivity to the prohibiting factors. For instance, contrary to individuals within medium sized households, those living in small households are mainly not interested to participate and have serious health concerns.
- ***House dwellers:*** Individuals living in a house mainly rejected the participation decision because of the reason that they infrequently travel by PT services. Hence, if the CS platform decides to improve its supply using house dwellers, they should inform them that it is not a requirement for them to be a frequent PT passenger to participate unless they have some other reasons rejecting the participation choice decision.

5.4. Anticipated sustainability gains from the CS system

In this study, we address the issue of participation intention in the CS system by developing a model. To assess sustainability benefits, additional factors should be incorporated such as the CS task acceptance model for PT passengers and the strategic and operational design of PT-based CS systems. However, in this section, we offer a preliminary estimate of the potential maximum sustainability gains (savings in external costs) achievable through this PT-based CS system.

This PT-based CS system is designed for transporting light and small to medium-sized parcels. Therefore, van deliveries will still be necessary for heavy and large parcels. We denote ρ as the percentage of heavy and large parcels requiring van delivery. Within our model, $\widetilde{FA}$, $\widetilde{PA}$, and $\widetilde{AC}$ represent three probabilistic parameters with expected values of $\overline{FA}$, $\overline{PA}$, and $\overline{AC}$, reflecting the probabilities of PT passengers being familiar with the CS system, participating in it, and accepting CS tasks, respectively. Additionally, $\widetilde{e_1}$ and $\widetilde{e_2}$ are two other probabilistic parameters with expected values of $\overline{e_1}$ and $\overline{e_2}$, indicating the external costs associated with one parcel delivery in the van-only and CS delivery systems, respectively. Given the specific inputs for a case study and considering a total daily delivery volume of N, we calculate the daily external costs before and after implementing the CS delivery system (EC_{before} and EC_{after}) using Equations (6) and (7), respectively

$$EC_{before} = \sum_{1}^{N} \widetilde{e_1} \approx N\overline{e_1} \tag{6}$$

$$EC_{after} = \rho \sum_{1}^{N} \widetilde{e_1} + (1-\rho) \sum_{1}^{N} \widetilde{FA}\widetilde{PA}\widetilde{AC}\widetilde{e_2} + (1-\rho) \sum_{1}^{N} \left(1 - \widetilde{FA}\widetilde{PA}\widetilde{AC}\right)\widetilde{e_1} \approx$$

$$N\rho\overline{e_1} + N(1-\rho)\overline{FAPAAC}\,\overline{e_2} + N(1-\rho)(1-\overline{FAPAAC})\overline{e_1} \tag{7}$$

In Equation (6), $N\overline{e_1}$ represents the total expected external delivery costs incurred when exclusively using van delivery. The expected external costs within the CS delivery system, in conjunction with van delivery, can be broken down into three distinct cost components. The first component, $N\rho\overline{e_1}$, calculates the external costs associated with delivering large and heavy parcels, which must be exclusively handled by vans. The second component estimates the expected external costs for delivering small and light parcels via the CS system. Within this term, $\overline{FAPAAC}$ denotes the overall expected probability of successfully delivering a parcel through the CS system. This probability encompasses the PT passenger's familiarity with the CS system, their participation in it, and their acceptance of a CS delivery task. The final component estimates the external costs resulting from unsuccessful attempts to outsource small and light parcels to PT passengers, necessitating a return to the van delivery system. In this term, $(1 - \overline{FAPAAC})$ reflects the probability that CS delivery could not be executed successfully.

Mohri et al. (2024) have previously calculated the anticipated probability of accepting CS tasks for the same PT-based CS system and case study examined in this research. Their findings indicated an expected acceptance probability of approximately 86 % among passengers willing to participate in the CS initiative. Given the 60 % expected participation rate observed in our study, and assuming a 100 % familiarity rate with the CS initiative, the combined probability $\overline{FAPAAC}$ would amount to 0.516 (or 51.6 %). Furthermore, roughly 21 % of parcel deliveries in Australia consist of large and heavy parcels (Mohri et al., 2023b). Thus, $\rho \approx 0.21$. Parcel delivery by PT passengers through the CS system incurs no external costs, whereas transporting parcels to lockers in PT stations via vans does entail some external costs. Since the van delivery system primarily serves large and heavy parcels, and some of these parcels would typically destined around PT stations with lockers, it is reasonable to assume that, in the best-case scenario, there would be minimal detouring of delivery vans when loading small and light parcels into lockers at select PT stations. Consequently, $\overline{e_2}$ is significantly smaller than $\overline{e_1}$, approaching zero. With the defined parameter values used in Equation (7), EC_{after} can be calculated as $0.59N\overline{e_1}$. As a

result, it can be deduced that the utilization of the CS system can yield savings in external costs of up to 41 %.

6. Conclusion and managerial implications

This study explores the intention of PT passengers to participate in PT-based CS initiatives. Given a survey data from 2208 PT passengers in the Sydney metropolitan area and using two quantitative and qualitative techniques, the intention to participate is studied. As the quantitative technique, a binominal logit model is developed whereby the characteristics of passengers showing a willingness to participate are identified. Next, an inductive thematic analysis is employed to recognize the main factors prohibiting passengers to participate.

The results of the binomial logit model show that being female, senior adult, low-income person, full-time employee, retired, and having high PT trip frequency, and medium or high number of deliveries per month are associated with a decreasing likelihood of CS participation. In contrast, being young, living in large households, caring to achieve sustainability in freight delivery systems, and having had prior experience with parcel lockers or preference to use them is associated with increasing the utility of intention to participate in the CS initiative. By computing the elasticities of variables in the model, it is observed that elasticity estimates for medium- and high-volume delivery are the largest, but negative. In contrast, the largest positive elasticity estimates belong to having had prior experience with parcel lockers or preference to use them in addition to caring to achieve improved sustainability in freight delivery systems.

The results of the inductive thematic analysis show there are nine major categories of factors prohibiting PT passengers to participate: (1) time, (2) physical/mental ability, (3) compensation, (4) responsibility, (5) safety and security, (6) social/labor aspects, (7) convenience. (8) infrequent PT passenger, and (9) not interested. Lack of time and a regular time schedule, infrequent use of PT services, having physical and mobility restrictions, and expecting higher compensation are the main reasons that participation in the CS initiative is rejected by respondents. Fear of responsibility, safety, taking jobs of traditional laborers in delivery markets, and potential concerns regarding becoming package receiver of CS systems in the future are the other interesting reasons of rejecting the participation choice decision by respondents.

Within the categories of the prohibiting factors, characteristics of respondents were explored to show the degree of sensitivity individuals with different demographic and socio-economic profiles are to the prohibiting factors. Several observations are provided in Section 5.3. For instance, it is observed that physical health concerns can prevent women, low-income persons, and those living in small households to participate in the CS initiative.

Providing a large and balanced supply (i.e., crowdshippers) with demand (i.e., delivery tasks) in CS systems is of utmost importance, particularly in the initial phases of launching CS initiatives. If an oversupply or overdemand situation exists, a deadweight loss will occur which leads to market inefficiency. This study can help CS managers keep the demand and supply balanced. For example, once a surge demand situation is present, CS managers can focus on attracting PT passengers who participate with a higher probability by taking an optimal advertising strategy. For instance, young male passengers with high PT trip frequency and having experience in contacting parcel lockers can be prioritized for labor absorption. Once, CS managers decide to expand their market share and the rate of labor observation is declining, they can shift from generalized to personalized marketing strategies. This study has some recommendations for taking personalized marketing strategies as well. For example, women might have a higher intention to participate if their own safety and the jobs of existing employees in delivery markets are not threatened. Moreover, a larger labor absorption rate from full-time employees would be achieved if they could find it convenient.

We recommend future studies extend this research by exploring the intention of other potential crowds to participate in CS initiatives in different scopes such as occasional drivers, cyclists, and passengers of ride-sourcing or ride-sharing systems. Specifically for launching PT-based CS initiatives, PT passengers' intention to participate can be modeled by advanced discrete choice models such as mixed or latent-class discrete choice methods. Moreover, exploring prohibiting factors for participation in the initiative can be collected through interview-based surveys rather than online surveys with open-ended questions. Therefore, the possibility of building richer models based on grounded theory would be attainable. Furthermore, due to the fixed nature of the case study, we were unable to assess the influence of PT network characteristics, such as its level of accessibility, on the participation rate. Future studies could investigate these impacts by gathering data from diverse cases worldwide and examining whether PT system characteristics can indeed affect participation rates. Introducing compensation enhancements to PT-based CS systems can potentially boost participation in the PT system. Consequently, exploring the substitution effect on trips from other modes to public transportation, in response to modifications in the compensation scheme, presents an intriguing avenue for future research. Another future research stream would be more in-depth investigations into the factors that influence the participation rate in CS initiatives. While our current study has shed light on the restricting factors, we acknowledge the necessity of understanding the effective motivations and possible incetives that can drive individuals to actively participate. This study showed compensation alone may not be a significant deterrent, and a more nuanced exploration is required. To address this, we propose adopting robust data collection techniques, such as in-depth interviews, to gather qualitative insights into the economic aspects and other factors motivating individuals' decisions to engage in crowd shipping activities. This qualitative approach will provide a richer understanding of the complexities involved and contribute to the development of more reliable and effective CS initiatives. By extending our focus beyond the restricting factors and delving into the motivations for participation, future research can provide CS managers with a comprehensive toolkit for designing and implementing crowd-driven services. This holistic approach will not only enhance the reliability of CS initiatives but also contribute to the broader understanding of crowd participation dynamics in the evolving landscape of CS management.

CRediT authorship contribution statement

Seyed Sina Mohri: Conceptualization, Data curation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Neema Nassir:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing, Resources. **Russell G. Thompson:** Resources, Supervision, Writing – review & editing. **Patricia Sauri Lavieri:** Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

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

Data availability

We cannot share the raw data; however, there would be some possibilities to share some parts of the data on the request.

Appendix A

With respect to the variable referred to as the "sustainable role," a dedicated survey question was included to assess respondents' willingness to embrace sustainable delivery initiatives involving higher delivery fees, extended delivery times, or the use of alternative delivery locations like parcel lockers. The precise wording of the question can be found in Fig. A1. Accordingly, the "sustainable role" variable is defined as a binary indicator. If any of the first six suggested sustainable delivery approaches is chosen, the variable is assigned a value of one. Conversely, if the last option (none of the above) is selected, the variable is assigned a value of zero.

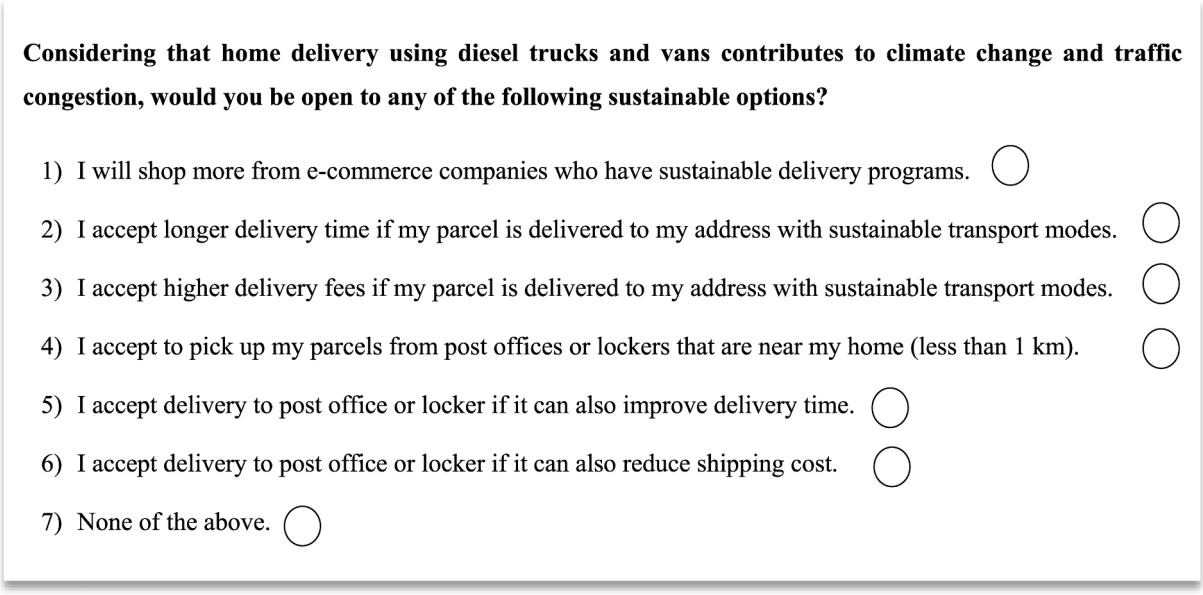


Fig. A1. The question for identifying individuals supporting sustainable urban freight initiatives.

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