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Review

Supply, demand, operations, and management of crowd-shipping services: A review and empirical evidence

Tho V. Le[a], Amanda Stathopoulos[b], Tom Van Woensel[c], Satish V. Ukkusuri[a,*]

[a] Lyles School of Civil Engineering, Purdue University, West Lafayette, IN 47907, USA
[b] Department of Civil and Environmental Engineering, Northwestern University, Evanston, IL 60208, USA
[c] School of Industrial Engineering, Eindhoven University of Technology, Netherlands

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 promises social, economic, and environmental benefits covering a range of stakeholders. Yet, at the same time, many crowd-shipping initiatives face multiple barriers, such as network effects, and concerns over trust, safety, and security. This paper reviews current practice, academic research, and empirical case studies from three pillars of *supply*, *demand*, and *operations and management*. Drawing on the observed gaps in practice and scientific research, we provide several avenues for promising areas of applications, *operations and management*, as well as improving behavioral and societal impacts to create and enable a crowd-shipping system that is complex, yet, integrated, dynamic and sustainable.

1. Introduction

Crowd-shipping (*CS*) is an emerging trend in freight transportation, primarily accelerated by the rapid development of app-based platform technologies that facilitates the connection of *supply* with *demand*. *CS*, alongside other emerging sharing-economy phenomena, is still in transition, and researchers have defined the field in various ways. McKinnon (2016) states "*CS* can be conceived as an example of people using social networking to behave collaboratively and share services and assets for the greater good of the community as well as their own personal benefit." Moreover, Lam and Li (2015) define *CS* as "a web or mobile-based courier service which leverages large groups of geographically dispersed individuals to match *demand* with *supply* digitally" (Fung Business Intelligence Centre, 2015). Punel and Stathopoulos (2017), however, consider *CS* as "a goods delivery service that is outsourced to occasional carriers drawn from the public of private travelers and is coordinated by a technical platform to achieve benefits for the involved stakeholders".

In this paper, we follow the broader definition by Buldeo Rai et al. (2017) who describe *CS* as "an information connectivity enabled marketplace concept that matches *supply* and *demand* for logistics services 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".

The selected couriers may be closest to the delivery route (Dash, 2014), offer the cheapest delivery fee, or have the best reputation in the system platform. While minor differences in the definitions of *CS*, on-*demand* delivery, crowdsourced delivery, and crowd-logistics are present in the literature, this study uses those terms interchangeably and defaults to the definition of Buldeo Rai et al. (2017). Moreover, couriers, *driver-partners*, or *CS* drivers are all defined as the actors who transport freight. Senders are actors who request to send the shipment via *CS*. The *CS* system conceptualization is displayed in Fig. 1.

* Corresponding author.
E-mail address: sukkusur@purdue.edu (S.V. Ukkusuri).

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Fig. 1. Conceptualization of a *CS* system.

Building on the sharing economy popularity, technological developments, and widespread wifi and smartphones, app-based *CS* start-ups are being launched worldwide. An app-based *CS* service provides a common platform where senders can announce their need for shipping freight and receive offers from system couriers. Furthermore, parties who are willing to carry packages, offer cost-effective logistics services for requests from the same platform (Botsman, 2014). In general, *CS* drivers can be categorized into three groups: (1) traditional logistics carriers (e.g., DHL or FedEx), (2) professional drivers, who engage in *CS* during their free time or utilize their unused vehicle capacity, and (3) the general public, who travel anyway (e.g. students, commuters, and retirees) (Botsman, 2014). *CS* operators either employ drivers directly or solely provide a common platform to match senders and couriers; with couriers from the second and third categories mentioned above.

CS platforms include a common set of features, with the objective of ensuring user's satisfaction, and delivery safety, and security. A rating system allows senders and couriers to evaluate each other and provide testimonials for future users (Punel and Stathopoulos, 2017). Real-time tracking and notification services supply both senders and couriers the exact freight location in real time (Le and Ukkusuri, 2018a). *CS* platforms typically provide a personalized delivery-time window option to reduce the rate of missed deliveries (Le and Ukkusuri, 2019).

In tandem with a rapidly growing and evolving market, the research community has investigated *CS* systems from a number of different angles in recent years. However, the bulk of these studies focus on specific research areas within a single system domain (e.g. operations with ad-hoc drivers). Furthermore, there are currently only a few studies which provide a comprehensive synthesis of the existing body of literature and provide recommendations for future research in this area, including *CS* practice gaps. Additionally, existing studies do not base their recommendations on empirical data. Therefore, there is a need for a review of both the state-of-the-art literature and the current *CS* practice.

Accordingly, the objectives of this study are first to review previous *CS* research and practical projects under three pillars: (i) *supply*, (ii) *demand*, and (iii) *operations and management*. The literature analysis is augmented by presenting recently collected CS data in each section. Previously unpublished analysis and graphs are presented to emphasize and interpret several salient *supply* and *demand* features. Finally, we identify the gaps of *CS* systems' implementations and provide suggestions to improve future design features of *CS* platforms.

This paper is organized as follows. Section 2 presents the research methodology. Section 3 reviews current *CS* research and practice which are supplemented and enriched by the authors' data. Section 4 summarizes the potential future topics of interest, gaps in implementing *CS* services, and several avenues for improving behavioral and societal impacts. In Section 5, this paper is concluded and possible directions for future research are suggested.

2. Methodology

CS is a topic of growing interest in the research community in the last five years. Using the keywords "*Crowd-shipping*," "Crowdsourced delivery," "Crowdsourced deliveries," "Crowdsourcing delivery," "Crowdsourcing deliveries," "On-demand delivery," "On-demand deliveries," "Crowdsourced logistics," and "Crowd logistics", we performed our search on the principal online literature databases, including Google Scholar, ScienceDirect, Taylor & Francis, and ResearchGate. We found a total of 57 conference proceeding, white papers (CW) and journal papers, book chapters, and dissertations (JD) directly related to *CS* (as of August 30th, 2018). As can be seen in Fig. 2 the number of *CS* publications emerged in 2012 and increased markedly in the last three years.

Following an examination of the literature and real market structure, this review is structured in three main themes, namely *supply*, *demand*, and *operations and management*. As a unique feature of this review, the authors incorporate unpublished empirical results from real operations and surveys. This adds important illustrations of unique realistic features and challenges of these platforms to strengthen the discussion and suggestions for practice.

- The first dataset (hereafter DATA1) is obtained from a survey, conducted from January to April 2017 in the United States (US). The dataset includes 549 respondents who answered questions about respondents' past shipping or ordering behaviors; courier-selection behaviors (stated preference); courier's history and preferences; willingness to join *CS* system behaviors (stated

Fig. 2. Plot of numbers of published papers per year in *CS* (as of August 30th, 2018).

preference); and socio-demographic characteristics. For more detailed information on the survey design, implementations, and descriptive analysis, readers are referred to Le and Ukkusuri (2018a).

- The second dataset (hereafter DATA2) used in this study is a US survey including a choice experiment of sender's decision between *CS* and traditional options in different shipment contexts. The survey was designed to study barriers and motivations to CS usages, as well as sender orientation towards sharing services more broadly. Data was collected in June 2016 from 533 respondents. Detailed sample and experiment descriptions are given in Punel and Stathopoulos (2017).
- A third dataset (hereafter DATA3) represents real *CS* operations by US users of a leading *CS* platform. DATA3 covers two continuous years of operation from the start of 2015 to the end of 2016 with a total of 16,850 delivery requests, including timing, shipment attributes, and user characteristics. More details are available in Ermagun and Stathopoulos (2018).

While DATA1 and DATA2 are smaller data-sets with deep information about users and a detailed representation of the choice process derived from choice experiments, they suffer from a potential risk of hypothetical bias (Murphy et al., 2005; Hensher, 2010). However, these two datasets are complemented by DATA3 given more representative real-world *CS* decisions and outcomes.

CS components, relationships, challenges, and potential benefits are summarized from inner to outer circles, in Fig. 3. The two inner circles display topics which are the focus of our review in section three, namely *supply*, *demand*, and *operations and management*. The second largest circle, however, shows challenges to the *CS* industry, for instance, network effects, trust, safety, security, legal (Rougès and Montreuil, 2014; Sundararajan, 2015; McKinnon, 2016; Torpey and Hogan, 2016; Jones, 2016; Hutton, 2016; Guardian editorial, 2016; Marx, 2016; Heller, 2017), innovations, and platform design features which will be addressed for future improvements in Sections 4.1 and 4.2. The outermost circle presents the expected *CS* benefits, such as faster delivery time, lower delivery cost, more flexibility, improved accessibility, sustainability, and employment opportunities (Rougès and Montreuil, 2014; McKinnon, 2016). To realize these benefits, several main channels are discussed in Section 4.3, for example, transportation system performance, industry competitiveness, consumers, labor market and regulation, and community and social connectivity.

3. Review, synthesis, and trends analysis

Given the emerging *CS* industry, most relevant studies are published within the last few years. Some researchers have reviewed *CS* operators and studies, such as Rougès and Montreuil (2014), McKinnon (2016), Buldeo Rai et al. (2017), Dablanc et al. (2017). Our research, however, brings an additional perspective to the existing reviews. Specifically, we study the three fundamental pillars in a *CS* system, namely the '*supply* side', '*demand* side', and '*operations and management*'. This distinguishing angle of analysis allows us to explore in depth, using a range of literature sources, the functioning of *demand* versus *supply* and how they come together to define the performance of *CS*.

For each subsection, we review evidence from three sources 'Industry and business perspective', 'Operations and stakeholders', and 'Empirical results'. The 'Industry and business perspective' subsection illustrates and discusses various practice cases and pilots which were implemented or are ongoing. The 'Operations and stakeholders' subsection presents a number of current academic studies. 'Empirical results' includes unpublished findings and illustrations from our surveys or data from industry collaborations.

3.1. Supply side

It is clear that the *supply* of resources needed for *CS* is different than traditional delivery processes, where drivers are on the payroll of a logistics service provider. In the latter case, operations and drivers are centrally managed, and deliveries are planned by these companies. Accordingly, drivers are expected to be available whenever needed (assuming good planning processes). In a *CS* context where the drivers are participating in the market mostly on a voluntary basis, their availability and their willingness-to-work are important aspects that need to be considered.

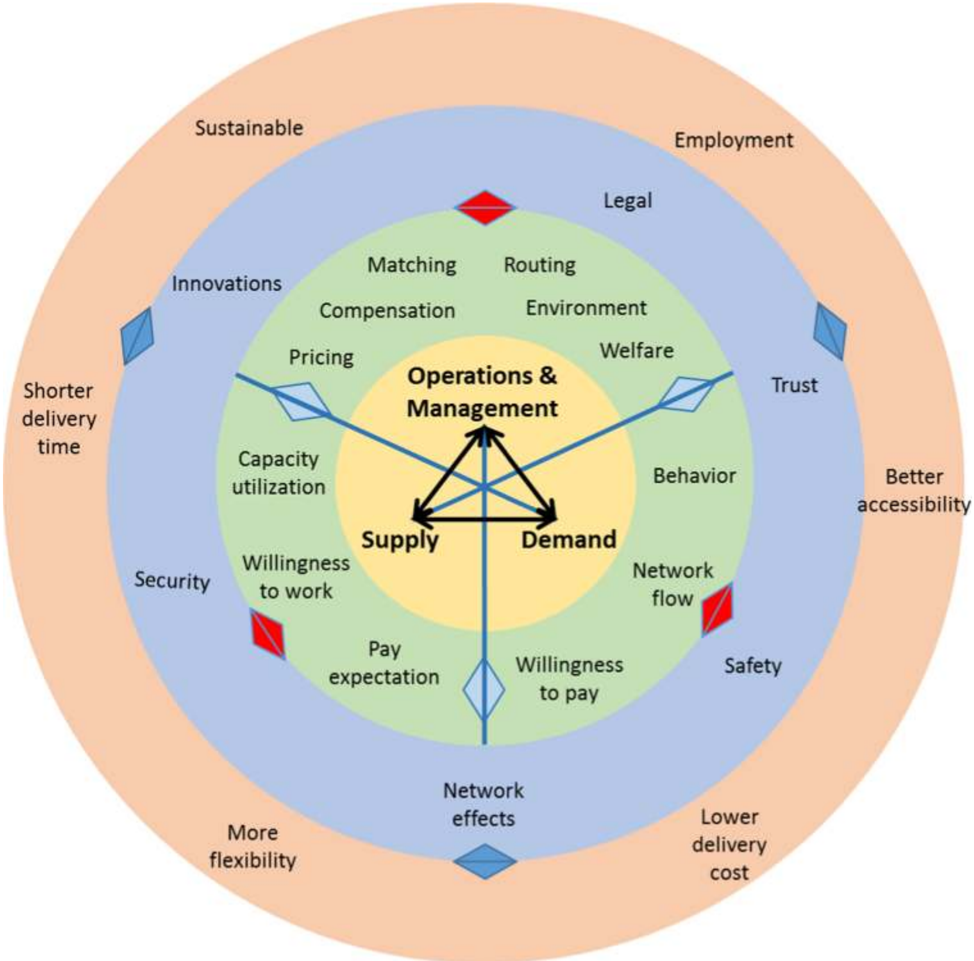

Fig. 3. *CS* components, relationships, challenges, and potential benefits (ordered from inner to outer circles).

On-demand services typically make use of independent providers (e.g., the crowd) to fulfill customer requests quickly and are paid accordingly. Work participation is highly dependent on actual earnings. Hence, the compensation paid for drivers is a key driver for *CS* success and their willingness-to-drive.

3.1.1. Industry and business perspective

Cargo hitching is a concept where the *integration of freight and passenger transport* plays an important role in efficient and reliable delivery services. Clearly, people and goods share the same infrastructure and might thus be combined into the same type of (people-based) transport resources, e.g. taxi, metro, bus, train, etc. (Trentini et al., 2010; Fatnassi et al., 2015). As such, this concept exploits the spare capacity available in public transportation networks.

In practice, cargo hitching applications already exist in long-haul transportation, i.e. airlines and rail, where both cargo and people are moved using the same resources. See, for example, applications like the DHL PostBus (DHL, 2015), where parcel transport and passenger service on long-distance intercity bus networks are managed. On the other hand, short-haul applications are limited. Effective and efficient coordination and synchronization are challenging. Moreover, so far only a limited number of research efforts are seen in the literature. Research which ranges from the use of scheduled transportation lines to the flexible use of taxis is presented in the next section.

Traditional logistics carriers (e.g., DHL), tech-based firms (e.g., Instacart, Google (Express), Facebook (Order food), and Uber), and major retailers (e.g., Amazon and Walmart) directly or indirectly hire crowds for delivery. These crowdsourced shipping service platforms vary from international (e.g., Shipyzi, Entruster, and Piggybee), long haul (e.g., Roadie, Gogovan, and Trucker Path), short haul (e.g., Cargomatic, Convoy, and Shipster), to last-mile delivery (e.g., Amazon Flex, Instacart, and UberEats). Many crowdsourced delivery services have been implemented in urban areas where most of the world's population currently live (United Nations, 2014). For example, Amazon has its own delivery fleets and has long been considering crowdsourced delivery. In 2014, Amazon tested taxis for a speedy delivery service in some California cities, but the experiment was not expanded (Bensinger, 2014). In 2016, the company introduced Amazon Flex, a delivery service that hires ordinary people to deliver a range of packages, mostly food and other grocery

Table 1
Crowd-shipping platform providers (Dablanc et al., 2017) (* means the platform provider offers more than one delivery service).

Range	CS firms	Unit size	Market segmentation	Vehicle
Urban	BigFoodie, Deliveroo, Delivery.com*, DiningIn/ Labite, Ele.me, FoodExpress, Foodora/Hurrier/ Suppertime, Gousto, Jinn*, Just Eat Delivery, Marley Spoon, Mesh*, Postmates*, Uber Eats	Parcel	Prepared meals, Meal kits	Bikes, Scooters, Cars, Vans
Urban	Delivery.com*, Ebay Now*, Google Express*, Instacart*, Jinn*, PiggyBaggy, Postmates*, Yihaodian*	Parcel	Grocery	Bikes, Scooters, Cars, Vans
Urban	Delivery.com*, Minibar	Parcel	Beverage, Wine, Alcohol, Spirits	Bikes, Scooters, Cars, Vans
Urban	Delivery.com*, Laundrapp, Laundry Republic	Parcel	Laundy	Vans
Urban, Regional, Long distance	Amazon Prime, Ebay Now*, Google Express*, Instacart*, Jinn*, Mesh*, MyWays, Nimber, Postmates*, Roadie, Yihaodian*	Parcel	Retailing	Bikes, Scooters, Cars, Vans
Urban Urban, Regional, Long distance	Box2 Home, BuddyTruck, FleetZen, Ghosttruck Baghitch, UberVan, UberFreight	Parcel, Bulky goods, Oversize	Furniture, Moving, Others	Vans, Pickups

products. This service is available in more than 30 US cities (https://flex.amazon.com/). Likewise, DHL has just started the "Parcel Metro" service in Chicago, Los Angeles, and New York City in March 2018 which use crowd-sourced and contract couriers. Uber, recently, has captured public attention by discussing the purchase of the food delivery company Deliveroo aiming to expand its market to Europe (https://www.bloomberg.com/news/articles/2018-09-20/uber-is-said-to-be-in-early-talks-to-buy-europe-s-deliveroo).

In addition to partnering with FedEx for package delivery, Walmart has its own Walmart Grocery Service (formerly Walmart To Go) delivery trucks. The Walmart Grocery program allows customers in some areas to order online and have packages delivered during a designated time window. Moreover, Walmart has also been testing *CS* for last-mile delivery. In 2013, Walmart introduced a program in which customers deliver packages to online buyers (Barr and Wohl, 2013). This program intended to shorten delivery times and cut transportation costs to compete with Amazon. In 2016, Walmart piloted delivery with Uber, Deliv, and Lyft (Bender, 2016). Walmart also implemented a 2017 project in which employees voluntarily delivered packages on their way home from work (Bhattarai, 2017).

Dablanc et al. (2017) studied 36 *CS* platform providers (Table 1) which mainly provide services in urban areas. Those firms build on-line platforms to connect senders and driver-partners. In general, *CS* on-line platforms facilitate real-time communication and tracking and tracing services which are more advanced than traditional logistics carriers. Additionally, *CS* potentially brings social, economic, and environmental benefits for stakeholders (Rougès and Montreuil, 2014). In fact, *CS* service users and driver-partners tend to be more comfortable using digital platforms (e.g., via smartphones or computers). The digital platform, however, is a barrier for population segments that lack access to connected device technology or a transaction account. A significant part of *CS* activities is happening via digital platforms. Section 3.3.1 discusses the main differences in firms' *pricing* operations and strategies.

Drawing on interviews with retailers, manufacturers, and logistics service providers, Buldeo et al. (2018) found the top three factors that influenced the success of platform providers are "happy crowd" (38.24%), "good service" (27.36%), and "maximum profit" (18.32%). On the other hand, "compensation" (45.36%), "good working environment" (27.05%), and "good platform operation" (16.88%) were the most important factors influencing the willingness to work among potential crowd-drivers.

3.1.2. Operations and stakeholders

- *Operational analysis*
  Scheduled transportation lines, like buses and trains, face a lot of under-utilization of their capacity for a significant amount of time. Clearly, based on contractual agreements, these resources need to be operated based on a given minimal fixed schedule, regardless of the actual passengers need. Due to those correlations, utilizing public transportation capacity is further discussed among the operations strategies which will be presented in Section 3.3.2.
  Taxis are more flexible as passengers determine pickup and delivery locations as well as times. Within a narrow interpretation of crowd logistics, taxis can thus be used to move freight within the city. This business model will be jointly discussed with *operations and management* strategies shown in Section 3.3.2.
  Alternatively, traditional logistics carriers may outsource packages to optimize their business (e.g., during peak-*demand* time). Given that some people are willing to make a single delivery for a small incentive, Archetti et al. (2016) developed a multi-start heuristic model that confirmed the reduction of delivery costs for traditional logistics firms depending on the number and flexibility of occasional drivers as well as the compensation scheme.
- *Behavioral analysis and surveys*
  Despite the fact that many studies proposed feasible *CS* system solutions, a few studies focused on the *behavior* of system stakeholders. A central question investigated is the *driver-partner's* willingness to work as carriers. Findings vary significantly,

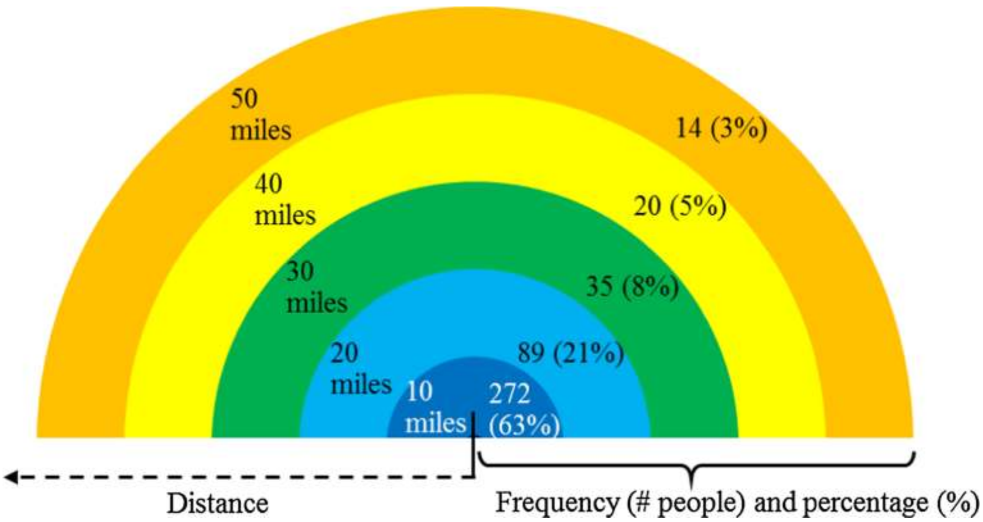

Fig. 4. Potential *driver-partners'* distance tolerances (based on original trip of 5 miles) and distributions.

whereas between 30% to 87% of respondents are willing to work for *CS* systems (Briffaz and Darvey, 2016; Marcucci et al., 2017; Miller et al., 2017; Devari et al., 2017; Le and Ukkusuri, 2018b). More broadly, the influencing factors on driver *behaviors* have been examined. Punel and Stathopoulos (2017) investigated potential senders' preferences for *CS* driver performance. Among the most notable findings, the driver reputation was in many settings even more influential than the delivery cost and speed. In a US study focusing on the crowd-courier decision to accept a delivery, commuters traveling for leisure or with more flexible schedules were most likely to be willing to work as occasional drivers, according to Miller et al. (2017). Le and Ukkusuri (2018a) presented a descriptive analysis of requesters and potential *driver-partners* using novel data collected from Vietnam and the US. In another study, respondents who had experience transporting freight or goods were more willing to work as *driver-partners* (Le and Ukkusuri, 2018b). Marcucci et al. (2017) found that 87% and 93% of Italian students were willing to work as *driver-partners* and receive their packages via a *CS* system, respectively. Briffaz and Darvey (2016) conducted research on *CS* in Geneva. Their literature review and surveys concluded that stakeholder expectations varied, which created additional barriers and challenges in the implementation of *CS* systems.

3.1.3. Empirical results

Fig. 4 displays distance tolerances of *driver-partners* from DATA1. Given the original trip distance of 5 miles, over 63% and 21% of respondents were willing to divert up to 10 miles or 20 miles to pick up and deliver packages, receptively. Fig. 5 shows respondents' expected compensations. Interestingly, about 53% of respondents were willing to deliver packages at \$10 or less (i.e. equal to around 67% of the cost charged by the traditional logistics carrier which represented the base case of \$15). Important to realize, about 89% of potential *driver-partners*, in total, charged \$15 or less for their delivery trip. Moreover, respondents from the same survey also showed their interest in working as *driver-partners* at most times, except weekend evenings or after midnight, as can be seen from Fig. 6. The time flexibility of potential *driver-partners* greatly facilitates *CS* companies ability to outsource packages once the *demand* exceeds their *supply*. In fact, there are a few studies on distance tolerances, respondents' expected compensations, and working time perceptions.

3.2. Demand side

This section summarizes the existing literature and points out the findings and gaps in understanding concerning the role and impact of *CS* from the *demand* perspective.

The main players that generate *demand* for *CS*, in the role of senders and receivers, are individual customers from the crowd, often in the form of e-tailers, retailers and logistics businesses, sending by themselves, or acting as brokers (Buldeo Rai et al., 2017; Sampaio et al., 2017). Zooming in on the characteristics of the *demand* for *CS* is essential to understand the potential societal impacts of the shift of freight deliveries to the crowd. The network flow of *CS* packages is indeed determined by the spatial (as well as temporal) *matching* between sender's locations and courier's routes (McKinnon, 2016). In other words, senders dictate the origin-destination dynamics of the shipments, and thereby how efficiently the *matching* can be done. This locational analysis is further complicated by e-tailing and customers propensity to accept delivery to lockers and other intermediary locations rather than home delivery.

The following sub-sections will highlight the findings from different research areas, from case-studies to operational analysis and empirical works. Each subsection will discuss findings related to; (a) the customer/receiver characteristics, (b) spatio-temporal aspects, (c) behavioral aspects.

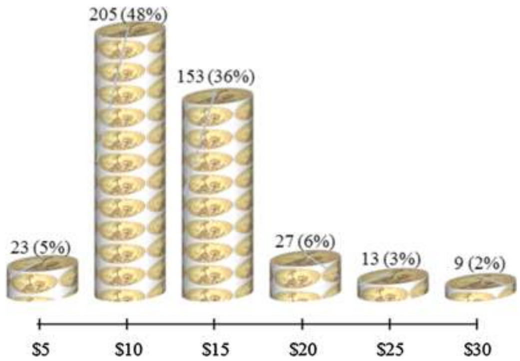

Fig. 5. Frequency (# people) and percentage (%) of potential *driver-partners'* expected compensation (base rate of $15).

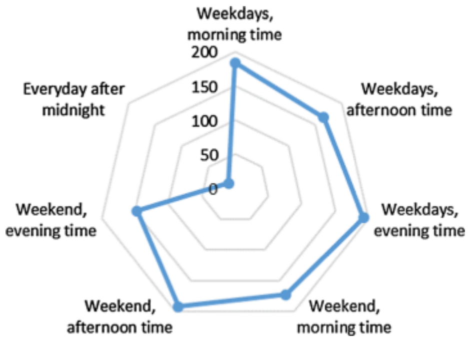

Fig. 6. WTW at a different time of the day and day of the week (multiple-choice question) (numbers represent frequency (people)).

3.2.1. Industry and business perspective

A number of researchers identify the factors that are most essential to understand the customer demand perspective drawing on business analyses and case studies. Carbone et al. (2017) study 57 crowd logistics initiatives and carry out content analysis on company website data. The authors find that linked to *CS* system performance and impact, the focus of *CS* operations is predominantly at the local scale. The paper highlights that not just transportation, but also handling and storing are affected by crowdsourcing. In each value chain, the common feature is the increasingly active role of the customer. Frehe et al. (2017) highlight the importance of service platform usability and customer trust in the crowd logistics company, along with the service itself, as the core features to augment *demand*. Furthermore, qualitative delivery (29.29%) and pickup (22.64%) (i.e. personalized, on time, undamaged), and *environmental* friendliness (20.76%) play the most significant role for customer *demand* (Buldeo et al., 2018).

Moreover, a few works have explored customer acceptance from revealed data. Among the limited empirical examples are Ermagun et al. (2018) and Ermagun and Stathopoulos (2018) who model real *CS* operations from a 2-year database of US crowd shipments from 2015 to 2016. Ermagun and Stathopoulos (2018) show that couriers are less likely to bid on shipments from senders that ship long distances, across state boundaries or who request strict delivery deadlines. Ermagun et al. (2018) compare *CS* performance in urban and suburban areas. Whether the sender is a business or an individual is among the most consequential for determining the delivery performance. The perceived reliability of a business sender appears to be the driving factor behind the improved performance.

Regarding potential market segments, Dablanc et al. (2017) surveyed 36 *CS* firms and found prepared meals, groceries, retailing goods, and laundry are the most common delivery items. A few *CS* firms provide services for delivering books, wines, alcohols, beverage, furniture, or moving services. The market segmentation and associated *CS* service providers will be summarized together in Section 3.3.1.

3.2.2. Operations and stakeholders

- *Operational analysis*

  Promoting public acceptance of *CS* along with the growth of customers willing to use *CS* is essential for 'the chicken and the egg problem' related to the scalability of *CS* (Rougès and Montreuil, 2014; Goetting and Handover, 2016; Frehe et al., 2017). Indeed, the customer base needs to grow on par with the couriers managed by *CS* platforms for the new system to be viable.

  There is a growing body of work in the operation and optimization literature on crowd logistics. While these works typically do not explicitly study the behavior of senders, the assumptions about sender locations and motivations are valuable to gain theoretical insight about the important dimensions and their impact.

The question about the location of *demand*, and hence the feasibility of minimal detours by carriers, and the creation of efficient logistics networks are explored in several works. Specifically, existing studies have explored the spatial feasibility of *CS* by mining data from location-based social networks (Sadilek et al., 2013; Yu et al., 2016) or inferring geolocations from mobile phone cell towers (McInerney et al., 2013; Yu et al., 2014) or mining GPS logs from taxi services to represent the potential for developing *CS* (Chen et al., 2014, 2017b).

These studies show how optimization analysis exploring *CS* frequently incorporates the customer perspective in the frameworks. However, this inclusion is not always based on actual behavioral findings.

- *Behavioral analysis and surveys*

Meanwhile, behavioral research has been carried out using hypothetical choices of *CS* services. Devari et al. (2017) bring to the fore customer's concerns about reliability, privacy, and accountability when contemplating the use of *CS* services. The authors employ a US survey (n = 104) to show that a majority of respondents will, however, consider shipping via the crowd from an acquaintance and that the proximity between the sender-driver dyad is crucial. Based on these insights, the authors define a realistic case-study for Alexandria, Virginia, relying on social networks to overcome customer reluctance and build a crowd-delivery system.

Le and Ukkusuri (2018a) study the priorities of both requesters and carriers using on-line surveys from 2017 administered in the US (n = 722) and Vietnam (n = 617). Requesters were found to favor CS carriers for specific goods categories such as dry cleaning, groceries, and home-delivered food, entailing higher delivery fees and requirements on delivery times. Instead, traditional carriers were preferred for less urgent goods, with an associated lover delivery cost. The main concern among the US and Vietnamese respondents was the delivery condition ”without damage” when carried by a crowd-carrier (around 85%). Concerning the timeliness of the delivery, the USA respondents were much more sensitive than the Vietnamese ones.

Drawing on a stated preference experiment in the US, Punel and Stathopoulos (2017) explore the acceptance of deliveries fulfilled by non-professional shippers using random parameter and error component models. Most shipping attributes, from shipment duration to driver training had variable impacts corresponding to the shipment distance (i.e. different preference patterns in the urban, inter-city, and long distance markets). Overall, the attributes related to driver performance are the most influential in the decision process.

In addition to this, Ballare and Lin (2018) identify factors which have strong relations to the successful deliveries, such as package size, delivery distance, *demand* frequency and distribution, as well as requesters' age, and pricing strategy. Additionally, Punel et al. (2018) study the factors separating users from non-users of *CS*, ranging from socio-demographics and attitudes of senders to the broader built *environment*. *CS* is found to be more common among young people, men, and full-time employed individuals. Concerning the attitudinal motivations, individuals who have a strong sense of community and *environmental* concerns are more likely users.

3.2.3. Empirical results

Fig. 7 presents willingness to pay (WTP) functions for seven product-groups which are coded from G1 to G7, using DATA1. G1 includes fast food, dry cleaning, etc products. G2 is coded for groceries products. G3 and G4 present beverage/dried foods and personal health/medicine products. G5 and G6 include apparel and consumer electronics products. G7 comprises the remaining products. As can be seen from Fig. 7, respondents were willing to pay the highest *price* for shipping groceries, fast food, dry cleaning, and similar products (i.e. G1 and G2). Meanwhile, apparel (i.e. G5) and consumer electronics (i.e. G6) had the lowest WTP for delivery.

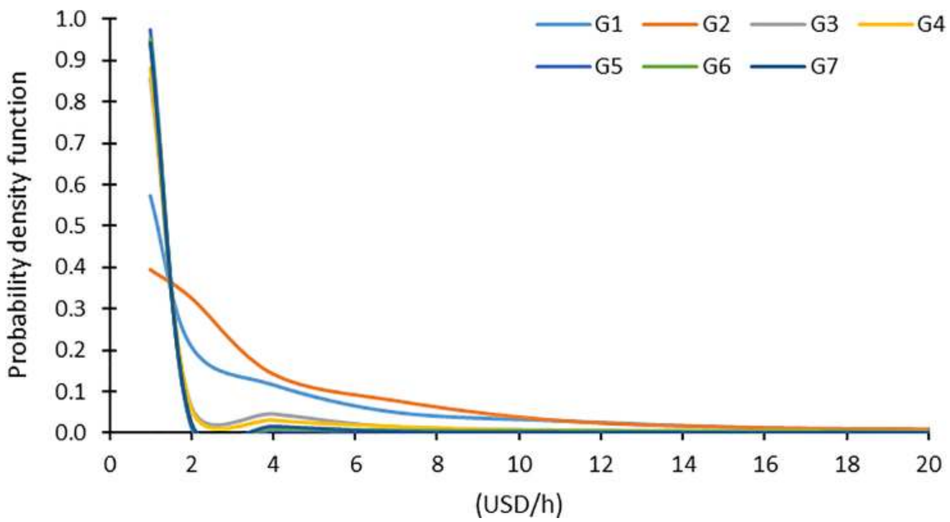

Fig. 7. WTP probability density functions for different product groups (Le and Ukkusuri, 2019).

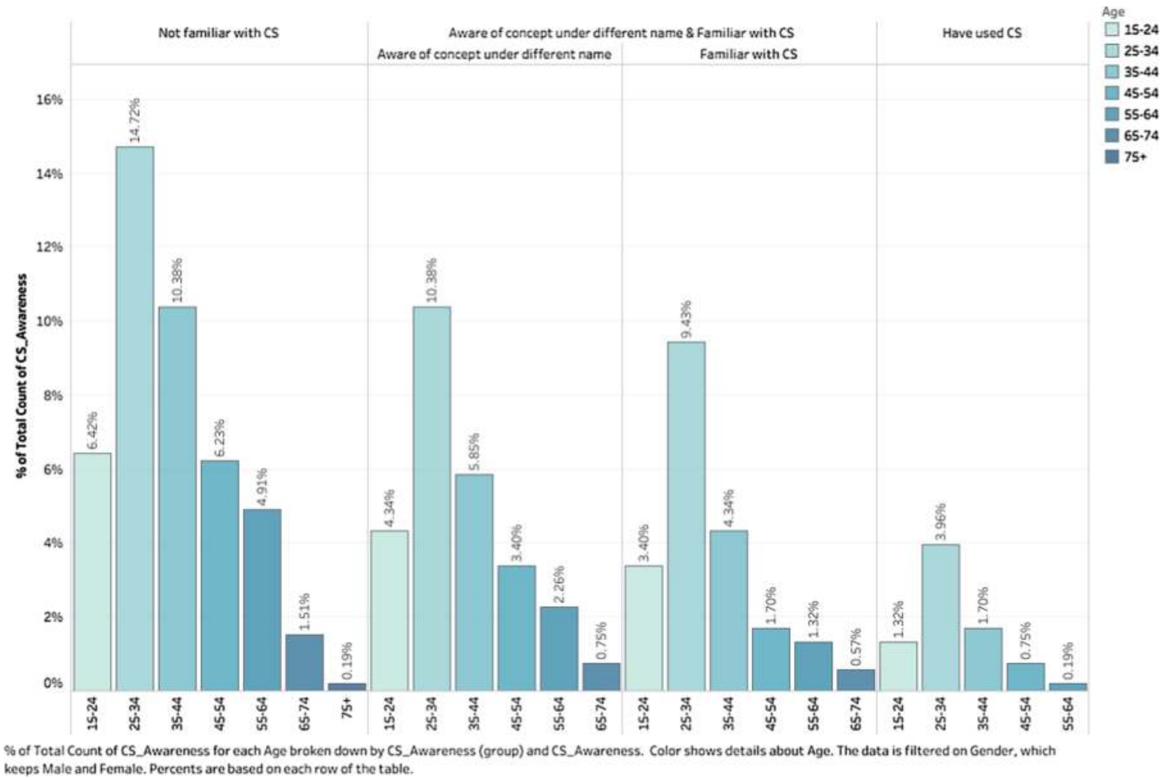

Fig. 8. Awareness and usage of *CS* by age groups.

Fig. 8, based on DATA2, reveals that the majority of prospective senders from the general public are unfamiliar with CS, with <8% having used this type of system (Punel et al., 2018). In line with expectations, and similarly to passenger ride-hailing, the respondent age plays an important role (Rayle et al., 2016). The highest propensity for CS use and awareness occurs in the age class of 25–34. This suggests a promise of CS system acceptance to pick up in the future as this generation ages.

Fig. 9 points to an intriguing aspect of the CS system use (DATA2). It shows that respondents with higher awareness of the service also consider it to be more complicated to use. This suggests that some of the practical challenges related to using CS are difficult to perceive for users that are not experienced with the service. Shipping via the crowd requires users to place a shipment request, secure bids and to reach an agreement with couriers, and these steps can present unforeseen challenges.

Understanding more about the behavior, motivations, and goals of *CS* customers remains a challenging objective. Such insights would contribute to building and pacing critical mass, tailoring the service (especially *matching* parameters such as *price*), and fostering retention and repeat service among customers.

3.3. Operations and management

The previous sections discussed *CS* in terms of *supply* and *demand*, from practice to research and empirical findings. The successful expansion of this emerging industry, however, heavily depends on its operational and management strategies. In the following subsections, platform characteristics, *matching and routing*, *pricing* strategies, and *environmental* impacts are discussed.

3.3.1. Industry and business perspective

There are a few real-world case studies. Qi et al. (2016) developed planning and operation models that were tested in a San Francisco case study. Four scenarios of shared-mobility (passenger cars) and trucks were investigated. The study found potential economic benefits reducing the delivery truck size and suggested operational alternatives (e.g., avoid peak hours and low-*demand* areas). The authors also confirmed that dynamic wages and *CS* service *prices* impeded operational flexibility. Due to induced trips, the expected *environmental* benefits are not yet achieved.

Rougès and Montreuil (2014) investigated 18 *CS* companies categorized into five *business models*. "Courier," "intendant," and "intra-urban" models target business efficiency control strategies, while "national" and "social delivery" models are based on business and trust, respectively. As such, the market segmentation strategies and revenue models vary across these business models. The clients range from business-to-business (B2B), business-to-customer (B2C), and peer-to-peer (P2P). Details are presented in Table 2. In a similar way, Buldeo et al. (2018) interviewed managers and higher position practitioners from 11 companies and defined five crowd

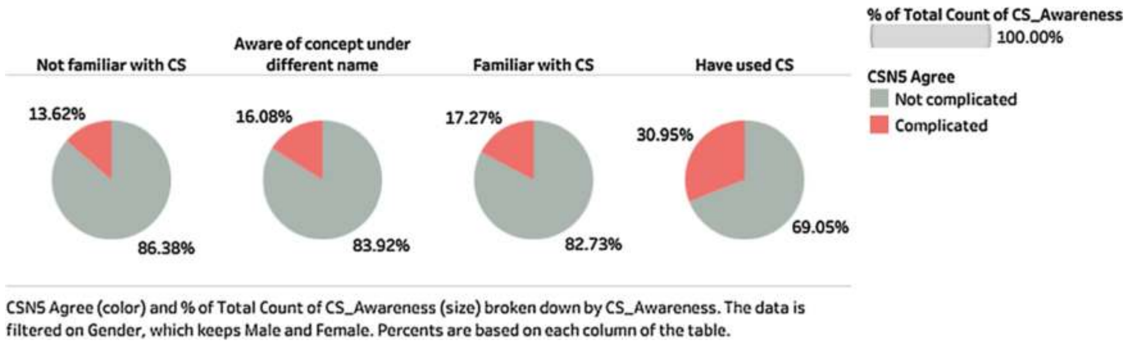

Fig. 9. Perceived difficulty to use service by awareness level.

logistics types which are "business marketplace," "community marketplace," "flex work platform," "commissioner platform," and "logistics marketplace". Those five types also map to the above-mentioned B2B, B2C, and P2P *business models*.

Pricing strategies are associated with the implemented *revenue models*. From their survey of 18 *CS* firms, Rougès and Montreuil (2014) identified five revenue models, namely "fixed price," "negotiated prices,' "financial and matching fees," "resale margin," and "membership." Some *CS* firms use multiple *pricing* strategies applied to different services. Based on Rougès and Montreuil (2014), we reviewed the pros and cons of each revenue model (Table 3). Alternatively, Dablanc et al. (2017) found that a large part of 36 *CS* firms does not reveal their *pricing* strategies and algorithms. *CS* users are only informed of the surcharges, such as in peak time or late night, without knowing the exact *pricing* model. Some *CS* firms (e.g., Postmates) provide a *pricing* comparison to other logistics providers for any request. Collectively, the authors found a range of *CS* management strategies that can be characterized as two poles. In centralized (or top-down) strategies, the platform owner sets *pricing*, extracts candidates for courier selection and guides driver-partners on optimal dispatch strategy and delivery routes. In systems that tend towards peer-to-peer (bottom-up) strategies, non-professional peers freely set and negotiate prices, select among a set of non-curated (e.g. locally available) candidates, and driver-partners use their own judgment on dispatch and routing. Theoretically, implementing negotiated pricing/ bidding strategies will cost the *CS* operator more due to more complex algorithms and computation efforts. On the other hand, some empirical research has suggested that peer-to-peer negotiations lead to a suboptimal performance of the platform, by causing less efficient bidding and delivery processes (Ermagun and Stathopoulos, 2018). The tension between the need for simple pricing/selection scenarios suited to crowd resources, and the aspiration for optimal strategies based on sophisticated centralized procedures requires further understanding of the interaction of the non-professional crowd patterns of behavior and motivations and novel technical shipping platforms.

Environmental benefits are found from a pilot case study in Finland, where *CS* was used to deliver library books and media (Paloheimo et al., 2016). On average, the pilot study saved about 1.6 km per car delivery trip. The authors also estimated a potential 4% reduction of mobility-related footprint if as many as half of the shopping and library trips were crowd-sourced. Future work should more systematically compute the environmental and energy impacts of the *CS* market using more comprehensive samples.

Research is currently limited by a lack of availability of business operation data (typically of a proprietary nature). Under some abstracting conditions researchers still conduct studies in these areas, using a range of methods, to provide alternative insights. These are summarized as follows.

3.3.2. Operations and stakeholders

Perboli and Rosano (2019) surveyed parcel service providers in Europe and revealed four main stakeholders of freight transportation systems, namely "international couriers," "managers of a traditional fleet," "managers of green fleet," and "customers."

Table 2
Crowd-shipping business models (Rougès and Montreuil, 2014).

Name	Clients	Offer	Area	Couriers	Revenue models
Courier	B2C	Deliver from a shop, a restaurant, a pharmacy, etc.,	Intra-urban	Professional or non-professional dedicated couriers	Fixed prices
Intendant	B2C	An order is placed on the *CS*'s website. The courier purchases the product and delivers to the customer	Intra-urban	Professional or non-professional dedicated couriers	Fixed prices, resale margins, financial fees
Intra-urban	2P or B2B	Deliver a parcel	Intra-urban	Professional, non-professional dedicated couriers, or commuters	Fixed prices
National	P2P or B2B	Deliver a parcel	Inter-urban/National	Travelers	Negotiated prices, financial fees
Social delivery	P2P or B2B or network	An order is placed on the business website. The courier proceeds to purchase, then to delivery	National/International	Travelers	Reward barter, financial fees

Table 3
Crowd-shipping pricing and revenue models (Based on Rougès and Montreuil (2014). Pros and cons are generated by authors).

Revenue model	Price determination party	Pros	Cons	Common implementation areas	Examples of platform providers
Fixed prices with incremental charges	Platform providers	Transparent price for customers. Easy to implement for CS firms.	Request for any individualized service will be charged with additional costs.	Intra-urban	Postmates, UberEats
Negotiated prices/ bidding	Senders suggest a preferred price and driver-partners bid for the task. Final price is bargained.	Facilitates services customized to sender-specific shipping needs and increases the probability to reach the sender-driver agreement for non-standard shipments. Final price reflects both parties' preferences.	Driver-partners may compete assertively to win the bid causing the final agreed price to fall below the minimum wage.	Inter-urban	Deliv, TaskRabbit
Financial and matching fees	Can be free shipping or different rewards. In case of charging for delivery, the price is typically set by senders. Platform providers charge a certain percentage for a matching fee.	The system promotes social value by increasing the probability of on-the-go delivery tied in with social networks.	This business model can limit the ability to ensure a driver is enrolled thereby offering a lower level of service. Can lead to legal issues (some products are regulated differently across countries).	International	Bernacle, Bistip, Kanga, Muber, Rideship, mmMule, PiggyBee, Easybring
Resale margin	Delivery can be free but CS firms have a cut from ordering commissions.	Promotes advantageous relationships between CS firms and retailers, possibly making the growing e-retail market more sustainable.	Limited coverage: CS platforms only offer shipment of customer products provided by retailers that are part of the CS firm have collaboration.	Intra-urban	Instacart
Membership	Platform providers set the membership fee and decide which services will be provided free and in which circumstances.	Assure a baseline *demand* from retailers who have frequent shipments.	Retailers have to pay a fixed cost, regardless of how many shipments they send.	Intra/inter-urban	Instacart

Because of the competition, freight service providers are motivated to develop better business strategies in order to gain advantages over new players in transportation markets. However, several barriers have been identified. For example, Schreieck et al. (2016a) developed a *CS* platform prototype for local retailers, identifying five main challenges: "smart matching algorithms", "leverage network effect", "platform governance", "data privacy," and "trust." Feasible countermeasures were then proposed to implement the platform.

Most research concentrated on some of these identified challenges of a *CS* platform. Specifically, the majority of available papers focus on *routing and matching* strategies. Clearly, *routing and matching* are intertwined decisions. The costs and feasibility of matches are depending upon the needed routes. Routes are relevant both for the supply (vehicle) to meet the demand (order), but also from the pickup to the delivery of the demand. Also note that the feasibility of matches also depends upon the available capacity and the actual demand requirements, e.g. time windows (both pickup and delivery). Moreover, these *routing and matching* decisions also cannot be observed independently from the *pricing* strategies. Overall, a comprehensive model, taking into account and integrating these decisions has not been researched as far as we know. Specifically, it combines OR-based combinatorial optimization models, pricing/revenue management principles, consumer utility theory, and multi-stakeholders.

- *Matching approaches*
  Setzke et al. (2018) created an algorithm to match travelers and packages with origin-destination (OD) locations and time constraints for both stakeholders. This model is unable to assign multiple requests to one courier, and cannot handle the transfer of a package between multiple couriers. Zhang et al. (2017) optimized travel routes under some business strategies of *CS* systems. The developed model provides the largest profit, smallest cost and risk compared to two other benchmark models.
  Moreover, Kafle et al. (2017) designed and modeled a crowdsource-enabled system for the integration of truck carriers and *driver-partners* into urban relay and delivery. The designated system was developed to be sensitive to specific customer factors, e.g. the "penalty for servicing outside customers' desired time windows".
  Li et al. (2014) reveal a trade-off between the benefits for taxi firms and the acceptance rate of parcels. Delivering more parcels will likely provide more benefits to taxi operators; however, once the number of parcels exceeds the maximum capacity of taxi firms, the acceptance rate will be low. Therefore, the taxi company may need to outsource the surplus parcels to traditional logistics carriers or *CS* firms.
  Masoud and Jayakrishnan (2017) look into the ride-matching problem within the context of a peer-to-peer ridesharing system, i.e. drivers need to find riders. The authors developed an algorithm to optimally solve this ride-matching problem in real-time. Within a crowdsourcing context, Schreieck et al. (2016b) managed to find an efficient matching algorithm connecting around 10,000 pairs of ride offers and ride requests in real-time. Safran and Che (2017) look into making real-time recommendations for matching workers to tasks, making the trade-off between skills and reliability. In their paper, Setzke et al. (2017) developed an algorithm leading to the assignment of drivers to transportation requests by matching them based on transportation routes and time constraints. They use a simulation based on mobility data from a German city, to test their algorithm.
  Overall, the current literature has a number of matching algorithms available, mostly within a setting of offering empty seats to riders in real-time. More research on translating these "people transport" -based matching algorithms into a real-time crowdsourcing context (i.e. for freight delivery) is needed. Real-time matching in a real-time context considering the future effect of the current decisions is a hard combinatorial problem involving dynamic programming. Moreover, integrating these decisions with the pricing, willingness-to-pay and willingness-to-work decisions, is very worthwhile investigating. Note that in the latter case, there are three stakeholders (i.e. drivers, requesters, and the platform provider) and their decisions involved, opening the door towards some interesting (non-) cooperative game theoretical aspects as well.
- *Pickup and delivery routing*
  Arslan et al. (2018) show that pickup and delivery is an important crowdsourced delivery problem. The study addressed the problem by optimizing the unused capacity of the available traffic flow. Results confirm the economic benefits of a *CS* service compared to a traditional delivery service. However, the authors assumed static arrival rates of requests and drivers, which is a less realistic setting in practice.
  Along the same lines of utilizing the unused capacity of existing flows, we mention the cargo hitching literature stream. The integration of passengers and freight transport is also explored in Ronald et al. (2016), Chen and Pan (2016). Ghilas et al. (2016b) considered the feasibility and opportunity of incorporating scheduled public transportation in the distribution of goods. Pickup and Delivery (PD) vehicles are used to bring (collect) goods to (from) a bus station, and spare capacity on the scheduled bus services, especially in off-peak hours, is used to move goods for part of their journey to their end destination. Masson et al. (2017) proposed a Mixed Urban Transportation Problem based on a two-tier network approach, using city buses for the first tier and regular service providers for the second tier. Other studies proposed time window solutions to pick up and delivery problems (Chen et al., 2017c), schedule lines (Ghilas et al., 2016a,b,c, in press), and stochastic *demands* (Ghilas et al., 2016d).
  Li et al. (2014) introduce and explore the Share-a-Ride Problem, which is an extension of the Dial-a-Ride-Problem (Cordeau et al., 2007), but considering the different requirements to transport people and freight using a taxi network (e.g., maximum ride-time, detours, number of stops, etc.). Taxis are allowed to deliver parcels as long as the service level for the passenger does not deteriorate significantly. A Freight Insertion Problem (FIP) is proposed to insert parcel collections in a given *routing* plan for passengers aimed at minimal passenger disruptions. Some other studies along these lines are Li et al. (2016a,b).
  Sadilek et al. (2013) used geotagged Twitter posts to approximate people's geolocations and estimated scenarios for a crowdsourced delivery service with different *routing* approaches. The study assumed that people are willing to carry packages during their daily travels. The tasks were formulated as graph-planning problems, and the results revealed significant speed and

coverage: a slack of 800 meters and 90 min is sufficient to cover 83% and 100% of the source-origin location pairs in the Seattle and New York City Metropolitan areas, respectively.

More recently, Sampaio et al. (2018) consider a crowdsourced system where drivers express their availability to perform delivery tasks for a given period of time and the platform communicates a schedule with requests to serve. The authors investigate the potential benefits of introducing transfers to support driver activities. At transfer locations, drivers can drop off packages for pick up by other drivers at a later time.

Routing strategies for *CS* systems need to be able to handle, match and route requests in real-time. Pillac et al. (2013) and Psaraftis et al. (2016) reviewed the literature on dynamic vehicle routing. Both reviews point to the need for more dynamic models, that are able to manage real-time requests. Following the taxonomy as presented by Psaraftis et al. (2016), the routing problems in *CS* context would probably be labeled as part of the dynamic and stochastic class. In terms of solution methodology, it seems that dynamic programming algorithms which develop some policy, to determine which next request to handle by whom and its routes, are interesting to investigate deeper. A promising approach is to identify a well-performing strategy involving anticipation, leading to an anticipatory pickup and delivery routing problem (in a dynamic and stochastic context) (Ulmer et al., 2015; Arslan et al., 2018).

- *Pricing*

  Pricing is among the most important characteristics of crowdsourcing services. Existing studies proposed alternative methods to determine the most attractive *pricing strategies* for both requesters and *driver-partners*. Bidding is a common suggestion (Kafle et al., 2017; Punel and Stathopoulos, 2017). *CS* is usually more cost-effective than traditional shipping services (Lozza, 2016; Kung and Zhong, 2017; Arslan et al., 2018). For example, using *CS* services helps requesters save about 50% of costs on two-hour delivery services, while the cost saving on one-hour delivery services is 60% (Lozza, 2016). Kung and Zhong (2017) developed three *pricing* schemes: "membership-based pricing," "transaction-based pricing," and "cross-subsidization". Interestingly, all three schemes derive the same equilibrium results. Moreover, using game-theory to study platforms as a revenue-maximization problem provides theoretical understanding of core parameters (Marx and Schummer, 2016; Ashlagi et al., 2017). The matching stability and revenue for the platform is a function of a number of market parameters (including the similarity of characteristics of actors and the relative sizes of the two sides of the matching market). This literature shows that the choice of optimal platform strategy needs to consider how large the demand and supply pools are and how well they match in terms of size, preferences, and socio-demographics. In another research, Yildiz and Savelsbergh (2019) develop a revenue-maximization problem that is constrained by the arrival rate of orders, the payment rate for couriers, the boundary of service, and service quality. The study reveals a significant relationship between profit obtained in a service area and compensation for driver-partners.

- *Integrating pricing, matching, and routing*

  As far as we know, papers that integrate decisions on *pricing*, *matching*, and *routing* into one coherent model seem to be absent and are an interesting open research domain. We do see that there a number of papers that are on the interface of two of these decisions. Cohn et al. (2007) integrate load *matching* and *routing* (and equipment balancing) for Small Package Carriers. The authors model this as a multicommodity flow (MCF) formulation and solve it via cluster-based solution approach, augmented with some column generation ideas. Along the same lines, Hou et al. (2018) consider a ridesharing problem *matching* riders to drivers and choosing the *routes* for the vehicles. In Gdowska et al. (2018), occasional couriers are considered as independent agents, which are free to reject assignments. The main contribution of their paper is a bi-level methodology for *matching* and *routing* problem for last mile delivery, combined with a professional fleet. A large neighborhood search algorithm is used to maximize the average loading ratio of the entire system.

  Lin et al. (2018) develop a bi-objective *matching* and differentiated *pricing* model focusing on efficiency and cost in an urban distribution setting. A two-dimensional and multi-stage roulette algorithm is developed, combining modeling and simulation. Ozkan (2018) studies the interaction between the *pricing* and *matching* decisions for a ridesharing company. He shows that optimizing in only one dimension (either *pricing* or *matching*) has no benefit, whereas jointly optimizing the *pricing* and *matching* decisions leads to a significant performance increase. Similarly, Rasulkhani and Chow (2017) use an assignment game to model the transportation markets' equilibrium and reveal sets of stable *pricing* and *matches*. Moreover, Korolko et al. (2018) review *matching* and dynamic *pricing* techniques in ride-hailing. They link both dimensions together via a pool-matching mechanism.

  Liu and Chen (2011) integrate *pricing* and demand decisions into an Inventory-*routing* Problem. Tabu search considering different neighborhood search is used to obtain efficient solutions.

  Clearly, the integration of these three components adds important value. Also, Mourad et al. (2019) present a survey of models and algorithms of papers on shared people and parcel transportation. In this paper, some aspects of the three dimensions are also visible.

- *Environment and other aspects*

  New *CS* services are expected to be more *environmentally* sustainable than traditional freight-shipping services. Using social networks for delivery contributes to the reduction of greenhouse gases in both urban and suburban areas (Suh et al., 2012). Devari (2016) found a 55% decrease in pollution in a case study on crowdsourced delivery using social networks. However, negative (Qi et al., 2016; Buldeo Rai et al., 2018) or contextually-dependent (Suh et al., 2012) *environmental* impacts are also identified. In line with this, Buldeo Rai et al. (2017) developed a set of criteria for evaluating the sustainability potential of *CS* services.

  Researchers proposed various alternative countermeasures for more *effective and efficient CS* systems, such as disclosing drivers' identity (Ta et al., 2018), but some areas still merit further investigation. For instance, how much time (how long a delay) should the platform allow driver partners to bid for shipping costs (i.e. their expected compensation). Some types of shipments need to be delivered immediately so any delay in the bidding procedure will influence delivery time, and thus, users' experience.

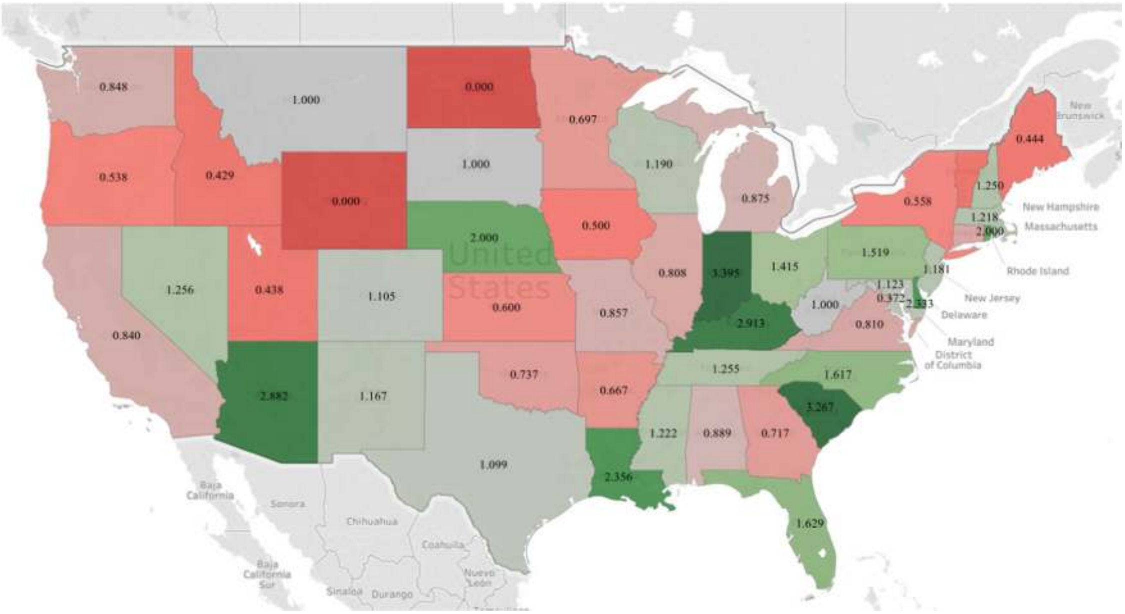

Fig. 10. Ratios of drivers to senders by the US states (green indicating an abundance of driver enrollment, red indicating a shortage of driver enrollment compared to requesters). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Furthermore, we also need to discuss issues related to the trade-off between matching efficiency and empty trips, and the challenges related to environment and energy impacts.

3.3.3. Empirical results

The information about requesters' WTPs and driver-partners' pay expectations is vital for *CS* companies to create *pricing* models and compensation strategies. From comparing the Figs. 5 and 7, it can be observed that the requesters' WTPs are much lower than the driver-partners' pay expectations. The *CS* providers should counterbalance this discrepancy to facilitate the popularity of *CS* services as well as to satisfy requesters' and driver-partners' aspirations. Moreover, Fig. 9 suggests that *CS* providers should improve platform features to become more seamlessly, integrated, and collaborative.

Fig. 10, using DATA3, illustrates ratios of drivers to senders for states in the US. Interestingly, the ratios of some states are quite high, such as Indiana (3.395), South Carolina (3.267), Kentucky (2.913), Arizona (2.882), Louisiana (2.365), Delaware (2.333), Rhode Island (2.000), and Nebraska (2.000). Accordingly, the *supply* is much larger than the *demand* for sending packages in those states. On the contrary, some other states have relatively low ratios, such as Iowa (0.500), Maine (0.444), Idaho (0.429), Utah (0.428). As such, there are more senders than drivers in those states. In general, the ratios, which represent the mismatches between *demand* and *supply*, provide knowledge supporting logistics companies to develop appropriate business strategies (e.g., *pricing* and compensation strategies) for different markets.

4. Promising areas and gaps

CS is a promising alternative for city logistics (Savelsbergh and Van Woensel, 2016), but it is still in its early stages, and service models and performance varies. While the participating companies have only a few challenges in terms of governmental regulations at this time, the industry faces various challenges in its implementation. The above review on the *supply* side, *demand* side, and *operations and management* motivated us to look further for other promising areas and gaps to be considered to facilitate the implementation of *CS*. This section is organized into three sub-sections; *Promising application areas, Operations and management*, *Behavioral* and societal impacts.

4.1. Promising application areas

This section presents gaps and challenges which stakeholders should address, individually or cooperating together, in order to facilitate *CS* implementations. Significant efforts should be invested to fill the gaps and address the issues, especially from *CS* firms and governments.

- *Market segments*

  Demand forecasting is vital for *CS* firms to have sufficient *supply* resources for the expected *demand*. Many on-*demand* companies are starting up for food and grocery deliveries (e.g., UberEats, Seamless, GrubHub, Doordash, Instacart, Postmates, and Deliv). Those products are typically peripheral goods or other small-size shipments requiring a tight delivery time window or needing an urgent delivery. In fact, the study of Le and Ukkusuri (2018a) also reveals another potential market segment for *CS* that is personal health and medicine products. Nevertheless, more investigation is needed to understand which type of shipment categories have the highest potential to be delivered by *CS* services. Who are the most likely customers of *CS* systems? For instance, Roadie has identified a new tangible market of delivering lost luggage from delayed flights by partnering with airlines firms (i.e. Delta Airlines) (https://www.roadie.com/resources).

CS platform providers can also use advanced techniques (e.g., data mining) to understand customers' tastes, behaviors, and preferences from analyzing various datasets, such as socio-demographic characteristics, searching and ordering history, and texts and images (from posts as some social media companies, such as Facebook, provide both ordering and delivery services). The insights are helpful to recommend products for customers and improve the likelihood of ordering the products. More creatively, a *CS* firm can even collaborate with retailers to provide niche products that are unique and can only be ordered on its platform and be delivered by that *CS* firm.

- *Network issues (effects)*

  Wirthman (2013) pointed out that the two biggest risks of same-day shipping are the lack of market density and consumer *demand*. For instance, some startups, such as Kozmo.com and WebVan, proved to be unsuccessful due to a lack of critical volume. Similar, Myways is no longer an active service (McKinnon, 2016) and Metro Post (a service of USPS) was discontinued (Rougès and Montreuil, 2014). However, in the context of the sharing economy and technology boom, *CS* companies may overcome these limitations. For example, most app-based food delivery companies, including Deliveroo, Postmates, Seamless, and Doordash, are partnering with local restaurants. This strategy supplies companies with a frequent and stable *demand*. Meanwhile, several *CS* firms open their own kitchen ('virtual restaurant') as an alternative option to provide prepared meals. This business strategy enhances customers' experience and makes *CS* firms more independent in peak ordering times or after restaurants' working hours. In addition, these start-ups usually operate in urban areas or college towns with a large potential customer population. Last-mile delivery is complex in its operations, and it has been a critical part of the logistics industry. The last-mile delivery requires many resources to address faster and more affordable delivery expectations. Therefore, the *CS* service availability potentially lightens last-mile delivery issues as well as provide additional options for requesters.

- *Reverse logistics*

  Another issue in the last-mile delivery field is associated with reverse logistics. In the Chinese e-commerce market, the rate of returned goods can be as high as 40% for some products (http://www.sina.com/). Moreover, the cost of reverse logistics is around three to four times higher compared to the forward flows (Gevaers, 2013). Inspired by those challenges, a few researchers discussed and proposed alternative counter-measure resolutions. For instance, Pan et al. (2015) designed a collection network that is flexible, efficient, and feasible for taxi drivers. Furthermore, Chen et al. (2017a) proposed strategies using taxi data, package pickup points, and an urban transportation network to handle the e-commerce reverse flow issues. As such, studies of Pan et al. (2015), Chen et al. (2017a) confirmed that using the crowd significantly reduces the reverse logistics costs by reducing the need to send a separate driver. The *environmental* and social benefits are also confirmed by those studies, based on real-world data. However, some areas in the reverse logistics field still warrant further investigation, such as efficient and effective logistics strategies for different types of reverse goods flows.

- *Future innovations*

  Innovative delivery vehicles may impact *CS* companies in the future. Advanced technology development may introduce unmanned aerial vehicles (UAVs) or drones (Bouman et al., 2017; Poikonen et al., 2017; Wang et al., 2017; Agatz et al., 2018; Otto et al., 2018), robots, and automated vehicles (Chung et al., 2018) to the logistics industry. These technological advancements are likely to reduce the need for delivery personnel (Lee et al., 2016). However, it is too soon to tell if human crowd-drivers will become obsolete. The advances in autonomous technology are going to have a direct impact on *CS* operations. In fact, Sheffi (2017) estimated that autonomous trucks will be feasible by 2040 at the earliest.

- *Insurance*

  One of customers' main concerns is *insurance*, especially for valuable shipments. Accounting for insurance costs in the delivery *pricing* to compensate for broken packages, theft, fraud, or lack of delivery on time may increase delivery cost for customers and make the shipping firm less competitive. Some *CS* companies only include a basic insurance package and let customers decide to pay for additional insurance.

- *Trust, safety, and security*

  Trust is one of the key factors of *CS* service development. Concerns originate from both *demand* and *supply* sides. Senders may question whether the packages will be delivered on time and without damage, while *driver-partners* may worry about hazardous or illegal products. Therefore, *CS* companies have implemented processes to ensure that the services they offer gain customers' trust and protect their couriers.

  Other *CS* challenges include privacy and *security* (Rougès and Montreuil, 2014; Kafle et al., 2017). Senders may be concerned about sharing their personal information, home address, and purchasing habits (Fatnassi et al., 2015). Most companies provide rating and comment systems to address these concerns. Other companies have an additional background check for driver-partners (e.g., UberRUSH and Deliv). Renren Kuaidi holds the packages' value on the *driver-partner's* credit card account after *matching* a request and prior to delivery. Furthermore, Renren Kuaidi deletes requester and receiver information as soon as the packages are confirmed "received" (mentioned in the study of Lam and Li (2015)). Secure online payment systems have been widely used by *CS* companies as an additional safeguard. However, following the fast development of information, communications, and technology,

security systems always need to be up-to-date.
Driver-partners also need to be protected from harmful or illegal freight (Rougès and Montreuil, 2014; Kafle et al., 2017). Therefore, requesters must agree to company terms and policies, including prohibited and restricted items. *Driver-partners* can rate and comment on requesters as well. However, *driver-partners* are not employees of a company, so they assume their own liability when delivering CS requests.

- *Legal*
Legal issues are another obstacle for crowdsourced delivery implementation. One of the *legal* issues relates to *supply* side dynamics which either facilitates or hampers *CS* development. For instance, in some Chinese provinces, at least 30% of the driver partners in a delivery company are required to have delivery licenses (Lam and Li, 2015). One other *legal* issue relates to intercity deliveries. A package can be requested to be transported across states' borders. However, the products inside the package may be *legal* in the state where the package is sent from, but illegal in the destination state. For example, some drugs are *legal* in Colorado state (in the USA), but illegal in many other US states. Moreover, *CS* services also face *legal* issues related to theft and fraud (Hübner et al., 2016).
- *Other issues*
Some *CS* companies have expanded their business in the last several years. However, those companies mainly have businesses within some metropolitan areas. A system may work for the last-mile delivery, but how will it perform for inter-city delivery? Will a given *CS* model perform beyond the last mile? For instance, can these systems work for medium distance travel (greater than 50 miles and less than 200 miles) and long distance travel?
Another concern is that a business model may have differential performance in different contexts. For example, a system works in the US, but may not work in the EU or Asia and vice versa. A potential reason can be cultural differences, diversity in pay expectations, infrastructure networks that support CS markets, legal hurdles and the availability of good quality Internet and penetration of smartphones.

The promising application areas challenge stakeholders on both *supply* and *demand* sides (e.g., market segments, network issues), *operations and management* (e.g., revise logistics, future innovations, insurance, trust, safety, and security), and government (e.g., legal) to implement *CS* systems that function collaboratively, dynamically, and sustainably.

4.2. Operations and management: Platform designing features

This section discusses various issues related to current gaps in platform design features, and ideas to address them. How can we design a *CS* system that delivers benefits to both *driver-partners* and requesters that is more attractive and effective than the existing systems? How can we improve the current *CS* platforms? In order to answer these questions, we investigate the features of *CS* services and provide insights and alternative solutions. For each feature, we identify the gaps and provide suggestions for *CS* services.

- *Pricing strategies*
Requesters will typically be able to lower their shipment costs by using *CS*, but will also have to contend with being contacted by several *driver-partners*. If requesters have to evaluate and respond to multiple messages, they may become overwhelmed. To address this issue, *CS* providers may consider a platform that allows *driver-partners* to bid on a package within a designated time window which is set by the requester. Moreover, the *pricing* schemes can be designed based on the urgency of the delivery. Delivery time window options and the corresponding rates can be designed for requesters' selection based on the *driver-partners'* schedules (e.g., those who are registered in the system).
- *Matching Assignments*
Rather than allowing open and unsupervised matching between requesters and couriers, based on accessing the entire pool of local couriers, some more tailored approaches are encouraged. *CS* providers could offer a selection of couriers the option to post their *prices* and other conditions. The requester would have the ultimate decision. This would enable the provider to model requests against couriers plans to travel in the same direction to make recommendations for consolidation. However, this approach complicates the *matching* process as a clear strategy of selection needs to be in place.
The *matching* assignment is a core feature of a *CS* platform. *Matching* occurs in real time between a requester and a *driver-partner*. The *matching* strategies should balance business objectives (e.g. maximize benefit) and societal impacts (e.g. drivers' income security and *environmental* impact). This is a challenge since the *matching* strategies solely depend on the company' business model.
- *Quality controls*
Survey respondents in DATA1 had two main concerns surrounding deliveries (Le and Ukkusuri, 2018a). First, about 85% of the respondents were concerned about damage to their packages. Accordingly, mentoring and training (e.g., for loading, unloading, and carrying parcels) for newly-employed *driver-partners* is recommended. Second, 46% of respondents in Vietnam and 67% of respondents in the US were concerned about delivery timeliness. Thus, the CS platforms need to include estimated delivery time features to provide reliable information for requesters, especially during peak hours or in cities with considerable traffic.
- *Flexibility*
CS aims to provide an adaptable service, especially for on-*demand* delivery. The service can be tailored to customers' delivery time and location preferences. However, there are still some challenges. The first challenge is that customers are often not present to receive their packages. This is problematic because couriers may have post-delivery constraints. The second challenge is

redelivery. Couriers may have to re-attempt the delivery the next day, which can be costly and inconvenient.
CS service providers are expected to foresee the problems that may occur during request and delivery. Providers should incorporate solutions into their platforms–via popup suggestions, for example–so that couriers, requesters, and recipients can solve the issues that may arise. One solution is to send an electronic notification of the courier's travel and estimated delivery time. Another solution is to ask receivers to provide a secondary location if they are unavailable at the initial delivery time, i.e. roaming delivery locations (Reyes et al., 2017). A network of electronic drop boxes is an alternative solution as well (Kunze, 2016).

- *Crowd-shipping platforms and related features*
There is a need to integrate *CS* systems with existing systems, especially third-party (requester) platforms, such that retailers can easily track inventory and manage shipments. A platform function should also allow customers to export their transaction history and financial report as well as customize these forms. Requesters should be able to send requests from their platform to a *CS* platform without significant effort. In addition, an auto-retrieval data feature for couriers' calendars is another worthwhile development (Setzke et al., 2018). Real-time assistance and voice-control features for hands-free capabilities are additional platform functions worth consideration. Separate modes allow users to seamlessly transition from requester mode to *driver-partner* mode or vice versa within the same account. Moreover, providing both ordering and delivery services help *CS* firms to obtain a richer dataset that enhances the understanding of customers' behaviors as well as facilitates their service customizations. Important to realize, coupons and incentives are traditional strategies, but that will also help *CS* companies to obtain customer data for forecasting and future service improvements.

The improvements of platform features mainly benefit platform providers by attracting senders and crowd-drivers to the *CS* systems. Nevertheless, efficient and effective *operations and management* also provide attractive platforms for senders (i.e. *demand* side) and crowd-drivers (i.e. *supply* side).

4.3. Behavioral and societal impacts

The increasing adoption of *CS* by companies and users poses important challenges for transportation researchers, policymakers, and planners, as there is limited information and data about how these services affect transportation systems and society more broadly. This sub-section discusses the main channels through which *CS* is most likely to make a societal impact.

- *Transportation system performance*
The transportation system is affected by *CS* via the possible shifts in mode-shares, along with added mileage to existing travel. Crowdsourced deliveries have the potential to "harnesses the dormant logistics resources of individuals." (Carbone et al., 2017). This implies that not only can drivers make better use of their excess vehicle capacity, but public transit commuters and bikers can deliver goods to each other along their way or during their free time in exchange for additional income. Ideally, to ensure that the transportation system performance is not negatively affected, two aspects of the system warrant further study. First, more research is needed to understand whether the deliveries are effectively made with no to minimal detour, along the way of planned movement. A second factor to analyze in order to understand the potential social impact, such as health or environmental benefits, is related to the modal choices of potential crowd-couriers (Paloheimo et al., 2016), such as biking and walking. There is a need for further work to understand the comparative advantage in terms of mileage and mode split changes.
- *Industry competitiveness*
The adoption of *CS* models by traditional logistics companies or tech entrepreneurs from outside the logistics industry is likely to impact industrial competitiveness. Outsourcing to the crowd enables asset-light infrastructure and operational flexibility that leads to minimization of costs (Botsman, 2014). In terms of altering the competitive landscape, *CS* platforms specifically enable smaller retailers to expand their market reach and offer new services. This is due to more flexible working arrangements on the employment side, and more flexible logistics arrangements to get products to niche markets (Erickson and Trauth, 2013). Thereby, the transition towards *CS* is likely to create new employment opportunities, increase market competition and provide better *matching* between *demand* and *supply*. From the early evidence, it appears that *CS* can level the playing field for small- and medium-size businesses. Competing via *CS* platforms is likely to enable short-term delivery and personalized, traceable shipments that bring smaller companies closer to the service offerings by larger retailers.
- *Consumers*
The impact on consumer satisfaction is mediated by both direct logistics-related experiences, and indirectly by expanding consumption opportunities. Early analysis by Rougès and Montreuil (2014) suggested that *CS* has the potential to give consumers access to a more extensive range of products. Similarly, the experience with the shipment itself promises to be more flexible (Mehmann et al., 2015; Punel and Stathopoulos, 2017), personalized (Rougès and Montreuil, 2014) as well as faster and more affordable (Arslan et al., 2018) than traditional delivery. The promise of *CS* needs to be weighed against the risks, such as lower reliability or challenges related to *matching demand* and *supply*. While broader examination of consumer experiences of *CS* are not available, stated preference data offers some insights. In studying declared advantages and disadvantages of *CS* among users and non-users, Punel et al. (2018) found that users had a more negative opinion of some *CS* features.
- *Labor market and regulation*
CS development is parallel to flexible labor arrangements. *CS* offers two main types of opportunities for employment for citizens. On the one hand, local commuters or long-distance travelers already on-the-go are given an opportunity to gain complementary revenues to help cover their travel costs (Miller et al., 2017; Le and Ukkusuri, 2018a). On the other hand, *CS* offers an opportunity

for dedicated or part-time delivery-employment via a flexible job with a *CS* company. In line with the surge in regulatory action to curb ride-hailing, however, there is a need to examine the *CS* employment structures carefully. While a customized work schedule can be a job asset, the lack of employment security could be unfavorable for the flexible *CS* employee (Guardian editorial, 2016; Buldeo Rai et al., 2017).

- *Community and social connectivity*
  Finally, there is a promise that *CS* can promote broader community cohesion by fostering social connections. In the first instance, the emergence of *CS* technology platforms bring together unorganized individuals and provides a tool to match *demand* and *supply* of logistics services (Buldeo Rai et al., 2017). In the context of the companies that adopt *CS*, the platform inherently generates a more community-oriented relationship between the company and its customers (Mladenow et al., 2016). Some research has suggested developing *CS* around existing networks of acquaintances (Devari, 2016) thereby ensuring trust and accountability of shipments. However, the use of *CS* even with unfamiliar shippers from the crowd has the potential to transform the way in which citizens deliver and receive packages. Ultimately, this can lead to a deeper entanglement between passengers and freight flows, and lead to developing new models for more efficient and socially sensible transportation and logistics services.

To summarize, there appears to be many connections between societal well-being and *CS* development, via companies, consumers, workers, and the general public. In fact, there turns out to be many reciprocal connections between society's functioning and the development of *CS*. This is exemplified by the finding that urban population density plays a role in generating critical mass needed for *CS* platforms to function, matched by the reciprocal findings that *CS* development can improve firm competitiveness, consumer satisfaction, and traffic performance.

5. Conclusions

CS is an emerging trend in freight transportation. Numerous startups are established worldwide to provide *CS* services. However, there are many challenges towards full-scale *CS* implementation. Accordingly, researchers have invested a considerable amount of time and effort to examine these *CS* systems. This paper systematically reviewed contemporary *CS* business practice and studies in order to investigate the gaps for implementations. The review was conducted under three pillars including *supply*, *demand*, and *operations and management*. The findings are additionally supported by our recent surveys in the US and using real-world data.

CS supply, *demand*, and *operations and management* seem to vary by contexts. Nevertheless, we discovered gaps in the studies and current practice as well as potential areas for applications. Moreover, we proposed suggestions for a *CS* system that is complex, integrated, dynamic, and sustainable. Our findings led us to make suggestions regarding *pricing* strategies, *matching* assignments, quality control, flexibility, platforms related features, and to better understand behavioral and societal impacts.

In conclusion, more *CS* research is necessary and we hope our study shapes appropriate research directions and stimulates researchers to conduct research in this emerging field. The growth of the *CS* industry highly depends on governmental policies. In fact, policymakers are urged to: (1) create policy frameworks and legislations to regulate the *CS* industry and minimize *CS* operational uncertainty; (2) identify a clear border between peer-to-peer sharing and business activities so subsidies will be allocated to the appropriate parties; and (3) provide innovation subsidies to fuel the growth of the *CS* industry. In the same way, *CS* companies should take the initiative to communicate and collaborate with local governments to overcome their challenges.

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.trc.2019.03.023.

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