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Crowdshipping for sustainable urban logistics: A systematic review of the literature

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A R T I C L E I N F O

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A B S T R A C T

Crowd-Shipping (CS) solutions have been gaining popularity in industry and academia. Despite numerous CS platforms having been introduced in the real world, only a limited number of them have managed to remain viable. Academics have explored many challenges facing CS platforms and recommended appropriate solution measures. While the growing literature sporadically indicates "*economic*", "*environmental*" or even "*societal*" benefits of CS initiatives, there is a lack of systematic and conclusive understanding of CS initiatives from these essential "*sustainability perspectives*". Considering that sustainability and societal impacts of such new and emerging initiatives are key factors in gaining public policy support and potential government investments and involvements, as critical success factors for the uptake, growth and continuity of these initiatives, this paper aims to present a review of this topic in light of sustainability considerations. A content-based framework grounded on the Triple Bottom Line (TBL) approach is adopted in this review and papers are reviewed, classified, synthesised, and analysed to reveal dominant research trends, challenges, potential and gaps. Furthermore, our analysis of the economic and behavioural considerations of CS actors reveals important insights into how various pricing strategies can be adopted to regulate supply and demand for operational continuity. Finally, using an intersectional sustainability approach, future research directions are also recommended to fill the gaps and improve the practical relevance of CS.

1. Introduction

As the result of increasing last-mile delivery (LMD) activity and changing customers' expectations for quick, free and flexible delivery services, cities are experiencing worsening levels of traffic congestion, air pollution, road accidents, and exacerbating challenges associated with couriers' operations in urban transport systems (Simoni et al., 2020; Pratap et al., 2023). Given infrastructure bottlenecks, several innovative initiatives have been proposed in recent years to foster further collaboration among stakeholders and improve the utilisation of existing resources to address the growing challenges of urban freight. A niche, yet emerging number of such efforts fall under the umbrella of "Crowd Logistics", which is defined by Frehe et al. (2017) as, "the outsourcing of logistics services to a mass of (not necessarily business) actors, whereby the coordination is supported by a technical platform, which is hosted and managed by a crowd logistics provider". While crowd logistics can comprise a wide range of logistics services (i.e., transport and warehousing), the dominant model is known as Crowdshipping (CS), also known as crowdsourced delivery. CS is a broad term with many definitions

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proposed in the literature (Gläser et al., 2021). In this paper, we reiterate the definition by Buldeo Rai et al. (2017): *"Crowdshipping is an information connectivity enabled marketplace concept that matches supply and demand for any kind of transportation of goods with an undefined and external crowd that has free capacity with regards to time and/or space, participates on a voluntary basis, and is compensated accordingly"*.

CS has become an integral part of urban distribution research with many well-recognised challenges, including dynamic delivery routing as well as pricing problems (Savelsbergh and van Woensel, 2016). Given the interest in CS among both researchers and practitioners and considering the environmental and societal implications of such emerging initiatives, this paper aims to present a comprehensive and timely review of this topic in light of growing urban distribution challenges. By utilising a systematic literature review (SLR) approach, this paper provides an analytical review of the recent CS literature published in top-ranked operations management, operations research and transportation journals and peer-reviewed conferences. Our SLR also incorporates a content-based framework grounded in the Triple Bottom Line (TBL) concept, through which we study the extant research efforts in relation to the topic of sustainability. Specifically, we intend to answer the research question, *How does CS contribute to the sustainability of urban logistics?*

The remainder of this paper is organised as follows. In Section 2, we describe the SLR protocol, along with a descriptive bibliographic analysis. In Section 3, we focus on studies pertaining to the operational and economic aspects of CS, followed by environmental and social aspects in Sections 4 and 5, respectively. Finally, concluding remarks and future research directions are provided in Section 6.

2. Review methodology

2.1. Extracting relevant scholarly works

The aim of this research is to survey the extant literature pertaining to the intersection of CS and sustainability, and subsequently, to determine topics of interest among researchers, research gaps and opportunities for future research. To achieve this objective, we conduct a systematic literature review (SLR), which is known to be an appropriate and unbiased approach to conceptualise the literature and provide direction for theory building (Ambikar et al., 2022). In contrast to narrative reviews that are less structured, SLRs employs rigorous methodologies to objectively observe research developments, particularly when studying emerging field such as CS (Kitchenham et al., 2010). To conduct the SLR, a protocol is needed to serve as our guiding framework for identifying, selecting, and analysing relevant studies (Dohale et al., 2022), as shown in Table 1. Our review protocol included articles published in English until 21 April 2023. We prepared a keyword string, based on the most prevalent terms used in CS research, particularly those pertaining to the applications of crowdsourcing for last-mile delivery. Scopus was considered as our main database, owing to its versatile search engine functionality and source coverage (Pournader et al., 2021). Furthermore, as CS is an emerging multidisciplinary field, we included Q2 journals and peer-reviewed conference papers to incorporate state-of-the-art topics.

Our review methodology is inspired by a five-step approach developed by Dohale et al. (2022) to justify, extract, analyse and report on the extant studies relevant to the domain of interest (Fig. 1). In Step 1, based on the SLR protocol, the initial pool of studies was established, resulting in 665 articles. In Step 2, we first conducted title and abstract screening, which reduced our pool to 196 articles. Subsequently, we performed full-text screening according to our inclusion criteria. This process resulted in 96 articles, of which 76 were published in Q1 journals and 20 associated with Q2 journals and high-quality conference proceedings. In Step 3. In Step 3, a full-text review of the papers was completed, followed by their analysis according to our TBL framework in Step 4. Finally, research gaps and future research opportunities were identified in Step 5.

Fig. 2 shows the distribution of journals and conferences, where Transportation Research Part E and European Journal of Operational Research are the leading outlets. Our pool also comprises 11 articles from INFORMS journals. This suggests CS is an emerging and scientifically relevant topic in the field of transport, logistics and operations research. Fig. 3 illustrates the count of journal papers in each year based on a three-year moving average, where an ascending trend is evident.

2.2. Existing surveys and paper contributions

At the broadest level, two categories of review papers study the topic of CS. First, studies such as Carbone et al. (2017), Ciobotaru and Chankov (2021), and Pourrahmani and Jaller (2021) conceptualise the concept of CS within logistics value chain and investigate

Table 1
Literature review protocol.

Protocol	Description
Database	Scopus
Publication type	Journal and conference papers
Article language	English
Timeline	Until 21st April 2023
Search fields	Title, keywords, and abstract
Utilised keywords	crowd logistics" OR "crowd-shipping" OR ("crowdsourcing" AND "delivery") OR "crowdsource delivery" OR "crowdsource-enabled delivery system" OR "crowdsourced shipping"
Data analysis	Content-based analysis grounded on the TBL approach

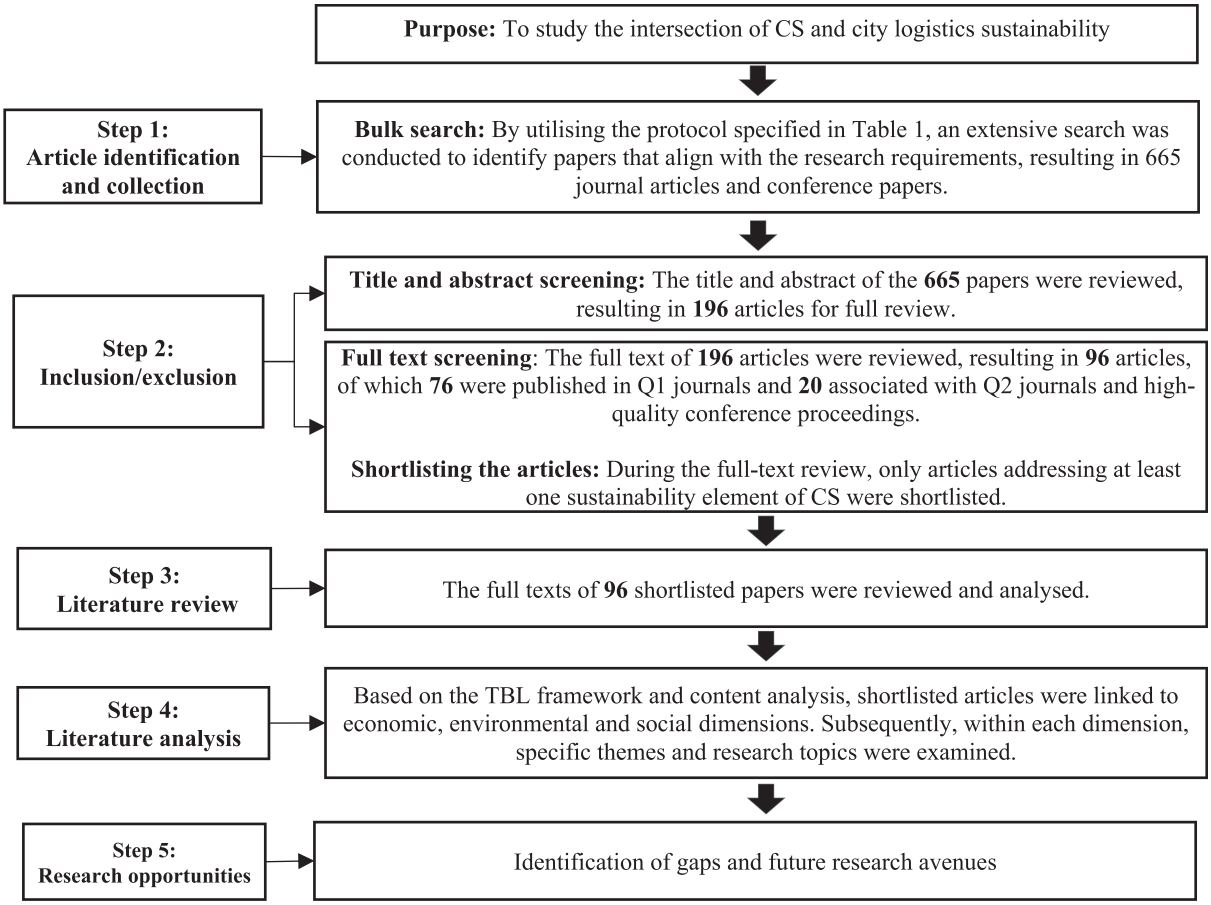

Fig. 1. Literature review methodology.

real-world platform characteristics, and business models. This category of studies, published in earlier years, predominantly relies on industry-based content and publicly available sources to achieve their respective research objectives. While providing useful directions for other research disciplines to further expand CS research, they are also informative for practitioners to better understand the business value of crowdsourcing in providing logistics services.

The latter category includes papers presenting more specific and technical content compared to the first group. For example, Le et al. (2019) studied CS based on three aspects of supply (crowdshippers), demand (receivers and senders), and operations and management models (CS platform). More recently, Alnaggar et al. (2021) adopted an operations research perspective to distinguish existing work in terms of their modelling techniques, decisions, assumptions, and objectives. Nevertheless, the study of Alnaggar et al. (2021) is relatively dedicated to elucidating the convergence between CS and ridesharing and ride-hailing systems. The study by Gläser et al. (2021) is a specific review paper that primarily examines academic research concerning the application of CS initiatives in last-mile logistics. Additionally, the paper delves into the challenges of CS in comparison to traditional delivery systems. Table 2 presents a summary of existing CS review papers.

We also acknowledge that the study of CS is evolving quickly. For example, since January 2019, nearly 55 high-quality papers have been published on various aspects of CS. This has necessitated the need for a recent and comprehensive review to provide state-of-the-art developments and findings on CS. Furthermore, recent studies emphasise the sustainability benefits of CS, specifically by proposing models that could lead to environmental and social outcomes (Ghaderi et al., 2022a;2022b). The review conducted by Le et al. (2019) analysed CS from the standpoint of its players, while Alnaggar et al. (2021) approached it from an operations research perspective, with a focus on modelling. However, the absence of a sustainability-cantered review is noticeable in the literature, particularly considering the net zero targets adopted by transport and logistics organisations, as well as retailers. Hence, given this research gap and evolving field, this study presents a unique taxonomical review of the CS literature based on a sustainability perspective, particularly to understand the working mechanisms and complexities associated with people (society), profit (economy), and the planet (environment) of this new business paradigm.

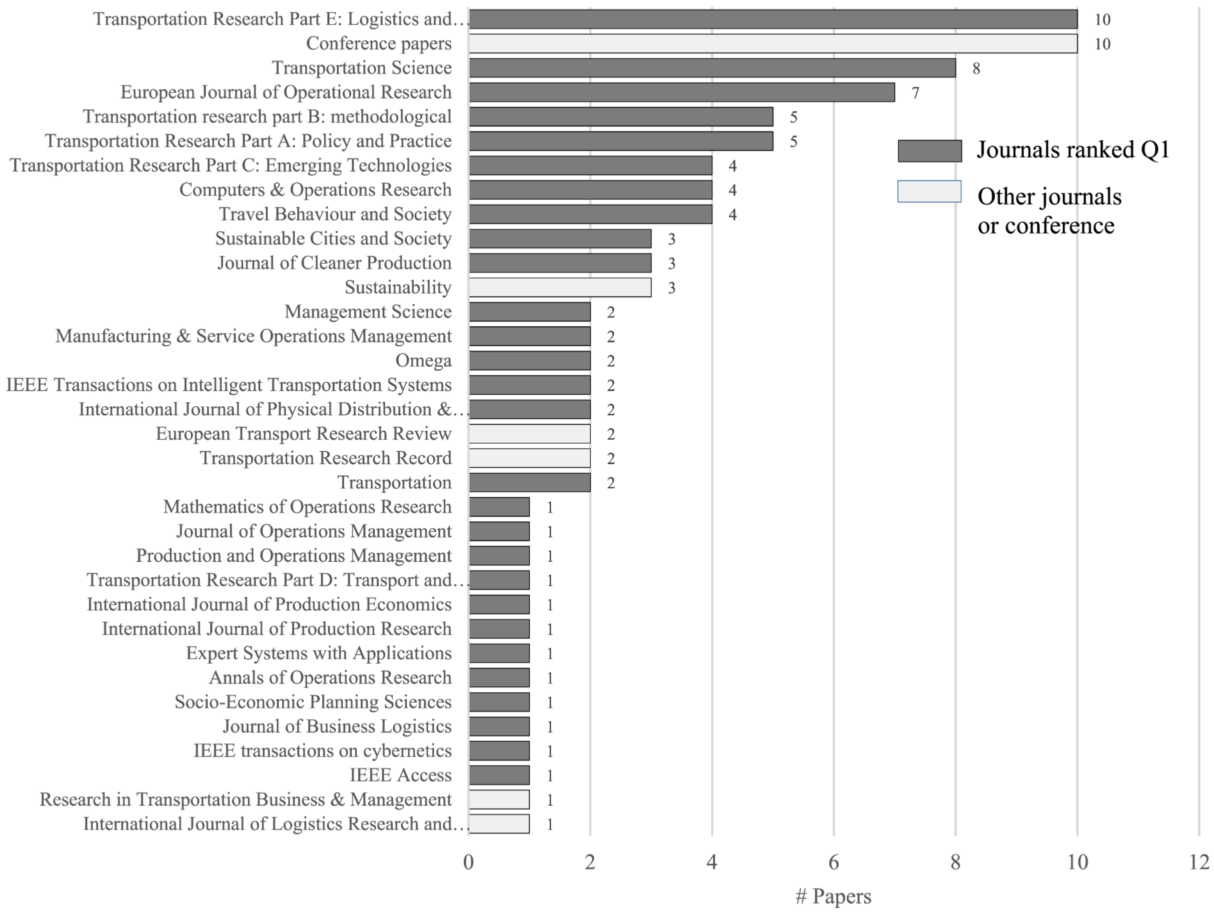

Fig. 2. Outlets with the frequency of published CS papers.

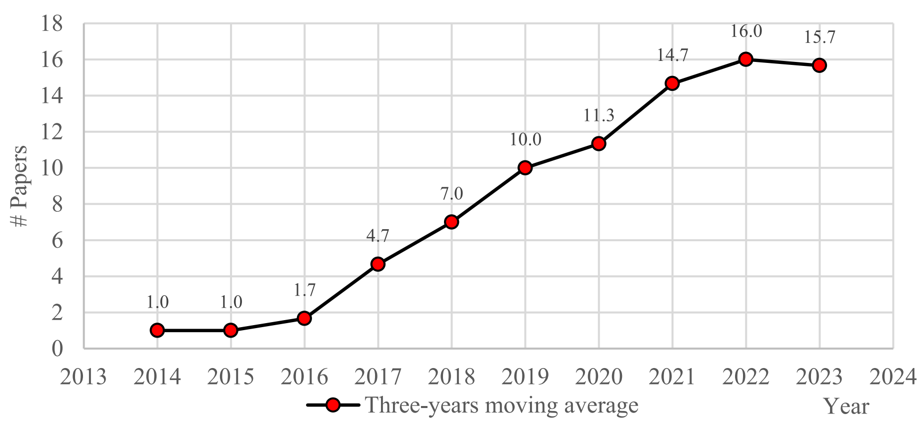

Fig. 3. Count of CS papers in selected journals.

3. Economic and operational aspects

CS is an emerging logistics service provision paradigm that is associated with new and less studied forms of business models and market dynamics, wherein players interact with each other by exchanging parcels, information, and financial transactions (Chen et al., 2022). Senders request the delivery service for an item, who can range from being a business providing a service or merchandise such as e-commerce companies, restaurants, and grocery stores, to non-profit organisations such as libraries and individuals. Similarly, receivers can be individuals or businesses. Given the characteristics of senders and receivers, four different CS business models can be

Table 2
Summary of existing review papers on CS.

Article	Review timeline	# Reviewed materials	Research method	Sustainability focus	Areas of study
Le et al (2019)	2012–2018	58 Papers	Systematic	No	CS Supply, demand and operations models
Alnaggar et al. (2021)	Not specified	Not specified	Narrative	No	Assumptions, decisions, modelling types and platforms
Gläser et al. (2021)	2006–2020	61 Papers	Systematic	No	Not specified
Current paper	2023	96 Papers	Systematic	Yes	Triple Bottom Line (3BL)

identified: Business-to-Business (B2B), Business-to-Customer (B2C), Customer-to-Business (C2B), and Customer-to-Customer (C2C), also known as peer-to-peer (Rougès and Montreuil, 2014). On the other hand, crowdshippers are occasional couriers who conduct the whole or a part of the delivery. Finally, the CS platform is responsible for coordinating both sides of the market in which crowdshippers (supply side) and senders/receivers (demand side) can interact efficiently. The CS platform's role involves four types of decisions: matching the task to crowdshippers, pricing the service, routing, and scheduling that involves determining the time for pick-up and drop-off (Alnaggar et al., 2021). Depending on the level of involvement in the coordination process, CS platforms can vary in structure and concept of operations. For example, platforms may (or may not) have any direct engagement in pricing decisions. On the other hand, platforms may simply facilitate a bidding/negotiation mechanism to allow demand and supply negotiation among different players for delivery fees (Ermagun and Stathopoulos, 2018). In this section, we examine the operational challenges faced by crowdsourced delivery systems, including pricing, matching approaches, sources of uncertainty, potential markets, among others.

3.1. *Demand and supply interactions*

Pricing and compensation decisions are at the core of any CS system and critical to manage supply and demand dynamics. Similar to any other market, CS demand and supply market are governed through pricing mechanisms (Yan et al., 2021; Triki, 2021). For example, rising delivery prices encourage more crowdshippers to participate in CS work, leading to increased supply base, while lower prices can lead to reduced participation (Kung and Zhong, 2017). Eventually, platform's profitability is determined, on one hand by the volume of transactions, and on the other hand, by the difference between delivery fees charged to customers and the compensation offered to crowdshippers plus management and operational costs associated with running the platform. The literature has explored different pricing decisions, their relative demand and supply interactions and how each impact on players' behaviour and decisions to engage in CS. We depict these pricing decisions in Fig. 4.

At the broadest level, pricing strategies can be categorised into centralised and decentralised models. In a centralised model, the platform has direct influence on pricing and costing decisions (Ghaderi et al., 2022a). However, in the decentralised model, the role of the platform is mainly associated with the governance of supply and demand. In such models, crowdshippers and shippers could influence decisions related to timing and pricing of tasks and may participate in auction and bidding processes facilitated by the platform (Ermagun et al., 2018). Platforms could also provide additional support mechanisms such as optimal routing, monitoring of traffic conditions and scheduling. The following subsections provide a more detailed analysis of the CS pricing literature.

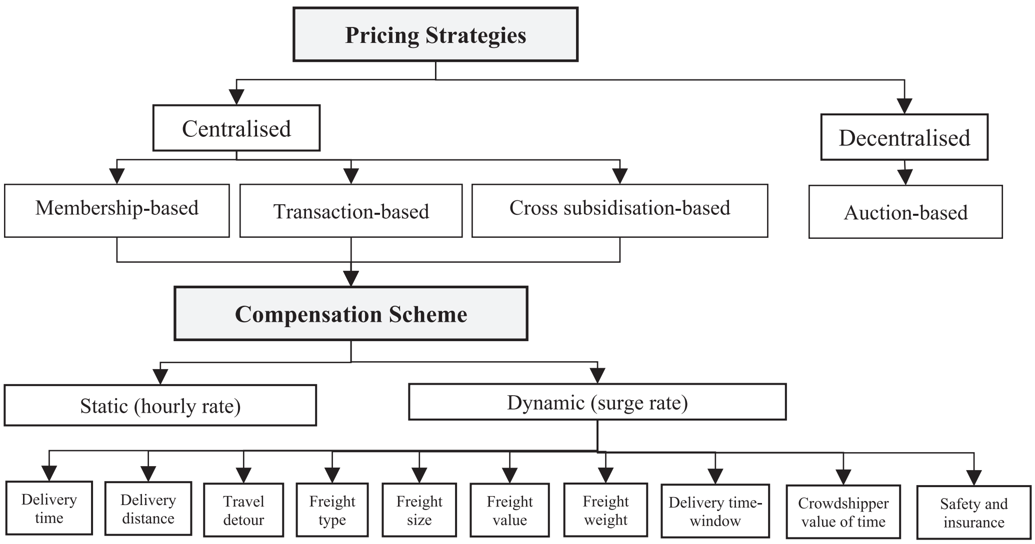

Fig. 4. Pricing strategies and compensation schemes.

3.1.1. Centralised pricing strategies

According to Kung and Zhong (2017), centralised pricing can be classified into three categories of membership-based, transaction-based, and cross-subsidisation methods. Membership-based pricing entails charging every consumer a fixed fee at the beginning of each membership period and providing free delivery for the entire service usage (Le et al., 2019). However, platforms could consider conditions on the maximum number of deliveries or their spatial scope. In transaction-based pricing, senders or receivers are charged per transaction, where the fee can be either fixed or variable depending on the delivery task characteristics. In the cross-subsidisation strategy, platforms receive both membership and transaction fees from senders or receivers and may keep the collected membership fees as their revenue and transfer the transaction fees (total or partial) to the crowdshippers.

In a centralised model, platforms design and implement various compensation schemes to reimburse crowdshippers. Reimbursing crowdshippers can be made in static or dynamic approaches. In the static approach, the platform compensates a crowdshipper based on the total hours of being active/available, regardless of the number of completed deliveries. Some platforms guarantee a minimum hourly rate when the crowdshipper is active to improve and maintain their pool of available crowdshippers (e.g., Grubhub, 2022). In the dynamic approach, also known as surge compensation scheme, the platform offers a compensation figure for each task, which can vary based on multiple factors (see Fig. 4). Our review identifies two evident research streams pertaining to centralised pricing strategies. The first stream involves studies that compare various centralised strategies to discern their respective strengths and weaknesses (Kung and Zhong, 2017; Dahle et al., 2019; Le et al., 2021; Yan et al., 2021; Wicaksono et al., 2021; Castillo et al., 2022). The second stream focuses on contrasting centralised pricing strategies in CS systems with pricing systems utilised in traditional delivery systems, aiming to highlight the cost advantages of CS (Shen and Lin, 2020; Cao et al., 2020; Fatehi et al., 2022).

Relevant to the first stream, Kung and Zhong (2017) conducted a study to compare the performance of different centralised pricing strategies. They developed a two-sided pricing strategy for CS in grocery markets using a game-theoretic optimisation model to maximise profit under each strategy. Findings show that when customer order frequency is price-insensitive, all strategies perform equally. However, if order frequency depends on the per-transaction fee and the platform is impatient for revenue making, membership-based pricing is the most profitable approach. To design the optimal compensation schemes, Dahle et al. (2019) incorporated personal threshold constraints in a pickup and delivery problem by examining the acceptance behaviour of crowdshippers. Three compensation schemes of fixed, distance-based and detour dependent were tested. Findings show that these schemes could save between 10% and 15% in total delivery costs of CS platforms, while increased compensation complexity may lead to higher cost savings. Le et al. (2021) modelled senders' willingness to pay (WTP) and crowdshippers' expectation to be paid (ETP) to identify the best pricing and compensation schemes for profit maximisation. Considering different demand and supply scenarios, this study shows that the platform's profit is more sensitive to increasing WTP than ETP.

The literature acknowledges the availability of crowdshippers in the market as a major constraint, particularly when they can freely choose to work for multiple platforms (Peng et al., 2016). On one side, platforms compete to attract adequate crowdshippers for their services. On the other side, crowdshippers compete over limited monetary rewards provided by the platforms. In this regard, Yan et al. (2021) studied a two-sided competition market between platforms and crowdshippers. Using a game theoretic approach, the behaviour of platforms and crowdshippers was modelled based on non-cooperative and evolutionary games using an agent-based simulation model. The results show increasing delivery fees and compensations can boost platform's profit to a certain point, however, profit can decrease gradually beyond that point. By utilising choice modelling, Wicaksono et al. (2021) investigated the demand and supply interactions for bike-based CS services to estimate the acceptance of customers for using CS services and the willingness of cyclists to work as crowdshippers. Based on a case study from the Netherlands, this study shows that although delivery fees appear to be the most important factor, flexible delivery time windows and reduced CO_2 emissions were other highly influential factors. Moreover, compensation, travel time, and package weight were factors that significantly influenced the decision of crowdshippers to participate. Furthermore, it was observed that customers are more sensitive to service fees compared to crowdshippers in relation to compensation. Castillo et al. (2022) explored the implications of customer tipping for CS delivery performance. Using a multi-agent hybrid simulation, this study concluded that tipping could minimise the uncertainty in CS supply size and reduce delivery costs and time.

For CS systems employing non-professional and part-time crowdshippers, significant uncertainties exist related to the availability and mobility patterns. Such uncertainties bring along challenges for platforms in developing a reliable workforce supply. In this regard, Shen and Lin (2020) utilised data from a CS platform in the City of Atlanta (USA) to predict short-term delivery trips and compare the effectiveness of the CS pricing scheme with the compensation provided by FedEx. Results show that CS service has a clear price advantage over FedEx, particularly for same-day and express delivery services, as well as oversized package deliveries. Cao et al. (2020) developed a CS model with the objective to minimise the expected delivery cost using dedicated drivers and crowdshippers, while maintaining optimal incentives for crowdshippers. Authors assumed that crowdshippers operate within a specified time interval (a day) and unserved parcels would be delivered by professional drivers at the end of the time interval. The problem was formulated as a discrete sequential packing problem. Results demonstrate that CS systems utilising both crowdshippers and dedicated drivers can achieve up to 33% savings in total delivery costs compared to van-only delivery systems. Similarly, Fatehi et al. (2022) proposed a robust optimisation model for CS labour planning and pricing, as well as optimal assignment of delivery tasks. The model was designed for the case of Seattle as an on-demand delivery system with guaranteed delivery time window. Considering experiments with uncertainty in demand, crowd availability and traffic patterns, findings indicate that, in comparison to a FedEx baseline scenario, CS can significantly reduce delivery costs.

3.1.2. Decentralised pricing strategies

In a decentralised strategy, the platform plays an indirect governing role (He et al., 2020). Accordingly, the majority of decentralised models rely on auction-based systems, in which crowdshippers and sender/receivers interact directly (Ermagun and Stathopoulos, 2018). Various types of auction-based systems have been employed in the freight transportation literature, where bidding systems are the most recognised model (Lafkihi et al., 2019). In the CS domain, reverse auction-based systems have received popularity, in which crowdshippers compete to win delivery work with the lowest bid (Hong et al., 2019). Triki (2021) studied the impact of bidding systems on total CS delivery costs by combining a winner determination problem and Vehicle Routing Problem (VRP) that involves dedicated vehicles and occasional drivers (ODs). Using data from an online bookstore with home delivery in Oman, authors reveal that delivery costs could be reduced by 30% when using ODs participating in an auction-based system.

In a similar context, Ermagun and Stathopoulos (2018) explored factors influencing CS supply size in the bidding system using large historical data from different cities across the USA. They considered package characteristics, built environment and socio-economic factors as the determinants of crowdshippers supply. By developing a two-part supply model based on the probability of receiving a bid from a crowdshipper (a binary logit) and the total number of bids (a negative binomial regression), results show strict delivery deadline could drop the number of bids. Ermagun et al. (2020a) formulated a nested logit model to measure the probabilities of bidding, acceptance, and delivery of CS tasks. Findings show larger shipment sizes increase the likelihood of bid placement, while strict deadlines have the opposite effect. However, this trend reverses during the delivery phase. Using a random forest machine-learning algorithm, Ermagun et al. (2020b) show that in addition to larger shipments, out-of-state destinations and customer-to-customer delivery have a lower chance of receiving a bid, which likely reflects the perceived risks of such transactions.

In summary, CS pricing and compensation schemes, along with their impacts on the supply and demand dynamics, are summarised in Table 3. About two-thirds of studies incorporate a centralised pricing approach, within them transaction-based models appear to be the most dominant mechanism. In terms of compensation schemes, static approaches have received significantly more attention compared to dynamic ones. This preference may stem from the simplicity of such payment systems and ease of understanding by crowdshippers. Advancements in computer science and artificial intelligence (AI) present opportunities for implementing behavioural and dynamic compensation schemes. Furthermore, the literature pertaining to decentralised systems is limited to negotiation and bidding processes. An opportunity for future research is to further model and understand other interaction mechanisms among crowdshippers, senders, and receivers. In terms of model development and pricing system design, the majority of research involves optimisation techniques using game theory. However, the inclusion of behavioural aspects, such as willingness to participate in CS systems and task acceptance, have received less emphasis in CS pricing design (Ermagun et al., 2020a; Wicaksono et al., 2021).

Table 3
Summary of studies exploring CS supply and demand interactions.

Reference	Pricing strategy	Compensation scheme	Research focus	Method	Observations
Kung and Zhong (2017)	Centralised: Membership-based, Transaction-based, and Cross subsidisation	Static	Comparing pricing strategies	Optimisation (game modelling)	Senders and crowdshippers are the same.
Le et al. (2021)	Centralised: Transaction-based	Static and dynamic	Pricing and compensation design	optimisation with behavioural constraints	Considering senders' ETP and crowdshippers' WTP
Dahle et al. (2019)	Centralised: Transaction-based	Static and dynamic	Pricing and compensation design	optimisation with behavioural constraints	–
Yan et al. (2021)	Centralised: Transaction-based	Static	Pricing and compensation evaluation	Game theory & simulation	Competition between CS platforms
Wicaksono et al. (2021)	Centralised: Transaction-based	Static	Pricing and compensation evaluation	Game theory & Choice modelling	–
Shen and Lin (2020)	Centralised: Transaction-based	Dynamic	CS trip generation	Deep learning	–
Cao et al. (2020)	Centralised: Transaction-based	Static	Pricing and compensation design	Discrete sequential packing problem	Real-time CS matching
Fatehi et al. (2022)	Centralised: Transaction-based	Static	Pricing and compensation design	Robust optimisation	
Castillo et al. (2022)	Centralised: Transaction-based	Dynamic	Evaluation of tipping	Simulation & netnography	Use of empirical data
Triki (2021)	Decentralised	N/a	Evaluating auction-based systems	Optimisation	–
Ermagun and Stathopoulos (2018)	Decentralised	N/a	Evaluating auction-based systems	Regression and choice modelling	Use of historical CS data
Ermagun et al. (2020a)	Decentralised	N/a	Evaluating auction-based systems	Choice modelling (nested-logit)	Use of historical CS data
Ermagun et al. (2020b)	Decentralised	N/a	Evaluating auction-based systems	Machine learning (random forest)	Use of historical CS data

3.2. Operational characteristics

Advancements in information and communication technology (ICT) and the widespread use of smartphone applications present opportunities to improve the efficiency and use of crowdsourced logistics (Mladenow et al., 2016). The availability of a large pool of crowdshippers connected via mobile phone devices allows for real-time and optimal matching and job assignment. This section reviews the important and emerging methodologies for enabling and maximising CS operational efficiency.

At the broadest level, point-to-point delivery employing crowdshippers presents several spatial and temporal constraints. These constraints are predominantly driven by the dynamic and stochastic nature of crowdshippers' mobility patterns and potential mismatch between demand (i.e., parcel delivery requirements) and supply (i.e., crowdshippers). When a CS system service commits to special offerings such as fast or same-day delivery, such constraints become even more pressing (Dayarian and Savelsbergh, 2020). To address these challenges, some studies propose advanced matching, routing and scheduling algorithms where the spatial–temporal constraints are explicitly formulated (Feng et al., 2019; Archetti et al., 2021). In this review, these studies are grouped under the category of 'Base Approach'. Studies pertaining to Base Approach contribute to the development of operational and tactical models that support task assignment and routing. However, due to their point-to-point structure, their performance is limited by time–space constraints. To gain further efficiency, four alternate approaches have been proposed in the CS literature (see Fig. 5) that relax some of the time–space constraints, which are summarised here:

- ***Approach 1:*** Offering a menu of CS delivery task options for each crowdshipper;
- ***Approach 2:*** Identifying and utilising crowdshippers with similar mobility patterns as the delivery job, resulting in quicker and more efficient matching and delivery (e.g., delivery along commute trip, or by in-store customers);
- ***Approach 3:*** Employing alternate delivery points (ADPs) as pick-up and drop-off locations;
- ***Approach 4***: Introducing temporary and permanent transshipment points (TPs) into the delivery network structure.

Furthermore, hybrid approaches exist that incorporate more than one of the abovementioned models. For instance, placing ADPs in public transport (PT) stations and employing PT users for moving parcels between ADPs (Fessler et al., 2022; Mohri et al., 2023b).

As the Base approach, certain CS studies incorporate time–space restrictions associated with crowdshippers' mobility patterns and delivery demands into operational models. For instance, Feng et al. (2019) proposed a generalised variant of the VRP with dedicated vehicles and ODs that represent heterogeneous costs, time windows, and vehicle capacities. With the objective of minimising total

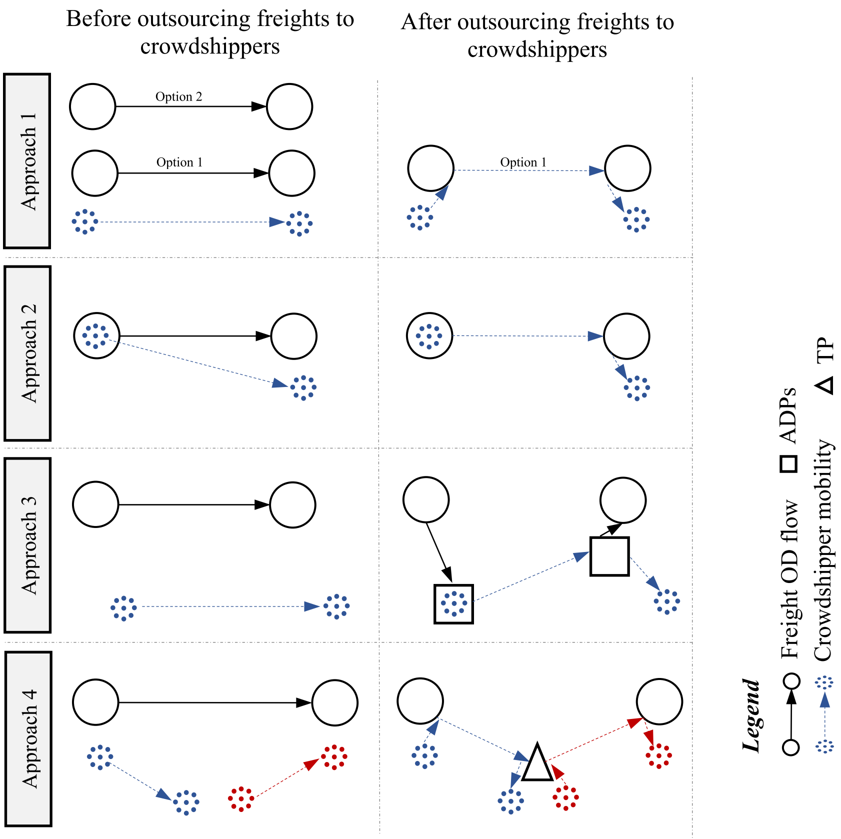

Fig. 5. Approaches for providing time–space flexibility.

fixed and variable costs, results show that employing ODs could significantly reduce costs due to their low fixed costs. Similarly, Archetti et al. (2021) studied an online VRP with company's owned fleet supported by ODs available in specific time windows. With the objective of minimising total distribution costs, authors considered a penalty function when time windows were violated. Assuming that customer requests were either known before distribution planning or placed during the distribution process, experiments indicate that finding high-quality solutions is challenging when both customer requests and ODs' availability are subject to variability. Pugliese et al. (2023) examined a CS system similar to Archetti et al. (2021) with a focus on the uncertainty in ODs' travel time. To model this uncertainty, authors formulated a robust optimisation model and solved it using both Benders' decomposition and column-and-row generation algorithms. Considering time–space and capacity restrictions, Ahamed et al. (2021) proposed a deep reinforcement algorithm for the CS task assignment problem. Results show that the model is superior to the previous techniques in terms of solution quality, computational time, and scalability.

3.2.1. Approach 1: Menu offering

Some CS platforms such as DoorDash and Roadie provide a full list of tasks to crowdshippers, allowing them to select their preferred tasks. Although this approach can reduce the spatial–temporal mismatch between demand and supply, studies such as Einav et al. (2015) and Newton (2014) demonstrate that such matching strategy results in a lower number of fulfilled deliveries. In this context, Horner et al. (2021) explored the possibility of offering a personalised menu rather than a full menu using a leader (platform)-follower (crowdshipper) game, where the platform optimises the menu with limited knowledge of crowdshippers' preferences. In the personalised menus, task duplications might occur. To tackle the challenge of eliminating duplicate CS tasks from multiple crowdshipper menus, Ausseil et al. (2022) proposed a two-stage stochastic model for optimising menu design, where the overlap between menus is bounded. The efficacy of the model was evaluated using data from the city of Chicago, and the results indicate that optimised menus not only enhanced the revenue of the platform but also led to an increased number of successful matches and reduced waiting time for crowdshippers and deliveries.

3.2.2. Approach 2: In-store customers

Traditional retailers with physical stores across urban areas could offer fast deliveries when utilising in-store customers as crowdshippers in return for compensation. Archetti et al. (2016) is one of the first studies suggesting the use of in-store customers as crowdshippers. In this study, the problem is formulated as a VRP, in which deliveries are performed using dedicated drivers/vehicles (i.e., dedicated company-owned or outsourced drivers/vehicles) and ODs from in-store customers. In-store customers declare their willingness to deliver parcels ordered by online customers after arriving at the store, therefore, the origin of all ODs is the store, compared to the Base Approach with varying origin point.

Ni et al. (2019) measured the performance of a CS system for same-day delivery utilising in-store customers, dedicated drivers and information-sharing drivers (ISDs). ISDs are ODs who share their forthcoming trips with retailers. A multi-period mathematical model was proposed, in which the orders are received periodically within a time horizon. The decision variables determine the appropriate depot for dispatching a parcel and selecting the best courier. The model minimises the total system costs, including delivery by different methods and a penalty cost for unfulfilled same-day delivery orders. The model constraints included maximum number of available ODs, store inventory, delivery processing capacity of stores and detour tolerance of ISDs. Dayarian and Savelsbergh (2020) studied the potential of employing in-store customers for same-day delivery, with online orders and in-store customer arrivals to the shop as stochastic inputs. Authors evaluated the overall performance of the system in terms of cost and service quality. Results show that a larger set of participating in-store customers could significantly improve service quality and reduce system costs. Another observation revealed that employing in-store customers is most beneficial when the delivery system is under stress (i.e., when there is limited information on future demand and short delivery requirements). Hou and Wang (2021) considered in-store customers' willingness to accept a delivery job. They proposed a two-stage stochastic model to match online orders to in-store customers with an optimal compensation scheme that minimises total systems costs. Results show that the average delivery cost can be reduced by 7.30%, compared to delivery by dedicated vehicles when incorporating a compensation scheme based on crowdshippers acceptance behaviour. Similarly, Barbosa et al. (2023) modelled the probability of delivery acceptance by in-store customers with a logit model based on questionnaire data, with incentive as the only explanatory variable. The logit model was integrated into a direct search algorithm to optimise CS routing, matching, and pricing decisions.

3.2.3. Approach 3: Alternate delivery points

Collection and delivery points, pick-up points, self-collection points, collection terminals or mobile parcel lockers are terms that are used interchangeably in the literature for ADPs (Pan et al., 2021). Incorporating ADPs in CS systems is known to be a successful mechanism to introduce spatial–temporal synergy among senders, receivers and crowdshippers (Vincent et al., 2022). Chen et al. (2016) contend that large-scale fast delivery would not be feasible without restructuring the delivery network and incorporating ADPs. Using a case study from Hangzhou, China, experimental results show that over 85% of packages can be delivered within 8 h when utilising ADPs, which is considerably faster than the conventional courier network model. Similarly, Gatta et al. (2019a), Fessler et al. (2022), Vincent et al. (2022), and Kızıl and Yıldız (2023) have also investigated CS networks involving ADPs. Gatta et al. (2019a) and Fessler et al. (2022) studied the application of ADPs in PT-based CS systems, in which PT passengers were the crowdshippers. Authors indicate that utilising the existing mobility patterns of PT passengers in CS without employing lockers as parcel pick-up and drop-off points in stations would not be practical. Kızıl and Yıldız (2023) suggest introducing a transfer facility (i.e., ADP) as a backup mechanism inside PT stations, by which passengers move parcels between the transfer facilities and lockers, while locker-to-locker movement is conducted by PT vehicles. Mohri et al. (2023a) investigated a locker-to-home CS system in which lockers are used as the only parcel pick-up points. Using survey data collected from Sydney metropolitan residents, authors observed that removing lockers as drop-off points can raise safety and security concerns for both crowdshippers and receivers due to their direct contact for fulfilling a parcel delivery. Vincent et al. (2022) evaluated the performance of ADP supported CS systems in which receivers can select their preferred delivery option. While only dedicated drivers could deliver parcels to ADPs, results show that incorporating such facilities could reduce costs by around 28%. Despite its theoretical advantages, there are operational and behavioural challenges that prevent the effective implementation of ADPs into CS systems. (Gatta et al., 2019a).

3.2.4. Approach 4: Employing transshipment points

The idea of using TPs, also called mini depots or micro hubs, in CS systems was initially introduced by Kafle et al. (2017). There is a consensus in the literature that TPs could significantly improve the overall performance of CS systems in terms of cost and service quality (Nieto-Isaza et al., 2022; Vincent et al., 2022). TPs can be categorised into two groups: stationary and mobile. Contrary to stationary TPs, mobile TPs can have flexible locations and capacities, hence providing a more flexible option for markets with dynamic demand and supply (Faugère et al., 2020).

Stationary TPs: Ballare and Lin (2020) compared the performance of TP-integrated CS systems involving ODs and cyclists as crowdshippers with a traditional hub and spoke system in terms of reduction in truck movements, fuel consumption and operational costs. The study indicated that the hub and spoke system outperforms the CS in small instances (less than 18,000 customers) in terms of daily operational costs, while CS performs better in larger cases located in high-density metropolitan environments. Similarly, using an experimental study conducted in the Hague, Netherlands, Lin et al. (2020) showed that delivering every package using multiple cyclists, as crowdshippers, without employing TPs will increase the level of intrusiveness to cyclists' daily trips. In the same vein, Yıldız (2021a) proposed a two-echelon CS system with ODs and dedicated vehicles to identify an optimal package routing policy for minimising total delivery costs. In the first echelon of the CS system, the movement of parcels from depots to lockers or from lockers to customer homes was optimised, while transfers between TPs were addressed in the second echelon.

Ghaderi et al. (2022b) explored the utilisation of green CS with parcel lockers, in which a delivery task could be performed by one or multiple crowdshippers using parcel lockers as exchange points. A two-phase algorithm was proposed to rate and select lockers from candidate locations. The algorithm initially classifies jobs into single and joint delivery and then scores parcel lockers by their utilisation in joint delivery. Numerical results of this study performed on large instances demonstrate that joint CS delivery enhances delivery success by up to 5%. From the findings of Ghaderi et al. (2022b), it can be concluded that collaborative or joint CS has the potential for parcel delivery in low-density-long-distance settings.

In another study, Nieto-Isaza et al. (2022) identified the optimal location and number of TPs in CS systems. A two-stage stochastic model was formulated with time-dependent delivery capacity and volume. based on Munich's PT network, authors show that employing crowdshippers could decrease the total cost between 2.1% and 7.6%, depending on the number of TPs. Moreover, it was observed that in large cases, 23% to 60% of the shipments allocated to crowdshippers were routed through TPs. Wang et al. (2023a) investigated the optimisation of parcel allocation to TPs and crowd routing. This study considers a cost minimisation problem with the possibility of multiple deliveries by crowdshippers, provided that delivery time windows, vehicle capacity, and route maximum duration constraints are met. Authors reveal that stationary TPs should be located between the boundary and the centre of a delivery region to improve delivery performance.

Mobile TPs: While stationary TPs provide several benefits to both couriers and customers, they come with inherent limitations. Mobile TPs or relay points, present spatial flexibility by utilising dormant assets such as in-operation trucks, vehicle trunks or any other assets with available storage capacity. In this context, Kafle et al. (2017) proposed a CS system for urban deliveries involving pedestrians and cyclists to perform the first and final segments of trips in cooperation with a truck. In this study, it was assumed that crowdshippers submit their bids and then the courier coordinates the crowdshippers with their truck operations by offering alternative relay points. A mathematical model was formulated in which the selection of crowdshippers, relay points and truck routing and scheduling are optimised, with the objective of minimising the total cost of truck operation, crowdshippers' compensation and penalty associated with delivering parcels outside customers' desired time windows. The experimental results show that compared to the traditional truck-only delivery model, CS can reduce the total costs and vehicle miles travelled (VMT) by 9.25% and 24%, respectively. However, the reductions are sensitive to factors such as crowdshippers transport mode and value of time. Lan et al. (2022) proposed a two-echelon CS system with mobile TPs. In the first echelon, trucks move parcels from a depot to TPs, while in the second echelon, ODs move parcels from TPs to customers' homes. A multi-objective model was formulated to minimise total delivery costs while maximising customer and crowdshipper satisfaction. Customer satisfaction was measured by the difference in actual vs. ideal delivery time and crowdshipper satisfaction was estimated by the ratio of the total deviated distance from their original itineraries. Results show that employing CS in conjunction with mobile TPs can reduce the average delivery cost by 3% and increase delivery speed by up to 42%. Similar to Lan et al. (2022), Mousavi et al. (2022) proposed a two-stage stochastic model with mobile TPs, in which crowdshippers' availability was subject to uncertainty.

In summary, studies related to time–space flexibilities reveal that effective matching is a challenging task due to the dynamic and stochastic nature of crowdshippers' mobility and demand patterns. In the literature, several solutions have been proposed to address this issue, which were reviewed in Subsection 3.2. Some studies suggest incorporating spatiotemporal constraints into matching algorithms or offering a menu of CS tasks to each crowdshipper. However, such approaches have shortcomings, leaving delivery tasks unfulfilled (Feng et al., 2019; Archetti et al., 2021; Horner et al., 2021). To address this challenge, others suggest involving different types of crowdshippers such as in-store customers, which again comes with challenges for online retailers that have no physical stores (Archetti et al., 2016; Savelsbergh, 2020). More recent studies aim to improve systems flexibility by introducing ADPs, allowing for improved assignment of deliveries to crowdshippers (Ghaderi et al., 2022b; Vincent et al., 2022; Chen et al., 2016). While ADPs can improve matching, challenges remain in the first and last legs of deliveries (between sender location and ADP, and between ADP and customer location). Accordingly, a new line of research proposes the inclusion of TPs to enable joint deliveries (Macrina et al., 2020; Mousavi et al., 2022). However, incorporating TPs and joint delivery also comes with challenges related to fairness of compensation. Furthermore, the decision of whether TPs should be stationary or mobile remains open in the literature.

3.3. Spatiotemporal uncertainties

In CS systems, the availability of receivers and crowdshippers, as well as the arrival of delivery tasks, are subject to uncertainty. To address the uncertainties associated with the availability of crowdshippers, Ulmer and Savelsbergh (2020) evaluate a combination of scheduled and unscheduled crowdshippers. Scheduled crowdshippers are those who are rewarded by the platform to be available for certain time periods. Their results reveal that the value of unscheduled crowdshippers is significantly less than scheduled crowdshippers, and if unscheduled crowdshippers announce their start time in advance, the service level could be largely improved. Similarly, Behrendt et al. (2022) proposed a machine learning approach to improve shift settings for scheduled crowdshippers. The methodology leveraged on simulation-based optimisation for offline training and employed a neural network for online solution prescription. The machine learning method resulted in solution quality comparable to that of a bespoke sample average approximation method, exhibiting superior performance for online solution generation. Inspired by the results of Ulmer and Savelsbergh (2020), studies of Yildiz (2021a) and Yildiz (2021b) proposed CS systems with registered ODs declaring in advance their planned trips, preferred pick-up and drop-off points and availability. The results show that CS systems using TPs and ODs (with advanced information) have significant advantages in terms of total operational costs under short delivery lead time. Zehtabian et al. (2022) estimated ODs' arrival time, where both daily demand and supply for a CS platform are subject to uncertainty. Using a Markov decision process, two look-ahead policies were assessed. The first policy considered a constant look-ahead horizon and the other applied a dynamically adjusted look-ahead horizon that outperforms the former by up to 19% in term of accuracy. Mousavi et al. (2022) modelled the availability of crowdshippers as the function of their observed commuting patterns. They proposed a matching algorithm with mobile TPs in a two-stage stochastic integer program setting. The objective function was to minimise the operational costs of mobile TPs, plus the cost of failed deliveries due to the unavailability of crowdshippers. Based on a case study from Toronto, results indicate a 3.35% to 6.08% improvement in the solution quality in the presence of uncertainty. Also, improvements are more significant when uncertainty in crowdshipper availability is higher. Ghaderi et al. (2022a) proposed employing clustering techniques to understand crowdshippers mobility patterns before assigning tasks to them. Using a two-step methodology, first, trajectory analytics are performed to profile the pool of crowd and identify the list of suitable/available crowdshippers, while task assignment is conducted in the second step to maximise profit. Silva et al. (2023) considered ODs performing multiple deliveries with uncertain demand and crowdshippers availability, where the uncertain variables were assumed to be dependent. Using a worst-case probability paradigm, the marginal distribution of every uncertain variable is calculated from historical data, while their joint distribution is considered unknown.

Unattended deliveries are another major source of complexity in urban freight systems. This issue is further exacerbated in CS systems compared with conventional courier models since holding or re-delivery of parcels by crowdshippers can be challenging. In this regard, Akeb et al. (2018) proposed a CS system in which neighbours of parcel receivers could collect and pass parcels to the final customer. The performance of this neighbour-based CS system was measured by running a simulation technique using a case study from Paris with high population density. Results show that the proposed model is economically effective and can solve the issue of unattended deliveries. Torres et al. (2021) proposed hiring ODs with uncertain availability who agree to start and end their trips at a parcel distribution centre. In this study, a routing problem was formulated using two-stage stochastic programming in which both ODs and dedicated vehicles can fulfil deliveries. In the first stage, ODs supply is estimated probabilistically based on historical participation records. A branch-and-cut solution algorithm was utilised to solve the model for modified Solomon instances, involving a pool of 100 crowd vehicles. Results show that improvements resulting from the stochastic solution are as high as 18% in comparison to solutions obtained from a deterministic simplification. Furthermore, expecting crowdshippers to make round trips to a parcel distribution centre could deteriorate participation level, leading to a smaller pool of available participants. To address this issue, Torres et al. (2022) proposed a new model in which the maximum duration of CS routes was restricted. The authors also strengthened the upper bounds of the initial branch-and-cut solution algorithm proposed by Torres et al. (2021).

In summary, this section examined mechanisms related to managing uncertainty in CS systems. Notably, the literature has primarily focused on mitigating uncertainty in crowdshippers availability, compared to receivers' availability. However, receivers' unavailability could also result in several operational issues such as failed or missing deliveries. It is important to note that CS

Table 4
Solutions for addressing uncertainties in the availability of crowdshippers and receivers.

Player	Strategies	Reference
Crowdshipper	Declaration of trip preferences by ODs	Declaring preferred start time (Ulmer and Savelsbergh, 2020)
		Declaring preferred trip's start time, start point and end point (Yildiz, 2021a; Yildiz, 2021b).
	Modelling trip uncertainty	Markov chain with look-ahead policy to model uncertainty (Zehtabian et al., 2022).
		ODs' Availability is modelled based on a worst-case scenario (Silva et al., 2023).
	Using ODs' historical commuting patterns	Mousavi et al. (2022), Ghaderi et al. (2022a), Torres et al. (2021), and Torres et al. (2022)
Receiver	Trusted ADP	Involving neighbours Akeb et al. (2018)
	Employing ODs accepting round CS trips	Set start and end points at a distribution centre (Torres et al., 2021; Torres et al., 2022).

platforms do not have a formal distribution network of conventional couriers such as consolidation points and full-time drivers with dedicated vehicles. Hence, management of failed deliveries could be more challenging. This introduces an important gap in CS research and how current CS businesses operate in real-world conditions. To manage uncertainties associated with crowdshippers availability, trip declaration (stated observation) and utilisation of historical commuting patterns (revealed observation) have been recently investigated in the literature (Yildiz, 2021a; Ghaderi et al., 2022a). These methods show promising results in managing supply uncertainty. However, with recent advances in mobility sensing technologies such as PT fare validation systems, mobile phone locational information and navigation apps, supported by advanced trajectory prediction methodologies, several future research directions emerge for managing CS spatiotemporal uncertainties. Table 4 provides a summary of strategies to manage uncertainties associated with crowdshippers and receivers.

3.4. Multiple and split delivery policies

Initially, CS was introduced as a community-based approach for delivering parcels, mainly via involvement of friends or neighbours (Paloheimo et al., 2016). Such models predominantly represent a single delivery approach. As technology becomes more accessible to coordinate CS activities, assigning multiple delivery tasks with the same and/or different pick-up or drop-off locations to crowdshippers has received increased attention (Behrend et al., 2019). As such, crowdshippers have the option to accept multiple deliveries collectively or individually while travelling to agreed locations. Fig. 6 visualises three delivery policies with single, multiple and split delivery approaches. The newly offered tasks might alter existing delivery sequences and routing. Therefore, path finding and routing decisions become the core of any modern CS system (Arslan et al., 2019).

In this context, Macrina et al. (2017) studied a VRP variant with time-window constraints for both dedicated drivers and ODs. In this study, the possibility of delivering parcels by ODs was evaluated under two policies. First, ODs can accept multiple deliveries with different origins and destinations, known as “multiple delivery policy”. Second, more than one OD can visit an origin point and receive a fraction of the delivery demand, which is defined as “split delivery policy”. Results show that performing multiple and split delivery policies would significantly decrease total delivery costs. Yildiz and Savelsbergh (2019) evaluated the impact of bundling deliveries at pick-up points as a multiple delivery policy in a food-based CS system. They observed that when courier availability is not a limiting factor, limited service improvement can be achieved (e.g., click-to-door time or ready-to-door time). The reason is that bundling of orders at restaurants adds waiting time and circuity to delivery routes.

Arslan et al. (2019) highlight the difficulties in performing multiple delivery policies because of time window constraints. Hence, they proposed a dynamic pickup and delivery problem with ODs and dedicated drivers for on-demand deliveries. A same-day delivery setting was considered in which both delivery tasks and ODs dynamically arrive over time. A matching-routing problem was formulated in which the total routing costs of dedicated drivers and ODs are minimised. Results show that including ODs and performing multiple delivery policies can save delivery costs up to 37%, where large savings occur when crowdshippers have high flexibility in time and willingness to stop more. Simoni and Winkenbach (2023) explored the order batching and assignment problem in a CS-based meal delivery system with the aim to consolidate orders with distinct pick-up and drop-off locations into same batches. This study revealed that increasing the batch size to more than three orders would provide little benefit, mainly due to time and capacity constraints. In summary, the literature shows equal popularity for both single and multiple delivery policies, while split delivery has received less attention. Theoretically, implementing multiple delivery policies via bundling of orders could reduce the

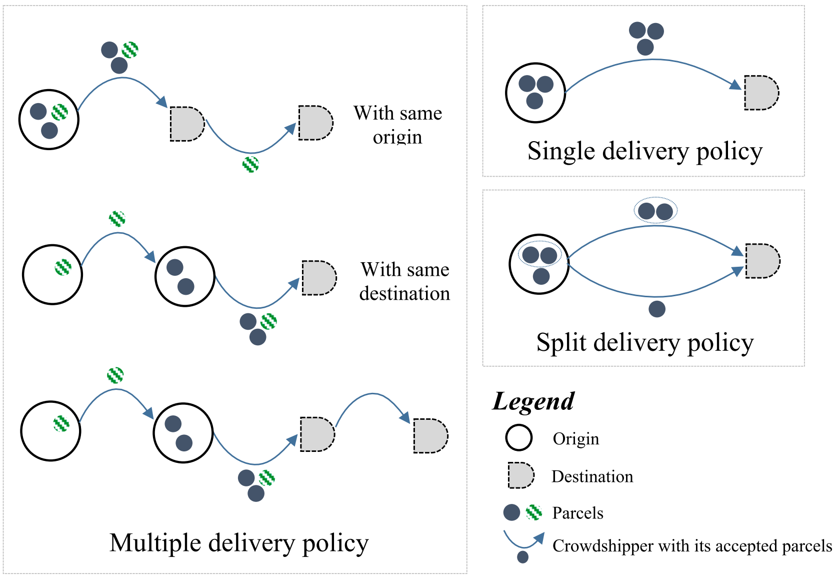

Fig. 6. Delivery assignment policies.

number of required crowdshippers and total delivery distances, plus minimising environmental impacts (Pugliese et al., 2023; Wang et al., 2023a; Fessler et al., 2022). However, this approach may lead to an inequitable distribution of delivery tasks among crowdshippers and restrict opportunities for new crowdshippers to participate in the system, resulting in lower participation in future (Triki, 2021). Due to the low spatiotemporal flexibility of PT users, it appears that single delivery policy is more appropriate for such crowdshippers, while those with dedicated vehicles could perform multiple deliveries (Fessler et al., 2022). On the other hand, while split deliveries could significantly improve geographical coverage and successful delivery rates (Ghaderi et al., 2022b), their uptake by crowdshippers could be low due to less financial incentives.

3.5. Potential markets

Since CS services vary in the nature of offering and characteristics, it is essential to understand their unique value proposition for different markets; where and how each CS model is best positioned. The early implementation of CS in real-world cases (e.g., UberEATS, Postmates, Amazon Prime, Deliveroo, and PiggyBaggy) aimed to address the LMD problem for food, grocery and e-commerce purchases in B2C markets. However, the literature demonstrates a growing number of applications relevant to library services (Paloheimo et al., 2016), healthcare and humanitarian logistics (Le and Ukkusuri, 2019b), food rescue and charity (Mittal et al. (2021), item sharing (Behrend and Meisel, 2018) and reverse logistics for e-commerce (Pan et al., 2015; Upadhyay et al., (2020). In this section, we provide a summary of markets that can benefit from CS services. Since the majority of existing CS literature focuses on food, grocery, and e-commerce markets, we only present the emerging and potential markets that are less known.

3.5.1. Item sharing

Item sharing is an emerging collaborative consumption concept in which community members can temporarily lease their items to others (e.g., party equipment and gardening tools). With item sharing, multiple members can sequentially use a specific item by renting it instead of purchasing. However, the physical transfer of items between lessee and lessor using traditional couriers is challenging because it can lead to increasing rental costs and environmental impacts, and consequently, deteriorate the attractiveness of item sharing (Behrend, 2020). Hence, Behrend and Meisel (2018) suggest that CS could be a suitable solution for the exchange of goods in item sharing with three proposed models: (i) self-sourcing in which the lessee conducts the delivery, (ii) delivery with an independent crowdshipper to the lessee's location and, (iii) a model in which crowdshipper performs the delivery to a neighbouring location where it is picked by the lessee. In Behrend and Meisel (2018), it is assumed that each crowdshipper can accept at most one item. To relax this assumption, Behrend et al. (2019) allowed private drivers to perform multiple deliveries at the same time if they had adequate vehicle capacity. This approach could lead to reduced delivery costs when several deliveries are combined in one route. Furthermore, such models could enhance drivers' interest to participate in CS as the result of improved reimbursement.

Later, Behrend et al. (2021) proposed a 'request-changing' extension to the item-sharing problem, in which items can be used by multiple customers before returning to their original locations. It is expected that request-changing could minimise total transportation costs and improve item availability as a result of eliminating return trips. From a modelling perspective, this extension can be classified as a many-to-many pickup and delivery problem with dynamic characteristics due to new incoming announcements. To address the planning dynamics associated with the deterministic and stochastic nature of requests, the problem was formulated as a mathematical model with a rolling horizon approach. To predict future requests, this study relied on the concept of 'word-of-mouth' as a mechanism driven by interpersonal communications around the experience of previous consumers. Results show that when simultaneous effects of requests are considered in multi-period planning, the system's profit is improved compared to the period-by-period approach.

3.5.2. Food rescue and healthcare

Food insecurity is a serious humanitarian concern. According to the U.S. Department of Agriculture (USDA), 10.5 million (13.8 million persons) U.S. households were food insecure at some time during 2020 (USDA, 2020), with many not qualifying for federal food assistance due to income ineligibility. At the same time, USDA estimates that 31% of the available food supply at the retail and consumer levels goes to waste each year (Buzby et al., 2014). The logistics of delivering excess food to demand locations presents major challenges, particularly considering the relatively small volumes and perishable nature of food items. Recently non-profit organisations and start-up companies in the US such as Food Rescue US and Goodr are recruiting volunteer drivers to pick up surplus food from restaurants and deliver it to soup kitchens and shelters (Food Rescue US, 2022). Applications of CS to address food insecurity have also received attention in academia. For example, Mittal et al. (2021) assessed the viability of a volunteer-based CS food rescue program from restaurants in Arlington, Texas using agent-based simulation models. This study considered couriers and senders to be represented as autonomous, heterogeneous and adaptive agents with their decision to participate in CS having interactive effects on others. While demonstrating the social benefits of CS for urban food rescue, Mittal et al. (2021) concluded that establishing an appropriate balance between the number of crowdshippers and restaurant donations is essential for the success of volunteer-based CS. In a similar context, Manshadi and Rodilitz (2022) aimed to maximise the engagement of volunteer crowdshippers to perform time-sensitive tasks, suggesting nudging mechanisms to notify a subset of volunteers. Since excessive notifications might hurt engagement, an online volunteer notification problem (i.e., online policy) was proposed in which the trade-offs between notifying more volunteers and saving them for future tasks were examined. In crowd logistics systems, senders show heterogeneous behaviour; some are willing to pay more for quicker delivery and some only want the lowest delivery cost. Le and Ukkusuri (2019b) explored how senders choose shipping services for different products, given the availability of both CS and traditional delivery in a logistics market. Using survey data collected from the US and applying discrete choice models, it was observed that personal health and medicine products appear to be a potential market segment for CS.

3.5.3. Reverse logistics

CS also presents opportunities for sustainable supply chains, including reverse and return logistics (Pan et al., 2015). More specifically, studies such as Le et al. (2019) have highlighted the potential of CS as a solution for product returns in e-commerce intensive markets. Collecting returned products is considered as one of the most expensive activities in urban logistics systems, mainly because of the lack of economies of scale and challenges with packaging. Chen et al. (2017) introduced CS to e-commerce reverse logistics, as an alternative solution to return goods from customers to retailers. Using a dataset consisting of shop locations, road networks and large-scale trajectory data generated by over 7000 taxis in China, various collection strategies based on passengers' destinations, collection points and online and offline taxi scheduling were proposed. The results of this study demonstrate that CS approach was superior compared with other strategies in terms of reducing economic and environmental costs. Moreover, the CS provides extra income for taxi drivers and offers more convenience to customers for returning their parcels. From a modelling point of view, in a CS system, reverse logistics could be incorporated as a pick-up problem.

3.5.4. Library services

Paloheimo et al. (2016) presented a study of CS for library services in the city of Jyväskylä in Finland. Due to long travel distances, competition with e-book solutions, and cost complications, many libraries are not able to maintain their service levels and struggle to remain commercially viable. As a remedy for this problem, a pilot research project was conducted in which the distribution of books from libraries to customers, and vice versa, was performed via the CS service of PiggyBaggy. Real-world observations showed that the trial attracted a large number of crowdshippers, mainly using bicycles, despite a low compensation rate (i.e., 2–5 euros per delivery). In contrast, the trial failed to quickly attract library customers even by offering a free service delivery. The analysis further showed that although nearly 80% of deliveries were within a 5 km radius, each CS delivery could reduce 1.6 km of travel, on average. More recently, Triki (2021) studied the application of CS services for delivering online orders from a bookstore in Oman by employing ODs in addition to the company's available fleet. This study reveals that bookstores can minimise their fleet of dedicated couriers by 30% when relying on the CS service.

4. Environmental aspects

Delivering parcels by crowdshippers is expected to contribute to enhancing the environmental performance of the urban freight ecosystem. Such initiatives can reduce delivery truck circulation, especially in local and residential areas, and reduce emissions, traffic congestion and safety risks, which benefits the general public significantly. Despite such importance, the topic of environmental assessment of CS systems or designing eco-friendly systems has received limited attention. The literature acknowledges that if CS requires dedicated trip generation by casual couriers travelling with unsustainable transportation modes, it could result in unfavourable environmental outcomes (Rai et al., 2018). The remainder of this section summarises the relevant CS research related to environmental implications.

CS with ODs: CS initiatives involving ODs could impact drivers' mobility patterns or even induce new trips into transport systems. Although at first glance replacing dedicated freight movements with existing passengers appears to be an eco-friendly option, such solutions could have adverse effects if they become a major source of trip generation (The New York Times, 2020). Currently, there is limited empirical and academic evidence addressing the negative side of utilising CS for parcel delivery (Rai et al., 2018; Allahviranloo and Baghestani, 2019). In this context, Qi et al. (2018) examined the operational and environmental benefits of CS systems compared to truck-only delivery systems using a case study in San Francisco. They revealed that CS is not as scalable as conventional truck-only systems in terms of operating costs. However, a transition to CS could reduce fleet size and improve operational flexibility via better access to high-demand areas and peak hours. Furthermore, the authors conclude that emissions may increase in CS systems due to the prolonged trip distances of crowdshippers.

Rai et al. (2018) explored the environmental impacts of CS utilising ODs based on historical data from the operations of a crowd logistics company in Belgium. This study formulated and evaluated the external costs of CS on society against a conventional parcel delivery system. By applying a multi-actor multi-criteria analysis, results indicate that the CS platform results in larger environmental impacts, as the result of the high number of dedicated trips, instead of capitalising on the existing mobility of individuals. Also, Rai et al. (2018) suggested that CS could provide higher synergy in B2B markets, because of higher economies of scale. In line with this argument, Allahviranloo and Baghestani (2019) study this phenomenon using an auction-based CS platform, in which senders submit pickup/delivery tasks and crowdshippers select the most compatible and desirable tasks. Benefiting from information on activity patterns from the California Household Travel Survey data (2001) to identify potential senders and crowdshippers, they indicate that the activity and travel patterns of both senders and crowdshippers could be impacted as a result of participating in CS. It was observed that CS can impact shifting travel demand from morning to evening hours. Ballare and Lin (2020) suggest a CS system with TPs involving drivers or cyclists. They compared the CS system with a hub and spoke delivery system in terms of sustainability objectives based on reductions in truck movements and fuel consumption. Results show that CS can reduce vehicle miles travelled and fuel consumption by up to 60% and 50%, respectively.

CS with Eco-friendly transportation modes: A growing number of researchers have investigated initiatives that utilise eco-friendly transportation modes such as PT, cycling and active transport (Marcucci et al., 2017; Kafle et al., 2017; Serafini et al., 2018; Gatta et al., 2019a; Gatta et al., 2019b; Binetti et al., 2019; Simoni et al., 2020; Lin et al., 2020; Wicaksono et al., 2021; Fessler et al., 2022; Mohri et al., 2023a; Mohri et al., 2023b). Kafle et al. (2017) presented one of the first studies to quantify the environmental benefits of employing cyclists and pedestrians as crowdshippers for the first and last legs of parcel delivery in urban freight systems, where TPs are used to connect crowdshippers with delivery trucks. This study shows that total delivery costs and truck travel distance could be reduced on average by 9.25% and 24%, respectively, compared with truck-only delivery systems. Simoni et al. (2020) performed a dynamic traffic simulation-based analysis to estimate how air pollution, GHG emissions, and traffic delay change after operating CS involving ODs and PT users. It was observed that operating a CS system with ODs will result in a slightly higher increase in air pollution, GHG emissions, and traffic delay (approx. 2%), while, running a PT-based CS system would reduce these factors by up to 35%. In a similar study from Rome, Gatta et al., (2019b) showed that implementing PT-based CS can reduce 239 kg of particulates per year. Kızıl and Yıldız (2023) proposed an eco-friendly delivery system with ADPs and TPs, involving PT users as crowdshippers for short trips and PT vehicles for long-distance movements. The delivery system was designed as a two-stage stochastic problem considering demand and CS capacity uncertainties. Using a case from Istanbul, results reveal that a CS-based approach can deliver up to 97% of the daily demand on the same day and reduce emissions such as Nitrogen oxides (NO_x), Carbon dioxide (CO_2), and Particulate matter (PM_{10}). In the work of Binetti et al. (2019), a CS system was proposed in which delivery tasks were outsourced to bike users of free-floating bike-sharing systems. Authors, in contrast, highlight that the demand for CS delivery causes a shortage in the availability of bikes for other cyclists and reduces the accessibility and utility of the bike-sharing system for personal trips.

Integration of passengers and freight: CS can be integrated into taxi, ridesharing, ride-pooling or carpooling systems to minimise environmental impacts. In this context, Chen et al. (2016) proposed a taxi-based CS system in which taxis move parcels between ADPs. By testing the system on a case study from China, authors claim environmental and economic benefits. Fehn et al. (2023) investigated the integration of parcel deliveries into ride-pooling services in Munich, Germany. Using an agent-based simulation approach that assigns parcels to existing ride trips, results indicate that total vehicle kilometres can be reduced by 48%, compared to a scenario when freight and passenger services are separate.

At the broadest level, compared to operational and economic aspects, research on environmental considerations of CS is limited, with conflicting views presented. Studies such as Kızıl and Yıldız (2023) report on reduced emissions and VKT, while others indicate higher impacts (Rai et al., 2018). Our review, however, concludes that several factors could determine the environmental performance of CS, including the type of vehicle used, transport mode, platform structure, service offering and most importantly, the nature of the participating crowd. CS systems that employ ODs delivering parcels as part of daily trips without creating new trips are reported to be more environmentally friendly (Ghaderi et al., 2022a). However, such models are also characterised by shortcomings, such as lower service levels, crowdshipper unavailability and poor incentivisation (Peng et al., 2016). To address such challenges, the more recent literature suggests the incorporation of TPs and ADPs into distribution network (Vincent et al. 2022), multiple and joint delivery options (Ghaderi et al., 2022b), integration of freight and passenger transport (Cavallaro and Nocera, 2022). Furthermore, a growing interest is observed in the utilisation of PT-based systems, particularly through the installation of parcel lockers in transit stations to improve service flexibility (Fessler et al., 2022). The benefits of PT-based CS systems are numerous, including lower cost, enhanced geographical coverage and the potential involvement of crowdshippers who are unable to drive.

5. Social and behavioural motives

5.1. Understanding players' characteristics

This section aims to summarise the literature characterising CS actors, with a focus on how they interact with each other.

Crowdshippers: One of the main challenges facing CS companies is to secure a reliable pipeline of individuals for delivery tasks. To achieve this, a platform needs to understand the characteristics of potential crowdshippers, their needs and behavioural considerations throughout the end-to-end CS process. Miller et al. (2017) studied the attributes of ODs choosing to work as part-time crowdshippers, specifically examining the likelihood of accepting delivery considering variables such as willingness to work (WTW). In contrast to WTP, which measures the trade-off between money and time saving, WTW determines the trade-off between an individual's time contribution and profit expectations. In this work, the acceptance likelihood was estimated using a mixed logit model developed based on survey data from the U.S. Results show that people in the mid-income range with a graduate degree are more willing to accept CS tasks. Furthermore, the median WTW estimated by this research was around 19 USD per hour. Similarly, Devari et al. (2017) studied a system in which friends or acquaintances of a customer in social networks act as crowdshippers, showing that nearly 72% of respondents would agree to deliver a package to their friends, from which 60% are willing to deliver for free, and 85% accept spending up to 15 min detouring from their regular trip for delivery. Marcucci et al. (2017) investigated the conditions under which students in Rome would be willing to act as crowdshippers. By surveying nearly 190 students, authors state that most students are unfamiliar with CS, but 87% of them would be willing to act as crowdshipper. Participation of students as crowdshippers would decrease to 55% and 40%, if the parcel is large and the reward is less than 5 Euros, respectively. Also, the maximum acceptable detour distance was around 1.5 km for carless students and 3.1 km for students owning private vehicles. Moreover, 57% of students acting as crowdshippers were unwilling to be tracked.

Studies such as Punel et al. (2018) explore the profile, behavioural factors, attitudes and preferences of crowdshippers when engaging in such activities. Using a binary logit model with an online survey conducted in the United States, Punel et al. (2018) showed that CS is more common among younger individuals, men, and full-time employees. Moreover, CS is more dominant in urban areas, where the delivery task requires medium-distance travel. Le and Ukkusuri (2019a) further explored behavioural considerations for engaging in CS work. Based on US-based survey and using a binary logit model, they reveal that parcel delivery experience, socio-demographic characteristics, and social media usage are key factors that influence respondents' decision to participate in CS. Furthermore, this study shows that crowdshippers' reimbursement expectation is correlated with their Value of Time (VoT).

An emerging stream of CS research focuses on examining parcel delivery using PT users (Marcucci et al., 2017; Serafini et al., 2018; Gatta et al., 2019a; Gatta et al., 2019b; Fessler et al., 2022). Conceptually, such services do not generate new dedicated trips for parcel delivery/collection and could potentially minimise the movement of delivery vans (and cars) in congested city centres. These PT-based CS systems predominantly utilise intermediary points such as parcel lockers to facilitate the process of picking up and dropping off parcels, which could have varying implications on the behaviour and preferences of PT users, receivers and CS platforms. Studies such as Serafini et al. (2018) and Gatta et al. (2019a) benefited from survey data to develop discrete choice models to explore the conditions under which commuters of the metro network would accept locker-to-locker CS tasks as part of their daily travel. Results of both studies show that PT passengers favour CS with lockers inside metro stations Furthermore, students show the largest marginal utility, while older and high-income passengers are reluctant to accept CS tasks. Fessler et al., (2022) used survey data of 524 respondents in the Greater Copenhagen Area with a mixed logit model to explore PT users' willingness to carry parcels on their trips. Results reveal that younger individuals, students, and employed and self-employed individuals, in that order, show the highest willingness to participate. Findings also show that the marginal disutility of time spent retrieving and dropping off parcels at lockers was higher for older (aged + 60) and higher income participants (i.e., earning more than 50,000 DKK/month), while it this figure was lower for people with lower educational levels (i.e., below 2 years education after high school). Fessler et al., (2022) also concluded that higher compensation rates increase the willingness to participate in CS, while increasing the number, size, and weight of parcels have negative impacts. Mohri et al., (2023b) modelled task acceptance behaviour in PT-based CS systems using a latent class choice model and survey data collected from 2208PT users in the Sydney metropolitan area. The latent class choice model was utilised to identify heterogeneous preferences for accepting CS delivery tasks, under different levels of offered incentives, package weight, and required detour distance at the destination. The study revealed three distinct user classes: leisurely, avid, and sceptical, comprising 19%, 53%, and 28% of the sample, respectively.

Receivers: For CS platforms, a preliminary step is to understand receivers' needs, expectations, and associated interactions. Marcucci et al. (2017) studied the conditions under which students in Rome would be willing to receive CS services. The results show that nearly 93% of students would be willing to act as a receiver and more than 80% expect to be able to track their parcels in CS systems. Devari et al. (2017) also showed that more than 60% of their study population were willing to receive their parcels through a CS service when delivered by friends or acquaintances in their social networks. Similarly, Punel et al. (2018) studied the attitude, preferences, and characteristics of customers who agreed to use CS for parcel delivery using a binary choice model and stated preference data. The results revealed that individuals with a strong sense of community and environmental concerns were more likely to use CS by 86.4% and 83.9%, respectively. However, individuals who had reservations regarding affordability and trust were less likely to use CS by 68.3% and 64.9%, respectively. In a similar study, Rai et al. (2021) employed a two-step clustering technique to examine receivers' preferences towards the use of CS. While the results showed low general interest in CS services, customers were supportive of neighbourhood delivery services. More specifically, Rai et al. (2021) stated that people who support CS were interested in LMD innovations and sustainability initiatives. Wang et al. (2023b) modelled factors influencing customers' adoption of CS delivery services based on the technology acceptance model (TAM) and norm activation model (NAM) considering trust, social influence and loss of privacy as explanatory variables. Through a cross-sectional survey of 2,333 participants in China, this study reveals that social influence and trust are the most influential factors in customers' acceptance of CS. In the same vein, the study of Cebeci et al. (2023) aimed to quantify the impact of trust on the receivers' choice between CS and professional courier delivery. To achieve this objective, a hybrid choice model with trust as a latent variable was developed and measured by indirect variables such as CS provider reputation, delivery damage likelihood, and insurance policy. Using data from the Netherlands, the authors conclude that reputation and the likelihood of damage significantly influence trust.

Senders: CS platform success is driven by the number of delivery tasks completed. Delivery tasks are predominantly initiated by senders in a CS system; hence, it is of utmost importance for a platform to sustain and improve its sender base (Dablanc, 2016). Punel and Stathopoulos (2017) studied senders' preferences for CS services by utilising a survey in the US. Multiple CS alternatives were offered to respondents to select from. The alternatives had specific attributes related to delivery distances, costs, durations, pick-up dates and times, and crowdshippers' experience and ratings. Using a multinomial Logit model, senders' utility function from each CS scenario was estimated. Results showed that for shorter delivery distances, senders highly regarded the transparency of the driver's performance along with delivery speed. However, for longer delivery distances, senders gave higher priority to delivery conditions and driver's training and experience.

CS platforms: Compared to other CS players, the academic literature on CS platforms is limited. According to Rai et al. (2018), CS is a new concept, hence platforms progressively alter their operations and strategies. The industry literature shows CS systems are either formal or informal. Formal CS systems are predominantly operationalised through digital systems. Ciobotaru and Chankov (2021) provided a comprehensive taxonomy of CS platforms operating across the world and reviewed their structures and business models. This study shows, existing CS platforms were mainly introduced by large international companies such as Amazon, Walmart, DHL, and Uber or smaller tech-based start-ups such as PiggyBee or Chronobee. Given its potential to create logistics value for different types of businesses, Bin et al. (2020) conducted a study of the factors influencing enterprises' willingness to implement crowd logistics systems. Using a technology-organisation-environment (TOE), authors concluded that a firm's absorptive capacity, relative advantage, market environment and external motivations are influential in the adoption of crowd logistics. CS could also take the form of informal models, for example, when players utilise social media platforms to connect, interact and execute delivery tasks (Guo et al., 2019). This form of CS could be popular for specialised and not-for-profit delivery services, including long-distance/overseas and healthcare deliveries (El Arifeen et al., 2013).

In summary, by examining the literature on players' characteristics, two behavioural instruments have received attention. First, one stream of research examines the intention of people to participate in CS work, and the other stream explores the willingness to accept CS service. The intention of participation approach provides insights into the characteristics and likelihood of engagement of potential users (Mohri et al., 2023a). On the other hand, acceptance of CS delivery by crowdshippers who have participated may vary depending on changes in parcel delivery characteristics such as incentives, types, and weight (Mohri et al., 2023b). Table 5 summarises the literature pertaining to these considerations, based on the method utilised and the region of study.

As shown in Table 5, in terms of methodologies utilised, basic discrete choice modelling such as binary logit and MNL techniques emerge as the dominant approach (Miller et al., 2017; Devari et al., 2017). On the other hand, recent studies, aim for more complex choice modelling approaches such as mixed logit and latent-variable models (Cebeci et al., 2023; Fessler et al., 2022). Furthermore, studies that aim to model the behavioural considerations of CS have mainly focused on one country, with no cross-regional comparison currently presented in the literature to explore cultural and social differences governing CS decisions.

5.2. *Trustworthiness*

Trustworthiness is an important behavioural consideration in CS systems that encompasses issues related to reliability, privacy, safety, security, and accountability. Strulak-Wójcikiewicz and Wagner (2021) examined five different CS platforms operating in Poland in terms of their structures, business models, managers' priorities, and community feedback. Results showed while the popularity of CS platforms is growing, users have concerns about their service quality and business model. It was also found that the platforms' managers are aware of trust-related concerns and associated impacts on their business (i.e., value creation and destruction). Studies such as Rougès and Montreuil (2014), Kafle et al. (2017), and Le et al. (2019) propose mechanisms to address the issue of trustworthiness in CS. In this section, we provide a summary of mainstream mechanisms reported in the literature that address trustworthiness. Platforms implement various strategies (e.g., removing information after order completion, concealing part of unnecessary information from crowdshippers) to protect sensitive and private information (Punel et al., 2018). The literature shows privacy protection remains a key decision-making factor for wider adoption of CS (Wang et al., 2023b). To improve confidence and engagement, many platforms utilise rating and feedback systems to understand the quality of the CS service provided by individuals. This feedback information can help senders and receivers in peer-to-peer systems to identify, rank and assign tasks to crowdshippers, appropriate to their performance and capabilities (Fessler et al., 2023). Insuring parcels is known as a mechanism to address concerns of CS users over problems related to the delivery of valuable and sensitive goods, damage, fraud, theft, and delayed deliveries. Crowdshippers also benefit from insurance provision that ease their concerns when moving expensive and/or hazardous parcels or unknown goods (He et al., 2023). Payments in Peer-to-Peer (P2P) CS platforms can cause concerns for both receivers and crowdshippers. Hence, some platforms provide a secure online payment system, by receiving the shipping fee from receivers in advance and then transferring it to either senders or crowdshippers, once the job is completed (Le et al., 2019). Furthermore, platforms employ systems to improve privacy and security when players communicate with each other. For example, some platforms provide secure direct messaging systems that enable receivers and crowdshippers to communicate with each other, without sharing their personal information (Marcucci et al., 2017). To ensure registered crowdshippers meet the minimum quality criteria and avoid scammers registering on the platform, many platforms conduct background checks such as a police clearance, interview and driving license for registration (Le et al., 2019). This is also known as a mechanism to protect platforms from potential reputational damage (Moayedikia et al., 2020).

The academic literature addressing the trustworthiness aspects of CS mainly focuses on models that involve community-based and informal approaches (Devari et al., 2017; Akeb et al., 2018; Boysen et al, 2022). For example, Devari et al. (2017) considered a CS model with friends or acquaintances of a customer on social networks as crowdshippers, which generally leads to less privacy, safety and reliability complications. Recently, one of Germany's largest online retailers and Walmart in the US invited their employees to deliver shipments after work to online customers living in their neighbourhoods (Bhattarai, A., 2017). Distribution centres and outlets could leverage their employees as a reliable and geographically diverse source of crowdshippers. Boysen et al. (2022) proposed the use

Table 5
Key aspects of behavioural studies on CS.

Reference	Player	Behavioural problem	Method	Case
Miller et al. (2017)	Crowdshippers (ODs)	Acceptance	DC: Mixed logit model	U.S.
Devari et al. (2017)			DC: Binary logit model	U.S.
Marcucci et al. (2017)		Participation	Descriptive analysis	Italy
Punel et al. (2018)			DC: Binary logit model	U.S.
Le and Ukkusuri (2019)			DC: Binary logit model	U.S.
Mohri et al. (2023a)	Crowdshippers (PT passengers)	Participation	DC: MNL model	Australia
Serafini et al. (2018)		Acceptance	DC: MNL model	Italy
Gatta et al. (2019a)			DC: MNL model	Italy
Fessler et al., (2022)			DC: Mixed logit model	Denmark
Mohri et al. (2023b)			DC: LC model	Australia
Marcucci et al. (2017)	Receiver	Participation	Descriptive analysis	Italy
Punel et al. (2018)			DC: Binary logit model	U.S.
Rai et al. (2021)			two-step clustering model	Belgium
Wang et al. (2023b)			TAE and NAM	China
Cebeci et al. (2023)		Acceptance	DC: latent variable choice model	Netherlands
Punel and Stathopoulos (2017)	Sender	Acceptance	DC: MNL model	U.S.
Bin et al. (2020)	CS platform	Participation	TOE Model	China

DC: Discrete choice; MNL: Multinomial logit; LC: Latent class.

of employees as crowdshippers with the objective to maximise the number of matched shipments, while satisfying the minimum expected earning of employees.

A handful of academic studies have looked at more formal mechanisms such as insurance. He et al. (2023) state that in China, CS platforms such as Dada Now and UU Runner have introduced value-insured services to enhance the trustworthiness of their systems and attract more users. In He et al. (2023), the authors examined the impact of three value-insured schemes of revenue-sharing, fixed-fee and reinsurance on the profitability of CS systems. Using a game-based approach model in which the CS platform is the leader, and the insurance company is the follower, the authors conclude that the reinsurance scheme is the preferred option when the average declared value is below a specific threshold. However, the fixed-fee scheme is more advantageous when the average declared value exceeds the said threshold.

6. Conclusion

With growing interest among researchers and industry practitioners in crowdsourced delivery systems as a sustainable LMD solution, this paper offers a comprehensive taxonomical review of such systems, with a specific focus on the triple bottom line concept. By synthesising the extant literature, it became evident that there was an absence of review unpacking the sustainability implications of CS. By acknowledging this gap, we explored several considerations of CS, including operational models, service offerings, and agents involved, under the lens of sustainability main pillars, namely, economic implications and considerations, environmental and societal outcomes. This conceptualisation allowed us to further inform the nexus between CS research and sustainable urban distribution, the underlying methodologies, and particularly breaking the stereotypes around the promised benefits. Furthermore, through our extensive review, we have identified and evaluated the critical success factors and conditions in which CS could contribute to sustainable city logistics.

The primary objective of CS is to leverage on underutilised crowd and associated resources to facilitate the delivery of goods, while meeting economic, social and environmental objectives. CS has the potential to reduce the environmental impacts of urban delivery tasks while supporting low-income participants and developing community by creating social constructs in markets that are not traditionally studied in the literature. Moreover, by reviewing CS applications, we conclude that CS has been mainly proposed as an LMD solution for food delivery and e-commerce, which explains why the majority of studies aim to address economic aspects such as profit maximisation through the development of task assignment tools and detour management. On the other hand, the application of CS in markets such as healthcare and reverse logistics, which are more aligned with environmental and humanitarian objectives, is very limited. Furthermore, we emphasise that changing economic conditions such as volatile job markets could have profound impacts on both supply and demand sides of CS. The literature, however, does not reveal any insights on how such macro-economic factors could impact the operational and financial viability of CS platforms. This is of particular importance for those start-up companies providing CS services. While this research aimed to investigate CS from a sustainability point of view, our observations indicate that the literature eliciting the interplay of economic, social and economic aspects of this topic is unusually scarce. For CS, as a human-centric business paradigm, the extant body of literature predominantly focuses on addressing the economic problems using mathematical approaches, although few studies such as Qi et al., (2018) and Tapia and colleagues (2023) follow a multi-objective approach (e.g., maximising profit, while minimising environmental impacts of CS) in their design. From this review, we recommend the following directions pertaining to the intersectional aspects of sustainability for future research:

CS for social good and humanitarian markets: Several incentive-based models exist for CS. While financial reimbursement methods have been largely discussed using dynamic and fixed payment practices, CS has also been proposed as a platform for humanitarian logistics via the voluntary participation of crowdshippers or senders (Mittal et al., 2021; Manshadi and Rodilitz, 2022). Modelling the intention to participate in such activities is challenging due to the absence of non-monetary and social currency. Therefore, the socio-economic utility of CS for voluntary work presents a research gap, which could facilitate the uptake of CS for humanitarian purposes.

Flexible workforce base: While the benefits of CS systems have been mainly studied from the perspective of technology-based platforms, logistics service providers such as traditional couriers could leverage on a large pool of dormant resources and people when coping with high demand. More specifically, CS can be seen as a solution to address the challenges of courier workforce shortage and over-supply when demand is volatile. For example, during the COVID-19 lockdowns, when demand for home delivery surged and delivery worker supply was limited, CS approaches could be utilised to improve access to essential goods in both B2C and B2B applications. However, we suggest future research be undertaken to identify appropriate business models to protect workers' rights and avoid potential exploitations while addressing the resilience and responsiveness of such systems. While the early research in crowd logistics provides the taxonomical perspective of the nexus between crowdsourcing and logistics work (Mladenow et al., 2016; Carbone et al., 2017), we recommend future empirical research to demystify the concept of fairness in both centralised and decentralised CS models (Ermagun et al., 2020a;2020b).

Behavioural consideration of crowdshippers: The literature of CS is mainly concentrated on optimisation studies, particularly the development of task assignment, supply and demand analytics, as well as pricing and compensation schemes to increase the operational and financial performance of platforms. In other words, the extant literature largely ignores the behavioural components of engaging and interacting with users. Recent studies such as Mohri et al. (2023a) highlight crowdshippers' concerns over security, availability, flexibility, safety, and responsibility besides monetary incentives are key prohibiting factors for participation in CS. Accordingly, qualitative and behavioural studies are suggested to further understand, model and simulate human agents, specifically, we recommend the application of choice modelling, agent-based systems and game-based optimisation. Furthermore, trustworthiness is an under-studied topic in CS literature, which could create significant value for users if managed appropriately. Given this research gap, we recommend qualitative studies followed by behavioural and system performance evaluation (i.e., measuring the trade-offs between trust and its impacts on supply, demand, and matching processes) to further measure the value of trustworthiness in CS systems.

Regulations and the role of government: Despite its potential to create social value and sustainable outcomes, CS and other sharing economy models have been criticised for unfair compensation and poor working conditions (Schor and Attwood-Charles, 2017). Existing regulatory frameworks used for traditional markets do not necessarily support a balanced approach between economic outcomes and the risks associated with not addressing safety, privacy and social inclusion. It is expected that appropriate regulatory frameworks could act as an enabling mechanism for the uptake of CS-like solutions to effectively respond to the growing sustainability challenges of transport systems. Additionally, the intersection of technology and regulation is an unexplored area. For example, how could appropriate technological solutions such as location-based and context-aware mechanisms improve safety, security and establishment of the chain of custody?

Collaborative consumption: CS predominantly involves the provision of transport services. In a humanitarian context, delivery services could accompany other value-adding services. For example, similar to the work of Behrend et al. (2018; 2019) on item-sharing, delivery services could incorporate other collaborative consumption models with various sustainability benefits. In this context, CS could be utilised for second-hand markets, increasing the total economic utility for both sellers and buyers. As second-hand household items have lower prices, the use of commercial delivery services is not always viable. As a result, CS could create further utility in second-hand markets. In terms of new market creation, existing CS initiatives focus on short-distance lightweight delivery within urban environments. However, CS can be used for inter-city and inter-region services, similar to carpooling systems to minimise externalities. CS services can also be utilised for addressing the problem of reverse logistics, particularly the return of unwanted or defective products from consumers to distribution and/or disposal points (Upadhyay et al. (2020). Cost-efficient and accessible return services, through CS, would reduce the environmental effects of end-of-life or defective items.

Technology to support Crowdshippers: In essence, CS is facilitated via online platforms and mobile devices. Advanced geo-locational tools such as trajectory analytics could provide significant benefits to both crowdshippers and CS platforms. More specifically, in CS systems utilising ODs, understanding the spatiotemporal patterns of crowdshipper is critical. Such mechanisms support efficient task assignment by identifying the right crowdshipper for a delivery task, leading to reduced trip detour and environmental footprint, convenience, optimised reimbursement and higher participation in CS. To date, limited number of studies have explored the use of such techniques, mainly due to a lack of real-world data, computational complexities and challenges in modelling crowd behaviour (Ghaderi et al., 2022a,2022b).

Coopetition and resource sharing: Coopetition refers to the act of collaboration among competing firms. Competing CS platforms could create win–win situations when resources are constrained. By considering 'platform-to-platform' interaction, one CS could trade a delivery request to another when there is no suitable crowdshipper available in their pool. Furthermore, when a delivery task is complex, appropriate systems could support task sharing and joint delivery. How such interactions could be managed on a large scale, either as one-to-one or many-to-many interactions, is an important area of research for future studies. Furthermore, facility and infrastructure sharing could be another subject of collaboration in which platforms share the capacity of their existing resources such as depots, TPs, and ADPs.

In the end, we acknowledge that our study has some limitations. First, this work mainly incorporates quantitative studies, thus, qualitative works such as exploratory and conceptual studies were excluded from our analysis. Since CS is an emerging field with an important human interface, we suggest future studies and reviews to further demystify the behavioural aspects of CS through qualitative and case study approaches. Second, the scope of work was limited to journals associated with transportation, logistics, operations research and management. In recent years, CS is becoming a topic of interest among computer and data scientists, who employ a different set of methodologies. Hence, future review works could focus on such streams, and subsequently, compare methodological differences with what we have presented. Specifically, the applications of mobile computing and artificial intelligence to support real-time CS task assignment and pricing optimisation is a potential avenue.

CRediT authorship contribution statement

Seyed Sina Mohri: Conceptualization, Methodology, Writing – original draft. **Hadi Ghaderi:** Conceptualization, Supervision. **Neema Nassir:** Conceptualization, Supervision. **Russell G. Thompson:** Supervision.

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

No data was used for the research described in the article.

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