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Article *in* International Journal of Physical Distribution & Logistics Management · October 2019

DOI: 10.1108/IJPDLM-02-2019-0048

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Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review

Journal:	*International Journal of Physical Distribution & Logistics Management*
Manuscript ID	IJPDLM-02-2019-0048.R1
Manuscript Type:	Research Paper
Keywords:	B2C e-commerce, Last-mile delivery, Innovation, Efficiency

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Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review

Abstract

Purpose – The purpose of this paper is twofold. First, it reviews and classifies scientific publications dealing with innovative solutions aimed at increasing the efficiency of last-mile delivery in B2C e-commerce. Second, it outlines directions for future research in this field.

Design/methodology/approach - The review is based on 75 papers published between 2001 and 2019 in international peer-reviewed journals or proceedings of conferences, retrieved from bibliographic databases and science search engines.

Findings – Due to its importance in affecting the overall logistics costs and, as a consequence, the economic sustainability of a B2C e-commerce initiative, last-mile delivery process deserves particular attention in order to be optimised. The review highlights that, among the main factors affecting its cost, there are (i) the probability to have failed deliveries, (ii) the customer density in the delivery areas and (iii) the degree of automation of the process. Innovative and viable last-mile delivery solutions – that may impact the mentioned drivers – include parcel lockers, crowdsourcing logistics, mapping the consumer presence at home, and dynamic pricing policies. Eventually, some gaps and areas for further research activities have been identified (e.g. mapping customer behaviour, crowdsourcing logistics).

Originality/value – This review offers interesting insights to both academics and practitioners. On the academic side, it analyses and classifies relevant literature about innovative and efficiency-oriented last-mile delivery solutions, proposing directions for future research efforts. On the managerial side, it presents a holistic framework of the main factors affecting last-mile delivery cost and of viable innovative solutions that may be implemented to increase efficiency.

Keywords – B2C e-commerce; Last-mile delivery; Innovation; Efficiency

Paper type – Literature review

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Introduction

Business to Consumer (B2C) e-commerce is gaining increasing importance in many countries – in both mature and emerging markets – and online initiatives are proliferating across different industries (Mangiaracina *et al.*, 2016). Globally, B2C e-commerce is a rapid pace growing phenomenon and the online market in 2018 has been worth more than € 2,500 billion worldwide (B2c eCommerce observatory, Politecnico di Milano). If compared to offline market, B2C e-commerce opens new challenges for companies, which have to manage additional issues. One of these is the higher complexity of the logistics activities, and the intangibility of online transactions must not lead to underestimate them. In particular, many scholars agree that the most critical logistic process is the last-mile delivery, i.e. the "last stretch" of the order fulfilment, aimed at delivering the products ordered online to the final consumer (Lim *et al.*, 2018). As a matter of fact, on the one hand it is the interface between the merchants and the customer; on the other hand it is very expensive.

Considering online customers, they are very demanding in terms of service level. A special attention is thus paid to time performances (Lu *et al.*, 2016), namely the punctuality – i.e. receiving the products within an established delivery time lapse – and the delivery speed – i.e. the time interval between the customer order and the delivery. Nonetheless, consumers are usually not willing to pay for such stringent logistic requirements (Borsenberger *et al.*, 2016). Considering the perspective of the companies, last-mile delivery is the least efficient and most expensive part of the delivery process, due to the challenging target service levels, the small dimension of orders and the high level of dispersal of destinations (Macioszek, 2017): its cost can amount up to half of total logistic costs (Vanelslander *et al.*, 2013). Therefore, in order to be successful, B2C e-commerce players need to both be effective and reduce costs. In the online market, companies usually consider service level targets as constraints they necessarily have to meet to stay competitive. Then, given determined effectiveness requirements, they aim at finding ways to minimise costs.

In the academic literature, B2C e-commerce last-mile delivery has been mainly studied according to three perspectives: environmental sustainability, effectiveness (customer service level) and efficiency (costs). Sustainability issues got the interest of academics, and different papers on the matter have been published (Ranieri *et al.*, 2018). Even if most of the works focus on a limited scope, in terms of industry (usually fashion) and geographical context, the topic has been addressed by means of different methodologies, i.e. analytical models (Mckinnon and Tallam, 2003), empirical studies (Smith, 2012) and literature reviews (Mangiaracina *et al.*, 2015). Moreover, various measures of the effects of e-commerce on the environment – e.g. gas emissions, generated waste and energy use (Bertram and Chi, 2018) – have been considered.

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Different contributions may be found also related to the effectiveness of B2C e-commerce last-mile delivery. Both empirical papers – investigating the quality of home delivery services and the impact on customers' loyalty (Chou and Lu, 2009) – and conceptual studies – developing frameworks to measure logistics effectiveness (Xing and Grant, 2006) – have been developed. Moreover, many performances related to effectiveness have been addressed, e.g. delivery speed (Savelsbergh and Van Woensel, 2016), lead times (Fernie *et al.*, 2010), punctuality (Hays *et al.*, 2005), security (McKinnon and Tallam, 2003) and delivery customisation (Giuffrida *et al.*, 2012).

Eventually last-mile delivery efficiency has recently been receiving growing attention within the academic community, and an increasing number of publications appeared in last years. Among them, it is possible to identify two main categories of papers. The first group deals with how to optimise the traditional delivery mode (by truck, to the customers' home). Many authors (e.g. Geetha et al., 2013) propose different versions of the so called VRP (Vehicle Routing Problem), which consists in defining the optimal route to deliver a set of parcels to dispersed destinations. Some studies define the changes in the structure of the distribution network – e.g. introducing an additional echelon of transit points – to better manage B2C deliveries (Verlinde et al., 2014). Other works focus instead on the definition of the most efficient parcel location inside the truck (Lin and Yu, 2006). This field has been widely investigated, and many contributions have been developed. The second group of papers is focused instead on innovative solutions to increase last-mile delivery efficiency. An "innovative" solution – e.g. drone-delivery – introduces novel elements that make companies able to overcome traditional limits (such as the inability to saturate the transport mean or the high probability of failed deliveries). Among the most discussed innovative solutions, there are parcel lockers (Iwan *et al.*, 2016), crowdsourcing logistics (Wang et al., 2016), reception boxes and pick-up points (Kedia *et al.*, 2017), dynamic pricing policies (Klein et al., 2017) and drones (Ha *et al.*, 2018). This second field of study is more recent and still less investigated if compared to the previous one, with contributions that flourished only in the last years. Moreover, many initiatives have been implemented so far in this direction by practitioners, but there is still a great room for enhancement in terms of efficiency improvement.

Despite different contributions are now emerging in this field, the knowledge about innovative last-mile delivery solutions is still fragmented, and the academic community is starting to perceive the need of structuring extant knowledge and setting clear directions for future works (Lim *et al.*, 2018). Accordingly, some literature reviews addressing the topic have been recently published. Ranieri *et al.* (2018) take an environmental sustainability perspective: they analyse different innovative last-mile delivery options with the aim of evaluating the effect they may have on externalities (e.g. congestion and pollution). Considering instead the work by Lim *et al.* (2018), it

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develops a framework that associates the main last-mile delivery models to some identified "contingency" variables (i.e. drivers that may influence the selection of the last-mile delivery option, such as the demand or the characteristics of the products). Neither of the two aims at defining a comprehensive framework that considers all the viable efficiency-oriented last-mile delivery solutions, and at modelling the impact they have on last-mile delivery cost. As a result, opportunities for new research efforts in this direction are open.

The aim of this paper is providing a systematic review of the literature on innovative last-mile delivery solutions developed to increase efficiency with respect to traditional delivery modes, with a twofold objective: (i) identifying the main innovative solutions, and (ii) understanding the ways in which they may reduce last-mile delivery cost.

This paper is organised as follows: the second section describes the objectives and the methodology; the third section presents the results of the review based on the main axes (i.e. general features, methods, cost factors and innovative last-mile delivery solutions); the fourth section shows the implications of the review, the identified gaps and the potential directions for future research efforts; the last section draws general conclusions.

Objectives and Methodology

In line with the set objectives, this work addresses the following two questions:

(Q1) *What are the main factors impacting last-mile delivery cost?* - To understand how an innovative solution may decrease last-mile delivery cost, a clear and deep understanding of its main components and of the factors that affect it is needed.

(Q2) *What are the innovative last-mile delivery solutions that may have a positive impact on those factors, thus allowing a reduction of last-mile delivery cost?* - Once the factors affecting the cost have been outlined, the innovative last-mile delivery solutions impacting these factors may be identified, and the impacts may be evaluated.

To reach the aforementioned objectives, a systematic review was conducted, in line with recent literature reviews on similar topics (Lim *et al.*, 2018; Ranieri *et al.*, 2018). More in detail four main stages were performed: (i) literature search – papers were collected and selected, (ii) literature analysis – the literature was reviewed, (iii) hints for future research activities – research gaps and potential areas to be further investigated were identified and (iv) interviews with practitioners.

Phase 1: Literature search

The collection and selection of the papers followed five main steps (Srivastava 2007).

(i) *Classification context* – the focus of the analysis is on innovative solutions aimed at increasing the efficiency of B2C e-commerce last-mile delivery process.

(ii) *Unit of analysis* – the unit of analysis was defined as a single scientific paper, taken not only from black, but also from grey literature (e.g. conference proceedings). Due to the novelty of the theme and the considerable time needed for a paper to be published on international journals, relevant contributions referred to solutions that are still not present in the black literature could have in fact otherwise been missed.

(iii) *Collection of publications* – a search by keywords was performed in search engines and library databases (e.g. Scopus, ISI Web of knowledge). The keywords were selected and combined in order to investigate the papers whose contents lie at the intersection of two main areas, i.e. the last-mile delivery, and the search for efficiency optimisation. The resulting combination of keywords thus included "last mile" and "delivery" or "home delivery", as well as "optimis*", "innovat*" "cost" or "efficien*". These words were searched in the title, the abstract and the keywords, with the subject area being limited to the fields of Business and Management, Engineering, Decision and Social sciences. Moreover, only articles written in English were considered.

(iv) *Field delimitation* – the outcome of the previous steps, without considering duplicates, was a set of 432 eligible papers, that were then filtered according to specific criteria. More in detail, both the delivery of products not ordered online and the delivery of services were excluded because they were out-of-scope. Moreover, only the last-mile forward flow was considered. Accordingly, works addressing reverse logistics were excluded. Reverse flows often require specific network choices that are not suitable for the direct one (Mangiaracina *et al.*, 2015). Finally, only innovative solutions, that clearly differ from the traditional by-truck, attended home delivery, were taken into account.

The process followed three main steps: a first selection was made based on the title; a second refinement was made examining the abstract and finally the papers whose abstract was not sufficient to understand the alignment with the scope of the analysis were read. Finally, 75 papers published since 2001 were selected for in-depth examination.

(v) *Material evaluation* – contributions were reviewed and categorised based on different axes, i.e. their characteristics, the research methods and the addressed themes.

Phase 2: Literature analysis

In this stage, in order to identify the most suitable method for reviewing the papers, different previous systematic literature reviews (e.g. Mangiaracina *et al.*, 2015; Meixell and Norbis, 2008) were considered, and the adopted methodologies were examined. Accordingly, the analysis was conducted following two main steps. First, a descriptive analysis aimed at evaluating the main characteristics of the papers – i.e. year of publication, name of journal or conference, region/country – was performed.

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Second, the articles were classified using a two-pronged approach. First, they were categorised based on the research method(s) adopted by the author(s). Then, they were classified and analysed based on their content. In this way, it was possible to discuss the key topics, being able to highlight significant themes and trends, and to identify research gaps for future investigations.

This classification was performed according to the following process: first, 10 papers were jointly classified by all the four authors, in order to get to an agreement on the way in which the classification should be performed, and to come up with preliminary results in terms of both cost factors and innovative solutions. Then, the remaining papers were independently evaluated and classified by the authors, whose percentage agreement was 1 for the methodology, .91 for the cost factors and .90 for the innovative solutions. Agreement was considered to be reached in case at least 3 out of the 4 authors had come out with the same result. The obtained values may be considered good (Wowak and Boone, 2015). Those papers for which there was not initial agreement were jointly discussed and classified again by the four authors together, and a consensus was reached.

Phase 3: Hints for future research activities

In the third phase literature gaps were identified based on the findings emerged during the previous stage. More in detail, shortfalls of existing contributions were defined, and suggestions for future research activities were proposed. The topics to be further investigated were identified in order to be highly significant for both researchers and practitioners.

Phase 4: Interviews with practitioners

At the end of the review process, some interviews were performed with practitioners operating in the field, i.e. logistics service providers (mainly express couriers) and retailers selling online. Involving practitioners in academic studies is beneficial since they contribute in the sense-making of the findings (Shani, 2017), and they allow to get useful insights about the results. Their contribution was twofold: they validated both the framework emerged from the literature (suggesting to eliminate two last-mile delivery solutions) and the gaps (highlighting new research directions that are interesting not only for academics but also for companies).

Review of the literature

Main features of the articles

As common in literature analyses, papers were evaluated according to their main basic features, i.e. year of publication, name of journal or conference, region/country.

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In order to highlight their trend over time, an analysis of the works based on their publication year was performed. The first contributions date back to 2001, and this is in line with the identification of the late '90s and the early 2000s as the periods in which e-commerce started to spread. 18 papers were published between 2001 and 2015 (about 2 per year on average), showing that the interest in innovative delivery options has been quite limited for more than a decade. As a matter of fact, the efforts of both academics and practitioners in this period were aimed at optimising traditional last-mile solutions. Not surprisingly, the remaining 56 identified papers are dated between 2016 and 2019. Once traditional delivery modes have been widely analysed and enhanced, they offer very low room for additional efficiency improvements, and innovative ones "allow handling in a more effective way the last mile delivery in urban areas" (Ranieri *et al*., 2018). As a result, both academics and practitioners are now focusing on introducing innovative last-mile solutions.

Considering the sources of the selected papers, they are both scientific journals (55) and proceedings of international conferences (22). For what the former are concerned, more than half of the works (30) are published in journal pertaining to the logistics field, and among them 21 appear on journals that specifically target transport issues. Accordingly, the journals with the highest number of works are "Transportation Research Part C: Emerging Technologies" (5 papers), "European Journal of Operational Research" (4 papers each), followed by "International Journal of Physical Distribution & Logistics Management", "Transportation Science", "Transportation Research Part E: Logistics and Transportation Review" and "International Journal of Retail & Distribution Management" (3 papers each). Besides these journals, also sources not specifically dealing with logistics may be found. In these cases, published papers address a solution that is strictly linked to the core topic of the journal (e.g. the implementation of dynamic pricing policies for "Journal of Revenue and Pricing Management", or the analysis of customer behaviour through data mining techniques for "Industrial Management & Data Systems").

Papers were also classified based on the countries of affiliation of the first author. The most "productive" country is China (16% of the papers), followed by USA (11%), Italy (9%), Germany and UK (8% each).

Methods used in the papers

After the descriptive analysis, the articles were then classified based on the research method(s) adopted by the author(s). Meixell and Norbis (2008) identify seven main research methods: analytical models, conceptual models or framework, case studies, interviews, surveys, simulations, and others. Based on these methods, three main classes of papers may be identified: quantitative models (analytical models and simulations), empirical analyses (surveys, interviews and case studies) and conceptual models or frameworks (which include also literature reviews).

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Table 1 provides a comprehensive view of all the methodologies met in the analysed papers. When more than one method was adopted, the work was reported in all the related categories. The majority of the works (56) relies on a single method, while 19 are multi-method. Therefore, the total number is higher than the actual dimension of the sample.

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The most recurrent method is represented by quantitative models, followed by empirical analyses. Among the empirical works, the majority is represented by surveys aimed at investigating the intention of customers to use alternative home delivery solutions, e.g. automatic delivery stations (de Oliveira *et al.*, 2017) or consolidation points (Cherret et al., 2017), in different contexts. Considering instead conceptual models or frameworks, many authors list and categorise different innovative last-mile delivery options based on specific dimensions. For instance, Ye (2015) defines and studies some delivery "patterns" – e.g. door-to-door delivery by couriers, socialised third-party logistics, intelligent pick-up cabinets – developing a framework based on four variables, i.e. product, resources, network and economy.

While conceptual models and frameworks usually consider more delivery solutions, quantitative papers tend to focus on one or a few options, on which authors perform deeper analyses. Among these works, Devari *et al.* (2017) compare traditional by-truck deliveries with crowdsourcing logistics, while Song *et al*. (2016) quantify the economic benefits stemming from the implementation of parcel lockers and pickup points. Murray and Chu (2015) model the so called "traveling salesman problem" for drones and Reyes *et al.* (2017) treat the same issue in case deliveries are performed in the trunk of cars.

Among multi-method papers, the first method is typically an analytical model and the second a simulation or a case study, i.e. the application of the developed model to one – or more – fictitious (simulations) or real (case studies) context. For instance, Dorling *et al.* (2017), after developing a vehicle routing problem for drone deliveries, perform some simulations aimed at applying the model, and at comparing different sub-routes to select the best one. Akeb *et al.* (2018) and Qi *et al.* (2018) develop analytical models on crowdsourcing logistics and then apply them to case studies in Paris and San Francisco.

Review based on contents

Besides the identification of the research method, the analysis focused on the content of the papers. More in detail, based on the research questions, two main themes were addressed.

- *Cost factors* (Q1): they are all those factors that may influence the overall last-mile delivery cost. First, the formula of the last-mile delivery cost per parcel – and the different cost components – was defined; second, the factors impacting these components were identified. A scheme was then built aimed at catching and graphically representing the causal relationships among factors and cost.
- *Innovative solutions* (Q2): the second dimension refers to the innovative solutions that are proposed in order to try to increase last-mile delivery efficiency. In particular, for each solution, the impact on the different cost factors has been identified.

There is a strong link between these two elements: innovative solutions affect the last-mile delivery cost through the "direct" impact they have on the cost factors.

Based on the above: (i) a scheme of the relationships among the factors and the cost components was built (cost factors → cost components) and (ii) the graphical representation of the overall set of relationships existing among all the identified elements was derived (innovative solutions → cost factors → cost components). For both the figures, (+) (solid arrow) stands for a positive impact (A makes B increase), while (-) (dotted arrow) stands for a negative impact (A makes B decrease).

(i) Review of cost factors

The cost factors, the components of the last-mile delivery cost and the relationships among them are shown in Figure 1 and Table 2.

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The last-mile delivery cost (computed for a single delivered parcel) emerged to be composed by three main cost elements (namely the transport mean cost, the driver cost and the opportunity cost), according to the following formula:

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$$\frac{\left(\text{Transport mean cost}\left[\frac{€}{\text{delivery}}\right](1) + \text{Driver cost}\left[\frac{€}{\text{delivery}}\right](2)\right)}{\text{Parcels delivered in a delivery tour}\left[\frac{\text{parcels}}{\text{delivery}}\right]} \cdot (1 + \%\text{Failed deliveries }[\%]) + \text{Opportunity cost}\left[\frac{€}{\text{parcel}}\right](3)$$

(1) Transport mean cost

It is the cost linked to the use of the mean of transport (in case of traditional deliveries, the truck).

$$\left(\text{Transport mean travel cost}\left[\frac{€}{\text{km}}\right] \cdot \text{Travelled distance}\left[\frac{\text{km}}{\text{delivery}}\right]\right)$$

It depends on two main elements.

- The travel cost of the transport mean (Reyes *et al.*, 2017) per kilometre includes both the variable costs of resources used by the transport mean (e.g. fuel), and the allocation of fixed and semi-fixed costs (e.g. maintenance, insurance, tax) to one travelled kilometre. The transport mean travel cost thus depends on the resources consumption [A] (+) of the transport mean and on the share of (semi)fixed transport costs [B] (+) allocated (Dorling *et al.*, 2017).
- The travelled distance of the transport mean (Asdemir *et al.*, 2009) is the average number of kilometres travelled to perform a delivery tour. It depends on the customer density [G] (+), i.e. the number of customers in the same area (Boyer *et al.*, 2009).

(2) Driver cost

It includes the cost of the worker that perform the delivery (in traditional deliveries it refers to the so called "driver", who drives the truck and delivers parcels to consumers).

$$\text{Driver hourly fee}\left[\frac{€}{\text{h}}\right] \cdot \left(\text{Delivery time}\left[\frac{\text{h}}{\text{delivery}}\right] + \text{Problem solving time}\left[\frac{\text{h}}{\text{delivery}}\right] + \text{Travel time}\left[\frac{\text{h}}{\text{delivery}}\right]\right)$$

The main components are:

- the driver hourly fee (Kafle *et al.*, 2017), that increases if there is a higher level of specialisation of the workers [C] (+);
- the time needed, i.e. the time spent by the driver to perform all the activities. It is the sum of three components:
    - delivery time (Wen and Li, 2016), i.e. the time needed for the physical delivery of the products once the transport mean has arrived to the destination. In home delivery, it implies waiting for the customer to come, sign and collect the product. It may decrease with a higher degree of automation of delivery activities [D] (-) (Wen and Li, 2016);
    - problem solving time (Dorling *et al.*, 2017), i.e. the time wasted to face problems, such as traffic that may slow down the travel, or the need of performing specific activities if a

delivery fails (e.g. writing and leaving the delivery-attempt notification in the mail box, re-loading the parcel on the truck). It thus depends on both traffic/obstacles [E] (+) (Haque *et al.*, 2014) and failed delivery probability [H] (+) (Pan *et al.*, 2017);

- travel time (Giuffrida *et al.*, 2012), i.e. the time spent to reach the delivery destination. It depends on the distance travelled (Devari *et al.*, 2017) – and thus by the customer density [G] (+) – and on the involvement of the driver during the travel phase, which decreases if there is a high level of transport automation (i.e. there is low/no need of human intervention in the transport phase)[F] (-) (Murray and Chu, 2015).

The transport and the driver costs may be easily computed for a delivery tour (€/tour). In order to find the related cost for each delivered parcel, both the cost components have to be divided by the average number of parcels delivered in a delivery tour, which is in turn strictly linked to the customer density [G] (+).

Moreover, both the costs are multiplied by (1+percentage of failed deliveries). This percentage takes into account that an additional delivery tour has to be performed for those parcels that were not delivered due to the absence of the customer. This term depends on the failed delivery probability [H] (+).

(3) Opportunity cost

It includes those – real and figurative – costs aimed at quantifying the effects that customer dissatisfaction for the delivery service has on the company (Klein *et al.*, 2017).

$$\text{Cost for failed deliveries}\left[\frac{€}{\text{parcel}}\right][3.1] + \text{Cost for customer effort}\left[\frac{€}{\text{parcel}}\right][3.2]$$

It is the sum of:

- the cost for failed deliveries [3.1], which arises from the fact that customers are usually bothered of not receiving the ordered parcels (Reyes *et al.*, 2017). It considers the probability of having a failed delivery (Devari *et al.*, 2017), and the average figurative cost when it occurs (Pan *et al.*, 2017). The opportunity cost is estimated as the sum of the costs of different events, weighted by the associated probability of occurrence. These events include the potential loss in contribution margin both for – both current and future – lost sales and also for lost customers. Customers may decide not to buy again in the future not only in case he/she is not at home when the delivery is performed (home delivery case), but also if the operator misses the agreed time-window for the delivery (appointment or unattended delivery). The main factor impacting this cost is thus the failed delivery probability [H] (+).

$$\left(\text{Failed delivery opportunity cost}\left[\frac{€}{\text{failed delivery}}\right] \cdot \text{Failed delivery probability}\left[\frac{\text{failed delivery}}{\text{parcel}}\right]\right)[3.1]$$

- The cost for customer effort for collecting the parcels: when consumers, instead of just being at home waiting for the parcel, have to move to collect it, they will typically be bothered [3.2] (Wang *et al.,* 2014). The higher the distance to be travelled by the customers, the higher their dissatisfaction: as a matter of fact, the convenience of the location where the parcels are delivered (and thus the distance to be travelled to reach it) is one of the factors impacting the most on their intention to use this delivery option (Chen et al., 2018). Accordingly, the main factor impacting this cost is the delivery-home distance [I] (+), i.e. the distance between the place in which the delivery is performed and the home of the customer. The distance travelled by the customers is multiplied by the travelled distance opportunity cost (Giuffrida *et al.*, 2012), which is the average figurative cost the companies incur in for every kilometre travelled by customers to reach their parcel, e.g. the contribution margin for future lost sales.

Despite this is typically true for many e-purchasers, it sometimes happens that the so called "click and collect" option (i.e. the collection in locations different from home) is convenient for customers, who choose it because they prefer to collect the parcel themselves. This may happen, for instance, if the point of collection is near to a location the customers already have to reach due to other reasons. In this case, the company should not incur in a penalty, and thus the cost related to the customer effort should not be considered. In order to consider this circumstance, the described cost is thus multiplied by a factor ß – which may range between 0 (if the customer is not bothered at all) and 1 (if the customer is highly bothered) – aimed at weighting the previous cost component according to the considered situation/customer. In case the dissatisfaction of customer is neither null nor high (e.g. the customer voluntarily chooses the "click and collect option" since home delivery would fail, but is still disappointed by having to travel to reach the collection point), ß should be taken as a number between 0 and 1. This factor takes into consideration that the intention of customers of self-collecting the parcels may vary a lot according to many different indicators, related to the characteristics of the parcel lockers (e.g. location and time available for collection) (Chen et al., 2018), of the ordered products (e.g. weight and value) (Chen et al., 2018), but also of the customers themselves (e.g. age and employment) (Yuen et al., 2018).

$$ß\left(\text{Customer travelled distance opportunity cost}\left[\frac{€}{\text{km}}\right]\cdot\text{Distance travelled by customer}\left[\frac{\text{km}}{\text{parcel}}\right]\right) \quad [3.2]$$

(ii) Review of innovative solutions

The literature analysis highlighted the presence of multiple innovative solutions aimed at increasing the efficiency of last-mile delivery. For each solution, two elements were derived: (i) a definition/description of the solution, (ii) the cost factors affected by the solution and the type of impact on those factors. More in detail, (+) means that the solution makes the factor increase, whereas (-) decrease (Figure 2 and Table 3). The considered benchmark is the "traditional home delivery".

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The solutions are:

- *Reception boxes* – they are boxes, installed at the customers' house (usually in the garage or in the home yard), in which parcels are delivered (Wang *et al.*, 2014). They mainly impact on probability of failed deliveries [H] (-) and delivery automation [D] (+), since the customer does not have to be at home when the delivery is performed, nor to sign (Punakivi *et al.*, 2001);
- *Parcel lockers* – they are boxes owned by a retailer or a logistics service provider used by different customers, usually grouped into structures located in public places (e.g. supermarkets, post offices) (Wang *et al.*, 2014). The allocation of one specific locker to a specific customer is not fixed, but it dynamically varies according to the issued orders and to the availability. The customers are able to retrieve their parcel using a one-time password, barcode or QR code. They mainly impact on:
    - probability of failed delivery [H] (-), as it happens for reception boxes (a delivery fails in case the customer does not retrieve the parcel within the allowed time window or if the retailer/provider misses the agreed time window) (Wang et al., 2018);
    - customer density [G] (+), due to aggregation of orders coming from different customers in the same location (Giuffrida *et al.*, 2012);
    - delivery automation [D] (+), because the parcel is delivered in the box, and the customer does not need to sign (Wen and Li, 2016).
    - delivery-home distance [I] (+), since – differently from home delivery – customers need to move to reach the lockers where the parcels are stored (Chen et al., 2018).
- *Pick-up Points* – they are places that provide storage/delivery services: after goods have been delivered, customers can go there to pick them up. They may belong to or cooperate with logistics service provider or merchants (Wang *et al.*, 2014). Their impact is comparable to that of parcel lockers (i.e. probability of failed delivery [H] (-), customer density [G] (+) and delivery-home

distance [I] (+)). The main difference is that there is no delivery automation, since they often are kiosks or stores (Wang *et al.*, 2014).

- *Crowdsourcing logistics* – it consists in outsourcing last-mile delivery activities to a network of "common" people, i.e. the crowd (Carbone et al., 2017), that are available to bring a parcel from a point of origin to a point of destination. They often offer this service because they have to move on a similar route for personal or working reasons. The task may be performed under compensation (Wang *et al.*, 2016) or for free (Devari *et al.*, 2017). It impacts on:
  - driver specialisation [C] (-), because the crowd is usually composed by not-specialised people, who thus offer the delivery service at lower prices than couriers (Carbone et al., 2017);
  - share of (semi)fixed transport costs [B] (-), since the riders of the crowd usually rely on their own transport mean, or sometime even on taxis (Chen and Pan, 2016) or public transport (Wang *et al.*, 2016). This eliminates the share of semi-fixed/fixed costs of the transport mean faced by the delivering company.
- *Drones* – they consist in Unmanned-Aerial-Vehicles in which parcels are loaded. They are able to travel from an origin to a destination, relying on the on-board GPS. Once the destination is reached, the container is dropped off. Drones then have to come back to the warehouse (Dorling *et al.*, 2017) or to a truck that, in the meanwhile, has moved to a new destination (Murray and Chu, 2015). Here the driver changes the battery and loads the new container. They mainly impact on:
  - traffic/obstacles [E] (-), since drones do not have to travel on busy roads, but they fly avoiding traffic and obstacles (Murray and Chu, 2015);
  - transport automation [F] (+) and delivery automation [D] (+), as drones are able to autonomously complete the travel and drop off the parcel outside the customers' home, with very little remote intervention of "human pilots" (Murray and Chu, 2015);
  - resources consumption [A] (-), since drones do not rely on fuel to move (Kundu and Matis, 2017);
  - customer density [G] (-), due to the very low number of customers reached in a delivery tour – usually one (and no more than four) customer per tour (Dorling *et al.*, 2017). The main reasons are two. First, there are stringent weight and dimension constraints for the parcels drones can carry. Second, the battery has a low autonomy level, and drones must frequently reach the point of origin to replace/recharge it.
- *Trunk* – parcels are delivered in the trunk of the customer's car: couriers unlock the trunk through a one-time-use digital key associated to the specific order. The real-time information about the

car location is provided by the GPS system installed inside the vehicle (Reyes *et al.*, 2017). It impacts on:

- probability of failed delivery [H] (-) and delivery automation [D] (+), since the customers do not have to be present when the delivery is performed; parcels are delivered in the trunk, and they collect them at a later stage (Reyes *et al.*, 2017);
- customer density [G] (+), since parcels are often delivered while the car is parked in public places (e.g. supermarkets). If deliveries are performed when different cars of different customers are in the same place at the same time, it is possible to aggregate their demand (Reyes *et al.*, 2017).

- *Dynamic pricing* – when the delivery time is defined while orders are issued, implementing dynamic pricing means associating different delivery prices to different time windows. Customers are offered lower prices for time windows that optimise the delivery route of the truck (e.g. some close locations already have to be visited in the same tour), while higher prices are proposed for less efficient delivery options (Asdemir *et al.*, 2009). Pricing policy is defined as dynamic since it varies each time a new order is issued (Klein *et al.*, 2017). It impacts on:
  - probability of failed delivery [H] (-), since customers choose and know in advance the delivery time slot (Yang et al., 2014);
  - customer density [G] (-), because if customers can choose the preferred delivery time option, they influence the sequence of the destinations to be reached in the tour. Accordingly, companies are not able to optimise the delivery route (as it instead happens in traditional VRP tours). Nonetheless, implementing dynamic pricing policies increases the customer density compared to "simple" appointments. As a matter of fact, companies – implementing correct pricing strategies – may influence the choice of customers (who tend to select slots associated to lower prices) (Asdemir *et al.*, 2009).
- *Mapping customer behaviour* – based on a data mining process, mapping the customer presence consists in analysing a specific parameter that is correlated to the presence of the customer at home. While analysing the values of this parameter – e.g. electricity consumption (Pan *et al.*, 2017) – during the day and along the week, a probability distribution of the customer presence at home is derived. The delivery scheduling is then defined based also on these data, in order to minimise the probability of having failed deliveries due to the customers' absence. It thus impacts on the probability of failed delivery [H] (-), since deliveries are performed in the moment in which the probability that customers are at home is high (Pan *et al.*, 2017).
- *Underground delivery* – it relies on capsules containing the parcels moving within an underground pipeline system (Slabinac, 2015). They impact on:

- traffic/obstacles [E] (-), as capsules do not have to travel on busy roads, but under the ground;
- transport automation [F] (+) and delivery automation [D] (+), as workers are not required during the transport and the delivery phases (Slabinac, 2015);
- resources consumption [A] (-), since capsules do not need fuel to move in the pipelines;
- customer density [G] (-), due to the low capacity of capsules, that may carry only few parcels per tour.

- *Robots* – they are self-driving road vehicles that, moving on determined and controlled paths, reach the customers, who unload the vehicle retrieving their parcels (Slabinac, 2015). They impact on:
    - transport automation [F] (+) and delivery automation [D] (+), as workers are not required during the transport and the delivery phases (Boysen et al., 2018);
    - resources consumption [A] (-), since robots do not need fuel (Slabinac, 2015);
    - customer density [G] (-), due to the reduced number of parcels robots can carry in a tour, for both dimension and weight constraints.

The validity of the derived framework is tied to the definition of B2C parcel, since some last-mile solutions cannot work for specific deliveries. More in detail, the main typologies of parcels for which it may not be considered as totally valid, are three:

- very large parcels: even if some experimental initiatives have been implemented about big-dimension lockers (e.g. *Ikea*), this solution cannot be considered as a real effective and feasible option for very large products. The same considerations are valid also considering other solutions, e.g. drones, underground deliveries and robots, due to capacity constraints.
- e-grocery: some grocery products (e.g. eggs) are characterised by peculiarities (e.g. perishability/fragility) that require specific storage and transport conditions; in addition, the order dimension is usually much higher than the typical few-lines and few-products e-commerce orders (Fernie et al., 2010). Therefore, not all the last-mile delivery solutions are suitable for delivering an average e-grocery basket: drones and capsules, for instance, may entail significant capacity problems.
- products that need on-delivery services: if considering products such as home appliances, which may need to perform some activities when delivered (e.g. installation), many last-mile delivery solutions – e.g. parcel lockers, collection points – are not viable.

Gaps and future directions

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Although the literature review revealed that many aspects have been investigated about those last-mile delivery solutions that are innovative and efficiency-oriented, some elements should be further analysed, in order to both provide academics with a comprehensive view about the theme and support practitioners in taking decisions in the field. More in detail, three main types of gaps have been identified.

(i) High-level papers, that present a comprehensive view of all the innovative last-mile solutions and compares them analysing the cost factors they may affect, seem to be missing. The majority of papers focuses on one or just a very limited number of solutions, typically finding ways to optimise their application or evaluating the benefits they imply with respect to more traditional deliveries. Literature reviews or frameworks are also generally partial, since they miss some alternatives or do not consider the different cost factors and the impact innovative last-mile delivery solutions have on them.

(ii) Some of the innovative solutions are still under-investigated. For instance, in-car deliveries and underground deliveries did not gain much academics' attention. The low interest seems to be linked to the problems and difficulties to be faced in their implementation – e.g. technological and legal barriers for drones and underground deliveries (Slabinac, 2015). Nonetheless, there are other solutions that have so far been examined only in part, due to their recent introduction, even if they seem to be both very promising and less difficult to be implemented. This is the case of mapping the behaviour of customers for predicting their presence at home: the found papers have considered few parameters to be monitored (mainly the electricity consumption) and they are typically focused on the grocery sector. Though, according to different authors (e.g. Pan *et al.*, 2017), literature could benefit from both the study of other parameters to be monitored and the potential applications to other industries. Moreover, new technologies are spreading that can map the behaviour of users (e.g. smart home speakers), and this opens many research opportunities in this direction.

(iii) Even among the solutions discussed by a higher number of papers, some limitations or aspects to be further investigated may be identified.

- *Parcel lockers* – literature shows different qualitative works, such as surveys aimed at evaluating the intention of customers to use this alternative last-mile delivery solution. Quantitative papers are fewer, focused on a limited number of industries (mainly grocery), with limited contributions coming from the managerial community (i.e. retailers and logistics service providers) and with very specific geographical scopes (mainly Northern Europe/Asia). Logistic operators – e.g. *DHL*, *InPost* – as well as e-commerce players – e.g. *Amazon* and *ePrice* – have implemented parcel lockers as an alternative to home

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delivery also in other countries, such as Italy (Ranieri *et al.*, 2018). Though, the adoption of this solution is much lower if compared to other contexts (e.g. UK or Germany), and this is mainly due to the scarce awareness of merchants about the savings to which they could lead. These scenarios would thus benefit from deeper quantitative analyses about the savings parcel locker may imply. In addition, the involvement of practitioners in these studies could allow to ground them on reliable data, that may be perceived as significant also by the managerial community.

- *Crowdsourcing logistics* – different qualitative works aimed at building conceptual frameworks or classifications may be found. There are also quantitative papers trying to estimate the economic benefits stemming from its implementation, but they usually consider cases in which deliveries are assigned to riders who already have to move on similar routes for personal reasons. Accordingly, low research effort has been put in analysing the "crowdsourcing logistics business model" (in which the crowd is considered as a source of on-demand workforce) despite this model represents an effective delivery solution, which is expected to have a great impact on urban logistics in many cities (Wang *et al.*, 2016). More specifically, interviews with practitioners revealed that there are various crowdsourcing logistics configurations, which – due to their significant differences – should be separately considered. More in detail, the main identified models to be investigated are:
    - the "multi-parcel courier" model (standard deliveries, large set of orders assigned to riders, few points-of-origin, usually warehouses or transit points);
    - the "pony express" model (super-express deliveries, one order per time associated to riders, many dispersed points-of-origin, e.g. stores). With regard to this second model, there is one peculiar application that is gaining increasing attention, and which should be better investigated: the so-called "food delivery" (i.e. the delivery of fresh prepared meals to customers' home from restaurants, supported by the use of online platforms).
- *Dynamic pricing* – it is mainly applied to e-grocery. This industry is characterised by very low margins and deliveries are by-appointment, and both those reasons make this sector suitable for such solution. Nonetheless, also other sectors could gain significant benefits from the implementation of dynamic pricing, and future research effort could focus on them. Considering for example not specialised retailers, on the one side the number of lines per order is much lower with respect to e-grocery (Fernie *et al.*, 2010), and it is thus very difficult to saturate the transport mean without an optimised delivery scheduling. On

the other side, the product perishability is much lower (Boyer *et al.*, 2003), and – since there is no need to come back to the warehouse to collect the parcels – these deliveries may be organised on wider time lapses, thus better scheduling them. Accordingly, the interest in applying this solution to industries different from the grocery one is spreading also among practitioners, and this is proved by the launch of initiatives such as *Milkman*.

Conclusions

In this study 75 papers, including both works published in scientific journals and conference papers, were reviewed. After considering their general characteristics – i.e. year, source and country – the contributions were systematically analysed following a two-pronged approach. More in detail, they were categorised based on the research method(s) adopted by the author(s), and then they were classified based on their content. Considering the addressed themes, two main analyses were performed. (i) First, the formula of the last-mile delivery cost per parcel was found, and the different components of this cost were identified. Based on this analysis, a comprehensive view of the main factors – positively and negatively – impacting on the found cost components was provided. Those factors are: the resources consumption and the share of semi-fixed cost of the transport mean, the specialisation of the driver, the degree of automation of both transport and delivery activities, the problems or obstacles met in the delivery tour, the customer density, the probability of failed deliveries and the distance between the delivery point and the home of the customer. (ii) Second, the viable innovative last-mile delivery solutions aimed at increasing efficiency – and the way in which they impact on the previously mentioned factors – were identified. These solutions are: reception boxes, parcel lockers, pick-up points, crowdsourcing logistics, drones, trunk delivery, dynamic pricing, mapping the customer behaviour, underground delivery and robots. Finally, stemming from the analysis, some areas for possible further research efforts were identified (e.g. targeting under-investigated solution such as mapping the customer behaviour or addressing the implementation of dynamic pricing to sectors different from e-grocery, such as not-specialised retailers).

This review offers insights to both academics and practitioners. On the academic side, it analyses and classifies relevant literature about efficiency-oriented innovative last-mile delivery solutions, proposing directions for future research activities stemming from the emerging gaps. On the managerial side, it presents a comprehensive analysis of the main factors affecting last-mile delivery costs and the viable innovative solutions that may be implemented, thus offering a tool that could be used while evaluating the right last-mile delivery strategy to be implemented by e-commerce operators.

This work has two main limitations. First, it may not be considered as all-inclusive in terms of analysed contributions. Nonetheless, the authors are confident that the general picture emerged from

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the review, both in terms of cost factors and innovative last-mile delivery solutions, is trustworthy, and that the presented results are representative of the up to date knowledge about the topic. Second, the suggested research directions focus on innovative solutions, and not on cost factors nor on cost components. In fact, cost factors and components have also been widely analysed in literature dealing with traditional last-mile deliveries, which is not included in this work.

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Research method	Number
Quantitative model	52
Empirical analysis	21
Conceptual model	11

Table 1: Research method

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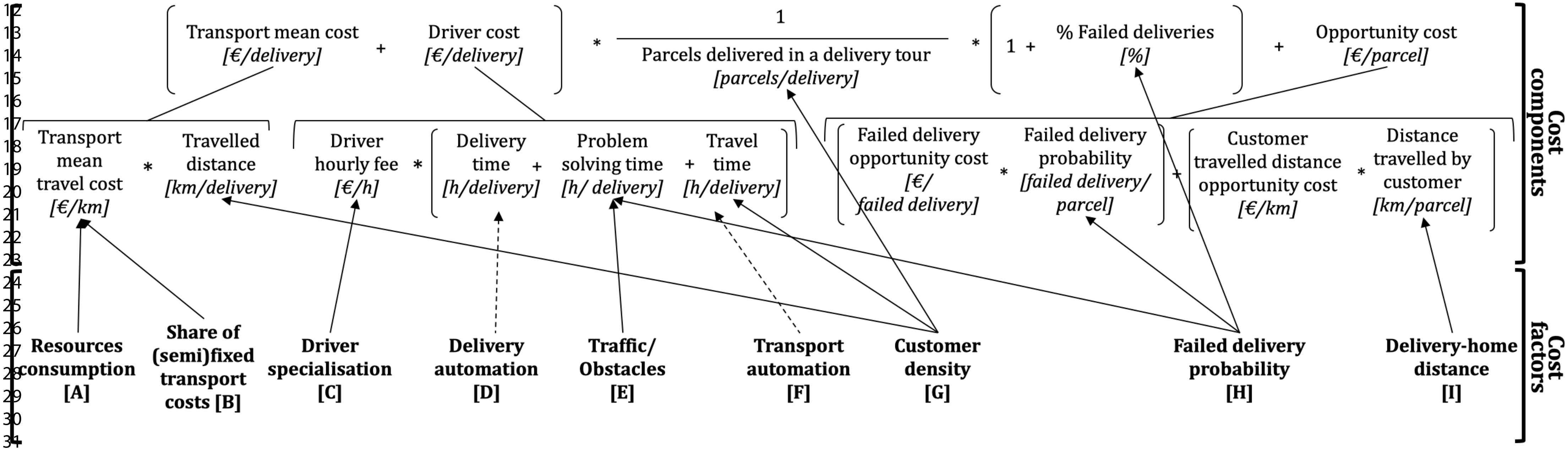

Transport mean cost [€/delivery]
+
Driver cost [€/delivery]
*
1
Parcels delivered in a delivery tour [parcels/delivery]
*
1 +
% Failed deliveries [%]
+
Opportunity cost [€/parcel]
Cost components
Transport mean travel cost [€/km]
*
Travelled distance [km/delivery]
Driver hourly fee [€/h]
*
Delivery time [h/delivery]
+
Problem solving time [h/ delivery]
+
Travel time [h/delivery]
Failed delivery opportunity cost [€/ failed delivery]
*
Failed delivery probability [failed delivery/ parcel]
+
Customer travelled distance opportunity cost [€/km]
*
Distance travelled by customer [km/parcel]
Resources consumption [A]
Share of (semi)fixed transport costs [B]
Driver specialisation [C]
Delivery automation [D]
Traffic/ Obstacles [E]
Transport automation [F]
Customer density [G]
Failed delivery probability [H]
Delivery-home distance [I]
Cost factors

		Cost components											
		Transport mean travel cost	Travelled distance	Driver hourly fee	Delivery time	Problem solving time	Travel time	Parcels delivered in a tour	% Failed deliveries	Failed delivery opportunity cost	Failed delivery probability	Customer travelled distance opportunity cost	Distance travelled by customer
Cost factors	Resources consumption	+											
	Share of (semi)fixed transport cost	+											
	Driver specialisation			+									
	Delivery automation				+								
	Traffic/ obstacles					+							
	Transport automation						-						
	Customer density		+				+	+					
	Failed delivery probability					+			+		+		
	Delivery-home distance												+

Table 2: Relationships among cost factors and cost components

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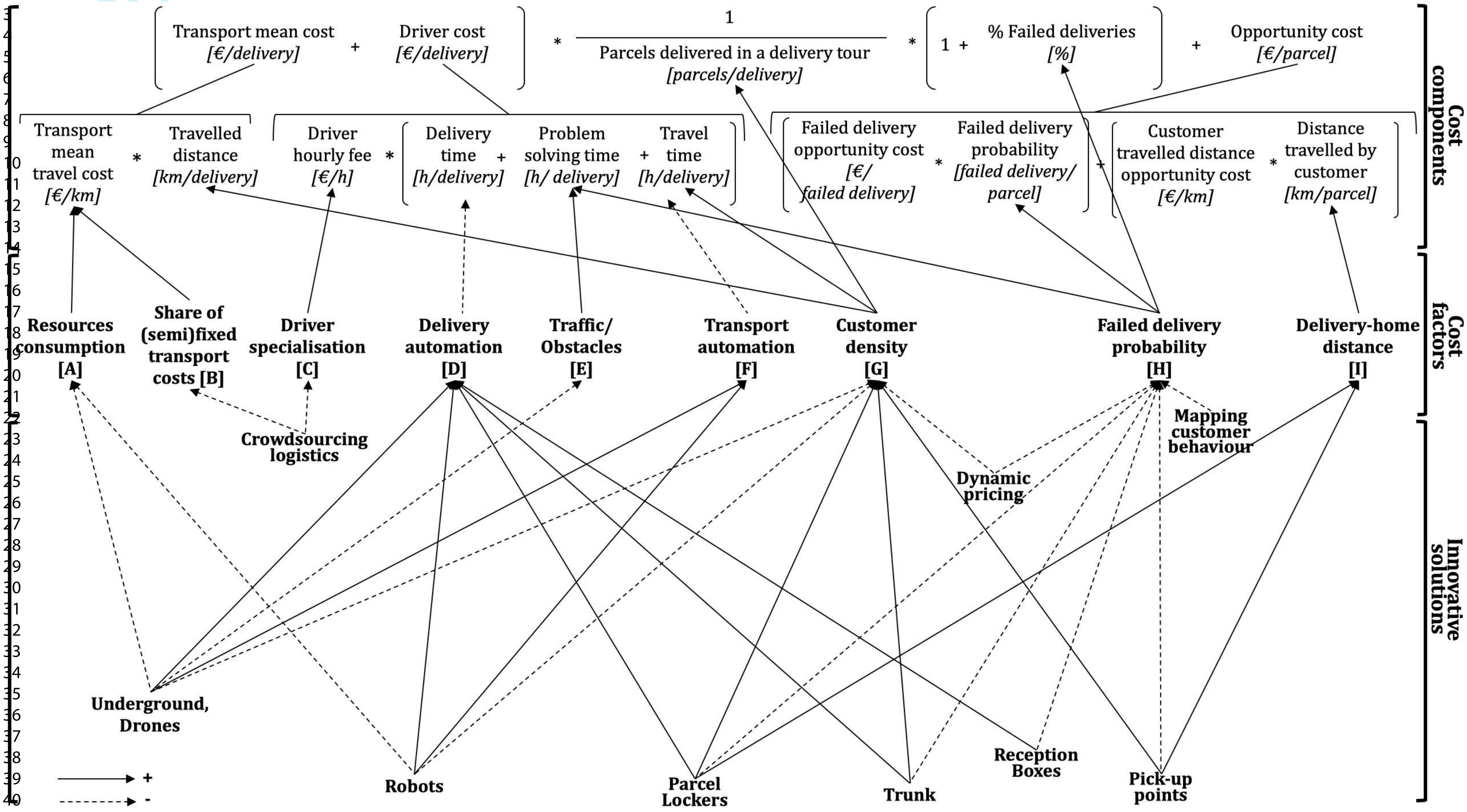
Transport mean cost [€/delivery] + Driver cost [€/delivery]
* 1 / Parcels delivered in a delivery tour [parcels/delivery]
* 1 + % Failed deliveries [%]
+ Opportunity cost [€/parcel]
Transport mean travel cost [€/km] * Travelled distance [km/delivery]
Driver hourly fee [€/h] * Delivery time [h/delivery] + Problem solving time [h/ delivery] + Travel time [h/delivery]
Failed delivery opportunity cost [€/ failed delivery] * Failed delivery probability [failed delivery/ parcel]
+ Customer travelled distance opportunity cost [€/km] * Distance travelled by customer [km/parcel]
Cost components
Resources consumption [A]
Share of (semi)fixed transport costs [B]
Driver specialisation [C]
Delivery automation [D]
Traffic/ Obstacles [E]
Transport automation [F]
Customer density [G]
Failed delivery probability [H]
Delivery-home distance [I]
Cost factors
Crowdsourcing logistics
Mapping customer behaviour
Dynamic pricing
Underground, Drones
Robots
Parcel Lockers
Trunk
Reception Boxes
Pick-up points
Innovative solutions
+
-

		Cost factors								
		Resources consumption	Share of (semi)fixed transport cost	Driver specialisation	Delivery automation	Traffic/obstacles	Transport automation	Customer density	Failed delivery probability	Delivery-home distance
Innovative solutions	Reception boxes				+				-	
	Parcel lockers				+			+	-	+
	Pick-up points							+	-	+
	Crowdsourcing logistics		-	-						
	Drones	-			+	-	+	-		
	Trunk				+			+	-	
	Dynamic pricing							-	-	
	Mapping customer behaviour								-	
	Underground delivery	-			+	-	+	-		
	Robots	-			+		+	-		

Table 3: Relationships among innovative solutions and cost factors

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