# Crowd-based City Logistics

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**Abstract**

Cities are drivers of economic development, providing infrastructure to support countless activities and services. Today, the world's 750 biggest cities account for more than 57% of the global GDP and this number is expected to increase to 61% by 2030. More than half of the world's population lives in cities, or urban areas, and this share will continue to growth. Rapid urban growth has posed both challenges and opportunities for city planners, not in the least when it comes to the design of transportation and logistic systems for freight. But urbanization also fosters innovation and sharing, which have led to new models for organizing movement of goods within the city. In this chapter, we highlight one of these new models: *Crowd Logistics*. We define the characterizing features of crowd logistics, review applications of crowd-based services within urban environments, and discuss research opportunities in the area of crowd logistics.
**Keywords:** urbanization, sharing economy, city logistics, crowdsourcing, crowd logistics, crowdshipping

## 1 Introduction

*City Logistics* advocates a holistic view of the transport and logistic activities within a city, considering the negative (e.g., congestion and pollution) as well as the positive (e.g., economic, mobility, safety) impacts on the city's population. It seeks cost-efficient, but sustainable, solutions that minimize required flows of people and goods (Savelsbergh and Van Woensel, 2016; Crainic and Montreuil, 2016). In this chapter, we focus on how the *crowd* may be part of such cost-efficient, but sustainable solutions, especially related to the flows of goods.

As the urbanization trend will continue in the coming decades, the number of people living in urban areas is expected to grow from today's 54% of the world population to 66% by 2050 (United Nations, 2015). Moreover, the largest 750 cities in the world are responsible for more than 57% of the global GDP and this share is expected to increase to 61% by 2030 (Oxford Economics, 2017). At the same time, in today's increasingly global and interconnected world, the share of e-commerce of total global retail sales is also expected to continue to increase, from 7.4% in 2015

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to 15.5% in 2021 (eMarketer Editors, 2017). Furthermore, consumers have higher service expectations than ever before. In a survey with more than 2,000 customers in the US, 64% of those interviewed indicated they are willing to pay a premium for faster delivery, and 39% would pay more for same day delivery (Accenture Interactive, 2015). E-tailers are stimulating and exploiting these service expectations by offering fast delivery options as a means to compete with brick-and-mortar retailers and, in many cases, are not even charging consumers for the increased level of service (Savelsbergh and Van Woensel, 2016). The population growth and urbanization, the explosion of e-commerce, and the proliferation of fast delivery options, require innovative solutions and business models to ensure cost-effective, but also environmentally and socially friendly, transportation of goods.

Logistic practices in which infrastructure sharing and service integration are core concepts represent a new trend in transportation systems aimed at providing a more economically and environmental gainful alternative to current practices. Facilitated by advances in information and communication technologies and the ubiquity of personal, mobile smart devices, a shift to new ways of collaborative consumption is seen. Often termed *sharing economy*, this new phenomenon is characterized by managing physical (underused) assets as services and recognizing the possible benefits of the temporary use of a third-party service over the long-term possession of an (expensive) asset (DHL Trend Research, 2017). Whereas the concept of outsourcing in and of itself is not necessarily innovative, what the sharing economy adds is a technology platform in which unorganized individuals (the *crowd*) can offer their services, i.e. outsourcing to the crowd or, as coined by Howe (2006), *crowdsourcing*. As a matter of interest, the aforementioned survey conducted by Accenture Interactive (2015) also reported that a significant share of those surveyed who enable geolocation on their mobile devices do so for travel and transportation applications, and that 73% of those surveyed would be willing to receive deliveries from third-parties rather than directly from a retailer.

As with most crowd-sourced activities, reaching critical mass is key to a successful implementation of the concept (Agatz et al., 2012; Klumpp, 2017). Combined with the fact that business-to-consumer (B2C) e-commerce ends at the customer's preferred location (e.g. house, office, trunk of the car), densely populated cities are, therefore, prominent environments where *crowd logistics* may flourish. Crowd logistics should thus be seen as part of a broader web/mobility logistics systems (Goetting and Handover, 2016).

In line with the essential aim of city logistics, i.e., reducing the number of vehicle movements to fulfill freight demands (contributing to reducing greenhouse emissions and enhancing people's life), logistics with the crowd begets manifold opportunities but also challenges. Recently, Buldeo Rai et al. (2017) provided a literature review on crowd logistics initiatives and conducted interviews with practitioners willing to adopt the concept to leverage their business activities. The authors list 18 characteristics defining the broad variety of concepts found, and assess the impact of each on economic, social and environmental sustainability in order to identify the factors that determine the overall sustainability potential of crowd logistics. Those characteristics are classified accordingly to the stakeholders they relate to, namely, receiver and commissioner (either business or consumer), logistic service provider, platform provider and the crowd, and include, among others, involvement of dedicated logistic providers, crowd motivation, and modal choice to perform the services. Most of the literature on crowd logistics limits itself to urban distribution and last mile activities, i.e., so far crowd logistics has been considered intrinsic to city logistics.

Despite growing interest in applications of crowd logistics, few studies exist investigating the many challenges that need to be resolved before a full realization of the concept can be achieved. The objective of this chapter is to provide an overview of applications of crowd-sourced logistics services, and also point out and discuss some of the relevant issues pertaining to the deployment of such innovative systems and their impact and relevance for city logistics.

A related and complementary initiative to city logistics is the *Physical Internet* (Montreuil, 2011), which takes the concepts of the Digital Internet to propose an efficient, sustainable, and resilient logistic infrastructure to move physical objects. In this conceptual vision, freight and people move in the transportation network similarly to how data travels through the Internet. Physical objects are encapsulated in modular packets ($\pi$–containers) having unique identifiers that help in the routing, monitoring and traceability, allowing them to follow distinct routes, even if having the same origin and destination, to get to their final delivery. Applied to an urban environment, the Physical Internet underpins what Crainic and Montreuil (2016) define as *Hyperconnected City Logistics*, for which crowdsourcing the transportation activities exemplifies the possible synergy between people mobility and freight logistics.

The remainder of this chapter is organized as follows. City logistics covers a variety of activities, and some of these activities lend themselves well to crowdsourcing. In Section 2, we present and discuss not only the obvious ones, e.g., the transport of packages to consumers, but also the less obvious ones, e.g., the receiving of packages on behalf of consumers, in neighborhoods, apartment complexes, and office complexes, and the return transport of packages to retailers. In Section 3, we highlight and elaborate on aspects that may be of special interest to the transportation science and logistics community, e.g., compensation schemes, supply management, and demand smoothing, and the implications on sustainability. Our perspective on the future of crowd logistics and its role in city logistics is given in Section 4. Finally, in Section 5, we present concluding remarks.

## 2 Crowdsourcing Logistics Services

Crowdsourcing initiatives have been considered for a variety of applications, ranging from real-time image search to journalism, from health and medical research to voting. Whereas the term entails the delegation of an activity or process to an independent mass of people (the crowd), there is no commonly agreed upon definition of the concept. A first attempt to integrate many of the existing definitions was made by Estellés-Arolas and González-Ladrón-de Guevara (2012), wherein the authors propose to identify crowdsourcing activities based on aspects such as who forms the crowd, the tasks it has to do, and the incentives it receives for doing them. *Crowd Logistics* concerns crowdsourcing of logistics activities (Mladenow et al., 2015), for example, the delivery of goods to consumers using non-professional drivers who are already on the road and willing to detour to the location of these consumers (*crowdsourced delivery*) or the offering of short-term storage space by non-dedicated third-parties for missed deliveries and later collection (*crowdsourced receiving*).

As with crowdsourcing, there is no agreed upon definition of crowd logistics. Recently, Buldeo Rai et al. (2017) defined the term 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*", which, in our view, indeed captures the essential characteristics of crowd logistics. The authors also argue that crowd logistics fits in the *4 A's of sustainable city distribution* framework proposed by Macharis and Kin (2017) wherein innovative concepts are classified accordingly to Awareness, Avoidance, Act and shift, and Anticipation of new technologies. As such, environmental benefits are envisioned as one of the main benefits of crowd logistics. Crowdsourced delivery, for example, allows for a better utilization of transportation capacity, by fostering consolidation and coordination of existent vehicle flows, offered by the crowd, potentially reducing congestion and greenhouse gas emissions, as it can reduce the number of vehicles dedicated to goods movements.

We note, however, that the "crowd" in crowd logistics refers to a (large number of) independent individuals (participating on a voluntary basis), but that the specific realization of this crowd can have a significant impact on whether or not crowdsourced logistic services contribute to improving city logistics. For example, when existent flows (e.g., existent vehicle movements) are exploited for service fulfillment, this will likely contribute to more sustainable city logistics (Paloheimo et al., 2016; Chen et al., 2017b; Punel and Stathopoulos, 2017). However, in many of the popular platforms for on-demand transportation services, either for people mobility (e.g., Uber, Lyft) or for freight delivery (e.g., UberRUSH, Lalamove), in which those seeking a service are matched/connected to independent agents providing that service, fulfillment is realized by creating new service flows rather than exploiting existing ones.

## 2.1 Examples of Crowd Logistics

In the following, we discuss a few examples of crowdsourced logistics services.

### 2.1.1 Crowdsourced delivery

Also termed *crowdshipping*, crowdsourced delivery within urban environments is considered as a promising opportunity to accommodate the higher consumer service levels, e.g., same-day or even 2-hour delivery. In this setting, a customer or business (crowdsourcee) uses an ICT platform (crowdsourcer) to place a request for a delivery service to be fulfilled by one of many independent drivers (crowd) registered in the platform. A matching system assigns the request to one driver based on the characteristics of the service (time, destination, capacity) and availability (proximity, en route drivers, detour).

Within crowdsourced delivery, we distinguish two main types of offered services: *door-to-door* and *store-to-door*. Hitch and Roadie are examples of platform providers facilitating door-to-door delivery services wherein travelers (drivers, bikers) pick up and deliver packages for shippers (senders). Hitch allows shippers to post requests for items they want picked up and delivered, and travelers to announce journeys they plan to undertake. Roadie takes the concept a step further and does not require travelers to announce journeys they plan to take, but continuously monitors the movements of its "roadies" and uses machine learning algorithms to recognize travel patterns and automatically identify travelers that can serve requests posted by shippers.

Crowdsourced store-to-door delivery services focus on the B2C market. As an example, e-tailer Zalando relies on Trunkrs to offer same-day-delivery for its customers in certain cities in Europe. Trunkrs uses crowdsourced delivery, but also established courier services. This allows them to provide the reliability demanded by its customers (the e-tailers). Walmart is considering another form of crowdsourced store-to-door delivery services by having in-store customers (the crowd) fulfilling the delivery of items purchased by its on-line clients (Barr and Wohl, 2013).

Other popular store-to-door delivery initiatives are found in the grocery and food service industry, where the platform provider not only arranges the delivery service, but also acts as store front and allows its customers to select the retailer/restaurant from which they want to purchase. Instacart, for example, offers same-day grocery delivery for products bought at grocery stores selected by the customer. This is also typical for meal delivery services, like GrubHub, UberEats and Foodora wherein couriers (drivers or bikers) pick up a meal at the restaurant selected by the customer and deliver it to the customer's home.

Despite the fast growing number of companies offering crowdsourced delivery, literature addressing aspects and issues related to these services is still limited. Paloheimo et al. (2016) conducted a case study in Finland applying crowdsourcing to library deliveries, e.g., books and other media. The study highlights the potential carbon footprint reduction, on average, an equivalent of 1.6 kilometers in spite of the fact that 80% of the deliveries involved trips of less than 5km, and the benefits on leveraging social cohesion that can be achieved with crowdsourced deliveries. Based on the crowdshiping concept envisioned by Walmart, Archetti et al. (2016) introduce the Vehicle Routing Problem with Occasional Drivers (VRPOD). The occasional drivers are the in-store customers willing to deliver an online order for a small compensation. The authors stress the challenges associated with designing an appropriate compensation scheme and the need to continue to employ company drivers to be able to ensure a certain service level. A more in-depth study of this form of crowdsourced delivery is provided in Dayarian and Savelsbergh (2017). We discuss pricing and supply management related issues in more detail in Section 3.

Kafle et al. (2017) proposes a two-tiered delivery system, in which the second tier is crowdsourced. In that second tier, cyclists and pedestrians (the crowd) relay parcels from trucks and fulfill the last mile of the delivery. In the system, the carrier/courier posts pickup and delivery requests on a platform and individuals bid to carry out a subset of those requests. Relay points are locations where parcels are transferred between a truck and (one or more) individuals. The company decides on the winning bids and plans the truck routes that visit the relay points and delivery addresses of requests for which no bids were received (or for which the received bids were too expensive). Compared to a pure truck based solution, the system can provide cost reductions (including a reduction in penalty costs associated with late deliveries). The use of transfers points in crowdsourced delivery systems is also considered by Chen et al. (2017b). The authors introduce the Multi-Driver Multi-Parcel Matching Problem (MDMPMP), in which parcels may be transported by a single or by multiple drivers, being transferred between drivers en route to the parcel's end destination in this case. Relaying parcels between drivers allows for a more flexible matching of drivers and parcels, since drivers do not need to fulfill the complete parcel's journey and use transfer opportunities to bring the parcel closer to its end destination. Moreover, since trip duration is mostly important to the driver, as long as the parcel reach the customer in time, assigning longer paths to the parcels may facilitate the system-wide matching. Similar to Paloheimo et al. (2016), the authors also highlight that without the condition of using pre-existent vehicle flows, crowdsourced delivery operations may induce extra vehicle movements, reducing potential environmental benefits and positive impacts on city logistics.

### 2.1.2 Cargo-hitching

Integration of freight and passenger transport may also play a role in efficient and reliable delivery services, since people and goods may be able to share the same infrastructure for a part of their journey, especially within a city (Trentini et al., 2012; Fatnassi et al., 2015). Cargo-hitching is a realization of this idea and extends the crowdsourced delivery concept by (also) exploiting spare capacity available in public transportation, including tram, metro, buses and taxi service systems, in urban areas for the movement of freight. Trentini and Mahléné (2010) overview examples of freight and passenger transport integration up to the year 2010. They include not only examples of sharing transportation infrastructure for the movement of goods, but also sharing infrastructure for the temporary storage of goods, e.g., placing lockers in bus, metro, and train stations and parking garages.

Long-haul implementations of cargo-hitching have existed for many years in the airline and railroad industry. Short-haul implementations, however, are less common. PostBus Courier (DHL, 2015) is a DHL service integrating parcel transport and passenger service on its long-distance intercity bus network. Initially, in 2015, the service was offered between Berlin and Hamburg, particularly for same-day, urgent, shippings for both B2C and B2B customers. In a fully integrated system, however, different stakeholders may be involved (Jesus Gonzalez-Feliu and Routhier, 2014; Arvidsson et al., 2016), e.g., a logistics service provider who leases (spare) capacity on buses from a city bus operator. Coordination and synchronization are challenging in such environments and only a limited number of research efforts exploring these issues have been reported in the literature.

Masson et al. (2017) propose a Mixed Urban Transportation Problem consisting of two tiers for the distribution of goods within cities. In the first tier, city buses are used to transport goods from distribution centers to a set of bus stops and then, in the second tier, goods are transferred to city freight distributors to be delivered to the end customer. Ghilas et al. (2016) consider 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, which can be high, especially in off-peak hours, is used to move goods for part of their journey to their end destination.

Whereas buses and other public transport modes operate on predetermined routes and schedules, taxis are more flexible as passengers determine pickup and delivery locations as well as times. Thus, taxis may be used, at times, to move freight within the city on an individual on-demand basis. Li et al. (2014) introduce and explore the Share-a-Ride Problem, which is an extension of the Dial-a-Ride-Problem (Cordeau and Laporte, 2007), but taking into account 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. Chen and Pan (2016) specifically refers to a "crowd of taxis" to propose, in the same vein as the solution for reverse flows in Chen et al. (2017a), using a taxi fleet in the city in tandem with a network of 24/7 shops to satisfy last-mile delivery requests.

## 2.2 Beyond Traditional Crowd Logistics

Crowd logistics, up to now, has been seen mostly as an opportunity to reduce the cost and the speed of delivery in the urban distribution of goods, in particular for the fulfillment of home deliveries. In the future, crowd logistics will likely cover a wider range of city logistics functions. We discuss some in this section.

### 2.2.1 Receiving Packages

For home delivery, an important aspect of the fulfillment process is the actual receiving of the package. Failing to deliver because a recipient is not at home to accept (and, possibly, sign for) the package will not only disappoint consumers, but will also result in extra costs, because courier companies usually retry delivery (a few times). To prevent missed deliveries, alternative delivery options have been introduced, e.g., customers are offered (convenient) locations to collect parcels, ranging from strategically located locker boxes (e.g., at subway or train stations) to pickup points at gas stations and convenience stores. Locker box solutions for apartment blocks and other housing complexes are offered, for example, by Amazon (The Hub). Such solutions not only help in reducing missed deliveries, but also in increasing service efficiency. Due to the large number of residents in apartment complexes, door-to-door delivery of every package can be quite time consuming. Moreover, the number of packages delivered in these residential buildings has been increasing as fast as e-commerce (17%) for the last three years (Rodrigue, 2017).

At such pace, even those alternative collection services, e.g., locker boxes, will soon reach the limit of their usefulness. Moreover, installing locker boxes is expensive and, even though unattended delivery can be mitigated, the problem is not entirely solved, since parcels may be kept in the locker for several days. The use of crowdsourced solutions might provide a better means to alleviate the situation.

Wang et al. (2016) propose a last-mile fulfillment system in which the delivery of a parcel, from a locker/pickup station to the end consumer, is crowdsourced to a pool of citizen workers. Compared to a self-collection model, having the crowd collect and deliver parcels from locker boxes can reduced costs, since potentially fewer locker boxes are required and the turn-over rate can be increased. Experiments using datasets from Singapore and Beijing show that the approach can be used in large-scale settings (with a huge number of workers and parcels to be collected and delivered).

Another crowdsourced solution is neighbor or neighborhood delivery, where an individual uses his/her available time and space (capacity) at home to receive and temporarily store packages. This is a possibly attractive proposition for elderly residents in a neighborhood, both from a social and economic perspective. In Europe, such service is offered by DHL and PostNL as long as the sender does not require strict delivery to the customer (signed delivery). Even though companies do not offer any compensation for the person receiving the package, such approaches not only mitigate the negative effects of unsuccessful deliveries but also can help in building a sense of community around the neighborhood.

### 2.2.2 Returning Packages

The continuous growth of on-line and e-commerce sales has also led to an increase in returns. To increase on-line sales, especially in the apparel industry, offering free returns has been not only essential, but has also become the norm. In Europe, customers have the right to return items within 14 days, for any reason, and get a full refund. Free returns, of course, are not free for the retailer and the need for more cost-effective ways to manage reverse flows has become obvious (de Brito and Dekker, 2004). Figures from 2015 showed that 30% of goods purchased on-line are returned (Reagan, 2016). On specific markets, as apparel and shoes, that rate can be even higher. Moreover, customers are more willing to buy when offered free returns (United Parcel Service of America, 2015) and "buy anywhere return anywhere" policies have contributed to omni-channel strategies that shortens the supply chain towards the customer but the impact of such strategies on city logistics is not yet clear (Savelsbergh and Van Woensel, 2016).

Thus, not only increased direct-to-consumer deliveries pose new challenges for city logistics, but also the increased rate of returns. However, integrating the fulfillment of both flows is not straightforward as an item might be returned to the same distribution center where it came from, to another distribution center, or to a store (omni-channel solutions), for example, and might require different handling. Nonetheless, and despite being more time flexible than the last-mile delivery, an efficient return process is beneficial for both customers and companies. For the former, a fast return may result in an earlier refund deposit or a new product delivered. For the latter, it impacts the possible reselling of the returned item.

Crowdsourcing reverse flow activities is, therefore, a promising option for companies and could also contribute to mitigate the negative effects of extra vehicle movements within a city to fulfill returns. Yet, real cases of such solutions are not known to the authors. Research on feasibility issues, though, has already begun, but is limited. Chen et al. (2017a) propose to use shops (since they provide flexible delivery and pickup times, and are more convenient to customer and drivers) to build a collection network for returned goods in which en-route taxi services are used to collect packages at shops, before picking up the passenger, or to deliver packages at the shops, after dropping off the passenger. Different collection strategies are used to dispatch the taxis to transport goods from shops to the distribution centers, exploiting the extra capacity for small parcel on taxis, thus diminishing the carbon footprint to fulfill the service compared to using a truck for the same purpose.

Whereas crowdsourced receiving solutions (e.g., neighborhood delivery) are mostly applied to support last-mile deliveries, returned goods might also be stored by the crowd, facilitating collection operations for companies.

# 3 Research Opportunities In Crowd Logistics

In this section, we discuss a few topics that are not only relevant to crowd logistics, but also provide, in our view, exciting research opportunities.

The rise of the sharing economy makes it possible to monetize goods and services not deemed as assets before (Geron, 2013). As a consequence, new models have emerged based on the (temporary) access to rather than the ownership of (expensive) assets. In the context of logistics, this represents a paradigm shift from traditional models with a focus on optimizing asset ownership for a given activity (DHL Trend Research, 2017). The adoption of crowd logistics follows a transition away from the traditional schemes, in which a company owns assets and employs workers to perform its logistic activities, or outsources its logistic activities to third-party providers. More and more, mixed schemes are developed in which a company reduces its owned assets (e.g. vehicles and workers) to perform its logistic activities, and relies, instead, on crowd logistics for some of these activities (and, potentially, even all of its logistics activities).

This paradigm shifts necessitates more research on a number of relevant topics. Clearly, for the time being, crowd logistics raises more questions than answers. Research addressing these questions is still in its infancy.

Below, we discuss the following research topics: **Consolidation using existing flows**, which avoids the need for additional resources to be put on the heavily congested infrastructure, thus leading to more sustainable logistics services. **Willingness to participate**, which is critical to the success of a crowd logistics market, and involves both the supply of capacity and the demand for capacity in the market. **Scale and dynamics**, which, for crowd logistics, are significantly different from more traditional logistics services, as the number of participants (both on the supply and the demand side) tends to be much larger and their entry and exit faster and less predictable.

## 3.1 Consolidation using of existing flows

Consolidation, coordination and cooperation are fundamental to city logistics, and central for achieving an integrated system in which freight movements are performed as efficiently as possible e.g., by minimizing the fleet size, reducing empty traveling. Most of the literature considers the availability (capacity and time) of *preexistent* flows as a central aspect to crowd logistics.

Clearly, independent agents, not necessarily already performing another duty (e.g., a commuting driver), can be considered as part of a crowd-logistics solution. However, Paloheimo et al. (2016) also point out that rebound effects, where drivers travel longer distances, particularly motivated by monetary compensation, can reduce the potential environmental effects. Additionally, Chen et al. (2017b) mention that crowdsourcing activities not using pre-existing flows generate new movements, reducing the overall impact on sustainability.

One activity that best exemplifies the aforementioned issues, in the context of people transportation, is ride-sharing (Kamar and Horvitz, 2009; Agatz et al., 2012; Furuhata et al., 2013), in which drivers offer empty seats to other travelers with similar itineraries and time schedules. Those arrangements benefit not only the driver (sharing the costs of owning and maintaining a car), but also the passengers, since sharing a ride can be less costly and more convenient than using traditional forms of transportation. Moreover, ride-sharing also has an impact on the efficiency of urban transportation: potentially less vehicles are used to provide the required mobility, traffic congestion can be reduced, as well as fuel consumption and greenhouse gas emissions.

BlaBlaCar is a platform providing ride-sharing support, connecting drivers with empty seats to interested passengers. Recently, Uber started to offer a new service, UberPOOL, wherein drivers can announce their journeys and are matched with riders heading in the same direction. Perhaps due to the collaborative aspects of these sharing platforms, non-economic benefits such as improving the environment and social welfare may be regarded as primary objectives of such services.

### 3.2 Willingness to participate

In a study investigating the motivations why people participate in sharing economy activities, Hamari et al. (2016) highlight that while sustainability aspects influence how collaborative consumption is perceived, participants are mostly motivated by economic benefits. Nevertheless, other factors such as enjoyment in performing the activity and social awareness are also important. This is in accordance with the results reported in Paloheimo et al. (2016) for the case study of a crowd-delivery pilot for a library, where monetary compensation, while important, was not the main driver for participation.

An important characteristic of crowd logistics services is that they are offered by independent providers on a voluntary basis i.e., there is no employee-employer agreement between the company (platform owner) and the crowd. Relying for all or part of your logistics activities on the crowd is thus a non-trivial strategical/tactical decision that has major implications. In the context of crowd delivery, professional drivers are more expensive, but are available when required and do what you need, thus providing certainty and reliability. Independent drivers are less expensive, but are only available when it is convenient for them and perform tasks that they deem beneficial, leading to uncertainty and, potentially, a significant loss of service quality. Additionally, a characteristic of on-demand services is that customers are sensitive to price and waiting time (Tang et al., 2016; Taylor, 2017). The availability of independent drivers may be a concern as well as the willingness of independent drivers to perform certain transportation requests. To ensure reliability and quality of service towards its customers, a company may still have to rely on (some) professional drivers (either company employees or third-party drivers).

A key mechanism to manage this capacity uncertainty is the compensation scheme utilized for the independent providers (crowd). Regardless of whether the crowd is driven by altruistic, non-monetary motivations or by the possible economic gains that can be achieved, an efficient compensation scheme is crucial for attracting participants. These can include both monetary and non-monetary incentives. On the platform side, relying on independent providers to fulfill real-time requests is challenging since the providers decide whether and when to work and this decision is driven by the offered compensation. Few providers implies that customers will have to wait more to be serviced which, in turn, will decrease customer satisfaction and demand. The platform has to choose an appropriate compensation level for providers, in some cases dynamically, given the available number of providers and customers. So far, this problem has only been modeled using concepts from queueing theory (Tang et al., 2016) but could also be framed using concepts of cooperative and non-cooperative game-theory. More research is required to better understand how to make these trade-offs, which will have to involve modeling the behavior of independent providers.

Economy of scales dictate costs and pricing strategies for professional logistic services providers, e.g., consolidating large amounts of low-valued small activities. Due to the nature of the services offered by the crowd (e.g., spare capacity on free time), crowd services tend to be more personalized and, thus, more fragmented. As an example, crowd-delivery services operate on a parcel level (e.g., the driver/agent only performs one delivery) and do not take advantage of consolidation. Setting appropriate prices should take into account a large number of small and low-valued single activities performed by different agents (Klumpp, 2017). Other pricing mechanisms, such as the bidding system proposed in Kafle et al. (2017), could be leveraged to address such issues. Operational planning for horizontal cooperations between road transportation carriers often is performed through auction-based mechanisms in which requests are exchanged among carriers (Song and Regan, 2003; Verdonck et al., 2013). In a crowd-delivery context, bidding mechanisms could allow for a better assessment for which compensation is considered appropriate for a crowd agent and, also, help the crowd logistic platform in deciding which activities to crowdsource. Furthermore, bidding mechanisms stimulate the use of existing flows or space instead of generating new traffic and/or capacity. For example an independent driver already heading to a certain delivery location has lower marginal cost and effort and thus can ask for a smaller compensation than someone who especially has to drive there.

### 3.3 Scale and Dynamics

As a highly interconnected and interdependent environment, information regarding different aspects of the city changes constantly. Congestion, for example, might have a significant impact on travel times. For delivery services, new requests might arrive after the route planning for the vehicle has been decided. For a survey on the inherent issues and challenges posed by vehicle routing optimization in city logistics contexts, the reader is referred to Cattaruzza et al. (2015). One of these challenges, in particular, is especially relevant for the crowd-sourcing of transportation activities, namely, how to handle dynamic incoming information to (re-)optimize decisions already made taking into account the new information. In the context of crowd logistics, since participation is voluntary, real-time information regarding crowd availability, for example, will be crucial for successful implementations.

To date, only few works have considered crowd logistic approaches taking into account dynamic information. Li et al. (2014) extended the SARP to consider dynamic scenarios in which passenger requests are accepted or denied in real-time (at the time of the call), but parcel demands are known (pickup and delivery locations and time windows) beforehand. Routes for the accepted passengers are generated and feasible parcels are inserted by solving an associated FIP. Arslan et al. (2016) introduces a variant of the dynamic pickup and delivery problem in which ad-hoc drivers (occasional drivers) are willing to make a small detour in exchange for a small compensation to improve on-demand delivery. Both ad-hoc drivers and delivery requests arrive in real-time and the crowdsourcing platform has to assign delivery tasks to drivers. Real-time information is handled in a rolling horizon framework that re-optimizes the system whenever a new request or driver is available. A simulation study is conducted to evaluate the feasibility of the concept, based on data collected from the city of Rotterdam, the Netherlands. Dayarian and Savelsbergh (2017) consider the dynamics of employing in-store customers to deliver online orders (as envisioned by Walmart).

## 4 Beyond City Logistics

The focus of the chapter is on crowdsourcing opportunities in city logistics. In this section, we briefly discuss crowdsourcing opportunities in inter-city logistics, which, of course, may impact city logistics as well.

Whereas the rise of car-sharing initiatives may in the future provide a valid, and possibly attractive, alternative to renting cars, P2P car-sharing, at the moment, still represents only a small share of the market. Regardless, a critical issue when supporting one-way renting (or one-way sharing) is repositioning. Rental car companies incur significant costs in the repositioning of cars in order to re-balance fleet availability among their rental counters. Such a re-balancing operation is either performed by trucks or by dedicated drivers. To reduce such repositioning costs, Transfercar, among others, initiated a service that connects rental car companies having cars to be repositioned, and drivers willing to perform the repositioning task: *crowdsourced repositioning*. However, a seemingly missed opportunity is to use the capacity created by the repositioning of vehicles for the movement of freight.

Inter-city flows, (e.g., the repositioning of a rental car from one city to another) while not having a direct impact on city logistics, still can influence the goods distribution inside the city. We provide two such examples in airline transportation. Airmule is a platform wherein air travelers flying with spare luggage allowance can register themselves as on-board couriers, offering a transport service from their departure to their arrival airports. Under the promise of improved access to products not available locally, Grabr is a door-to-door crowd-sourced delivery service but, differently from Airmule, the crowd also takes care of the purchase. The requester post a solicitation for a particular item to be purchased and travelers post offers for servicing such request (if they can buy the product while traveling and if they are willing to deliver the purchase upon their return). After the requester accepts an offer, the platform handles associated financial transactions, i.e., the traveler gets paid after the delivery has been confirmed.

Moreover, cities infrastructure in the future will more and more make use of technological advances such as sensors and other types of electronic data collection. Their use will not be limited to transportation systems, but will include the numerous other systems in urban areas (e.g., waste management, law enforcement), all of then integrated on a network to optimize the overall city performance. This will call for new strategies to extract information from the infrastructure and advanced data analytics methods to make sense of the data and use it to support (optimized) decision making. Finally, in these new scenarios, citizenship participation will be a central aspect.

## 5 Final Remarks

Crowd logistics, i.e., involving the crowd in freight related activities, is one of the strategies that may help achieve the goals of city logistics. Despite its significant potential, it is far from obvious how to best use the crowd for logistics services, from an economical, societal and environmental point of view. There is no commonly accepted definition of crowd logistics and of who constitutes the crowd, and yet crowd logistics, one way or another, will play an important role in city logistics.

To be able to achieve the objectives of city logistics i.e., reducing the number and improving the efficiency of freight movements within the city, it is necessary for everyone using the already stressed urban infrastructure and for everyone impacted by urban freight transport to come together (Jesus Gonzalez-Feliu and Routhier, 2014; Bektaș et al., 2015). The challenge is that these objectives can no longer be achieved by investing in extra capacity. There is too little space and the costs are prohibitive (Savelsbergh and Van Woensel, 2016). New strategies to organize and control freight movements within cities are required.

The goal of this chapter was to provide an overview of crowdsourcing solutions in transportation and logistics, from natural applications in (home) delivery to less obvious applications in receiving and returning of goods, and to highlight opportunities for interesting and high impact research. We hope that our perspective will stimulate and encourage others to seek creative and innovative solutions to the challenges of city logistics as more and more of us will be living in larger and larger cities all around the world.

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