Experts' opinions about lasting innovative technologies in City Logistics

Experts' Opinions about Lasting Innovative Technologies in City Logistics

Abstract

The COVID-19 pandemic has highlighted the relevance of goods delivery in urban areas. However, this activity often generates negative environmental impact and several technologies have been proposed in recent years to reduce it, thus forming a complex innovation landscape characterized by different levels of maturity and effects on the City Logistics (CL) system. This complexity causes a deep uncertainty over the future of CL. This paper aims to tackle this uncertainty by forecasting the future of a set of CL technologies. A Delphi survey has been submitted to experts of this field to achieve a stable consensus over 33 projections related to 7 CL technologies for the year 2030. Results show that real-time data collection will help the coordination process between stakeholders, engendering an increased awareness over the value of using logistics data as well as its potential drawbacks. Moreover, experts share a positive attitude towards the expansion of Parcel Lockers, which should be monitored by public authorities to avoid a negative impact on land use. Finally, technologies such as drones and crowd-logistics have drawn the lowest level of consensus due to their lower level of maturity, which arouse the necessity to further explore several issues such as legal and technical barriers.

Keywords: Technology forecast; City Logistics; Delphi survey; Statistical analysis

1. Introduction

The dramatic increase of last mile logistics, as a result of the booming trends of ecommerce, is causing several problems in urban areas such as traffic congestion, noise and air pollution. The ecommerce business has been significantly strengthened with the COVID-19 pandemic (Guthrie, Fosso-Wamba and Arnaud, 2021) and several studies state that consumers are going to maintain their new digital purchasing behaviors even once the pandemic ends (Kim, 2020; Sheth, 2020).

In this context, recent innovative technologies are being developed and applied in City Logistics (CL) that will likely bring significant changes in the next future. Currently, several recent technologies are reported in the literature. In particular, Taniguchi et al. (2020) identify Intelligent Transportation Systems (ITS), Autonomous Vehicles, Parcel Lockers, Crowd Shipping Platforms, and Electric Vehicles, as promising technologies to foster future CL systems especially if combined with Internet of Things (IoT) and Big Data. These technologies can be considered as pillars for CL implementations in the coming years (de Gauna, Villalonga and Sánchez, 2020; Dolati Neghabadi, Espinouse and

Lionet, 2021). Big Data Analytics (BDA) are also foreshadowing benefits in terms of real-time prediction, adaptation, quality of life and greater ease of movement (Kandt and Batty, 2021).

However, the implementation of these technologies is quite difficult, their returns on investment are uncertain, and several barriers must be overcome. In fact, CL projects must often deal with critical operations and financial feasibility (Katsela and Pålsson, 2020). As a result, many initiatives have reported promising outcomes in their initial implementation phases, but have not been able to survive in the long run due to their low profitability (Gammelgaard, 2015). Thus, there is a literature gap about the evaluation of the expectations on innovative technologies on CL that might be a support for driving future investments by private operators and for a more accurate design of policies by public authorities. This evaluation might be uncertain, and the point of view of expert professionals should be taken into account. Forecasting based on experts' opinions has the major advantage of rooting the forecasts in a detailed understanding of the causes underlying the future trends of a system (McKinnon and Piecyk, 2013). The Delphi method represents a structured approach to elicit experts' opinions on a range of subjects, particularly future developments and trends. Its objective is to structure complex group opinions (Rauch, 1979) and to develop consensus on future developments (Turoff and Linstone, 2002).

Hence, with the aim of bridging this research gap, the objective of this paper is to investigate the future scenarios related to a set of CL technologies that are identified through a careful analysis of relevant literature. The future scenarios are traced by eliciting experts' consensus via a Delphi approach. In particular, the opinions and the perceptions of a panel of last-mile logistics experts are gathered to assess the impact of the above-mentioned innovative technologies and to identify the levers able to support their diffusion together with the barriers than can negatively affect their adoption.

The paper is structured as follows. First, an overview of the current literature focusing on contributions that deal with technology forecasting methods as well as Delphi applications in logistics and supply chain is presented. After that, the methodological steps of the research are listed, namely the panel selection, the development of projections, survey submission and data analysis and testing. The results are then analyzed. In particular, it can be noticed that Intelligent Transportation Systems are expected to enhance the sharing of information among logistics operators and with the customers. Another important finding is the need of stronger involvement of policy makers for more standard regulations about the use of innovative technologies such as drones. Finally, discussions and conclusions are proposed.

2. Literature Review

This section of the paper is twofold. In the first part an overview of the existing literature on the possible methodological approaches for technology forecasting is provided. The other part is focused on describing applications of the Delphi method in the fields of logistics and supply chain management.

2.1 Previous research on Technology forecasting

Several approaches are adopted in the literature to anticipate and predict future impacts and applications of technology such as simulation, prediction, Artificial Intelligence, trend explorations and machine learning algorithms, analytical models and surveys.

Simulation methodologies provide a suitable approach to provide insights into the future outcomes of last-mile initiatives. For instance, Teo et al. (2012) and van Duin et al. (2012) propose an agent-based model combined with a vehicle routing approach to evaluate CL measures such as road pricing. System Dynamics has been adopted to assess the impact of public regulations and incentives aimed at reducing CO2 emissions (Stepp *et al.*, 2009; Egilmez and Tatari, 2012), as well as to explore the potential for diffusion of last-mile innovations such as electric vehicles (Gorbea, Lindemann and de Weck, 2011; Shepherd, Bonsall and Harrison, 2012; Cagliano *et al.*, 2017) and Information and Communication Technologies (ICT) platforms for enhancing stakeholders' interaction (Mangano *et al.*, 2019).

Prediction might be obtained through the exponential smoothing (Moghram and Rahman, 1989). As a consolidated methodology for anticipating the level of success of a product or service in terms of demand prediction. Temporal causality modeling exploits previous data to determine future time series (Nafil *et al.*, 2020). More recently, artificial intelligence can be used for predictions. This approach might be adopted together with more established methodologies such as Multi Criteria Decision Methods, in order to assign more precise weights to every criteria at issue (Savun-Hekimoğlu *et al.*, 2021). (Li *et al.*, 2019) combine the expert opinion with trend analysis approach for forecasting the trend of a technology. In this context, trend extrapolation as a numerical method that combines different approaches is able to overcome the limitations associated to the adoption of a single techniques and in turn to enrich the results of the analysis (Yuskevich *et al.*, 2021). Data Envelop Analysis might also be suitable for carrying out estimations on the technology rate of change (Anderson *et al.*, 2002). Finally, more recently machine learnings algorithms are exploited for evaluating and improving logistics processes (Baghdadi *et al.*, 2018). However, in order to adopt quantitative methodologies to extrapolate future states of a system from present behaviors scholars assume that past trends will continue indefinitely. Case studies might be used for carrying out an ex-ante assessment and consequently for providing scientific based issue to be used in future debate (Prosperi, Lombardi and Spada, 2019). They prove their suitability in testing the effectiveness of a selected measure of policy in CL systems (Bozzo, Conca and Marangon, 2014). Analytical models are typically developed for anticipate configurations of complex logistics systems, by considering different perspectives of the business such as the management of the inventory or the level of revenues and costs (Gu, Liu and Qing, 2017; Wang and Mersereau, 2017). Also, surveys can be taken into account as an excellent way to collect personal opinion on a certain product, service, policy, or behavior (Yabe *et al.*, 2021).

2.2 Pertinent Delphi applications to Logistics and Supply Chain research

Logistics and supply chain contexts represent an interesting field of application for the Delphi method. Scholars have been using Delphi surveys to project future trends in supply chain management (Melnyk *et al.*, 2009), supply chain risks (Markmann, Darkow and Von Der Gracht, 2013), logistics service industry (Von Der Gracht and Darkow, 2010), and greenhouse emissions in the transport and logistics sectors (McKinnon and Piecyk, 2013). Literature has also found fertile ground in exploring the potential of the Delphi method for technology foresight and developing future implementation scenarios, namely for autonomous trucks (Fritschy and Spinler, 2019) and Big Data Analytics in Supply Chain (Roßmann *et al.*, 2018). To the best of our knowledge, the proposed study is the first Delphi survey applied to last-mile logistics technologies.

Most of these studies apply a two-round Delphi survey built from initial formulations developed from multiple sources, usually pertinent literature, brainstorming and desk research, which were then pre-tested with a pre-panel of senior researchers or managers. The pre-test has the objective of testing for content and face validity of the survey items, which are usually closed-ended questions to ensure such validity (Hsu and Sandford, 2007). Scholars using the Delphi method in logistics, transportation and Supply Chain sectors have always been careful not to generate fatigue in the experts by proposing the right number of items for the experts' evaluation, generally spanning between 16 and 41. In all papers except one, survey items take the form of projections for a future timeframe, usually set at 15-20 years from the year of submission. The exception is represented by the paper of McKinnon and Piecyk (2013) where experts are asked to predict the changes in a set of key transport variables. Purposive sampling is used to select the most suitable and knowledgeable experts on the topic at issue, whereby expertise is further approximated with the years of experience or self-assessed by the experts. The number of experts participating in the survey ranges from 15 to 275, with different groups involved (e.g. academics, consultants, public authorities and other private firms) to ensure a variety of opinions. Therefore, the present literature review shows that the Delphi method supports the research objective by providing a structured approach to identify the future technological trends of the CL.

3. Methodology

A Delphi approach is used in this study because it stimulates a panel of experts to formulate a collective understanding through balanced communication that minimizes difficulties related to social status or personality traits in interacting groups (Rowe, Wright and Bolger, 1991). The Delphi method has proven to be efficient for gathering insights on a topic when only a limited amount of data is available or when future projections are explored (Markmann, Darkow and Von Der Gracht, 2013). In these contexts, reliable and stable results can be achieved through the subsequent rounds of a Delphi survey (Landeta, 2006; von der Gracht, 2012). Researchers have found that Delphi studies consistently outperform normal surveys, as experts provide a more accurate forecast than traditional survey groups (Rowe and Wright, 2001).

Hence, the research has been conducted through the following steps. First, a literature research about the identified technologies and their impacts and applications on last-mile logistics is conducted on scholarly databases, desk research and participation to international workshops.

Second, a group of experts is selected to take part to the Delphi survey. Third, two rounds of the questionnaire are carried out. At the end of the first one preliminary results are shared in order to give evidence about the consensus and the discord for the projections at issues. Then, the results are analyzed both qualitatively and quantitatively via the Kruskal-Wallis test.

3.1 Development of technology projections

Projections represent brief future statements with the intent to provoke a reflective assessment from experts. The year of reference for the projections is set to be 2030, which is consistent with the typical 10-15 years forecasting horizon of similar studies (Culot *et al.*, 2020).

The development of the projections is the result of a literature exploration conducted on SCOPUS, which is recognized as the most complete bibliometric database of scientific peer-reviewed literature (Vila *et al.*, 2020).

In last-mile logistics contexts, many innovative applications of recent technologies can be found, such as sharing the capacity of vehicles, distribution centers and information systems. For example, the pool of potential drivers that represents the "crowd" can benefit from flexible earnings opportunities (Carbone, Rouquet and Roussat, 2015) while customers can benefit from faster and cheaper deliveries (Arslan *et al.*, 2019). Furthermore, drones are gaining popularity in last mile services after a successful adoption in construction, monitoring and surveillance (Macrina et al., 2020) especially when several major on line retailer such as Amazon and Google have claimed to introduce drones for carrying out their parcel operations activities (Yoo, Yu and Jung, 2018).

Intelligent Transportation Systems (ITS) are innovative solutions aimed at supporting a proper management of transports and more in general of traffic with positive effects on air and noise pollution. They have been deployed during the past decade with a wide spectrum of devices such as smart infrastructure, vehicle connectivity and real-time information (Zhang *et al.*, 2018). In last-mile logistics they allow to save time, cost, and improve the operations effectiveness (Martins, Anholon and Quelhas, 2019). In addition, municipalities are trying to reduce the amount of traffic congestion by promoting the adoption of zero-emission vehicles such as cargo bikes and electric vehicles for last mile delivery (Cattaruzza *et al.*, 2015). In particular cargo bikes are proving to be suitable for low weight parcels, and might achieve short delivery times. At the same time, they are able to ensure significant congestion reduction with no emissions (Nürnberg, 2019). Similarly, freight vehicles powered with electric engines represent and interesting solution in decarbonizing CL operations especially if electricity is generated from renewable energies (Lebaeu et al., 2016). In fact, since electric engine do not emit any gas emission, the electric vehicles are considered as a crucial lever for improved air quality in the cities (Soret, Guevara and Baldasano, 2014). Low impact vehicles are often used together with parcel lockers, typically located in high frequency areas (such as train or bus stations) (Enthoven *et al.*, 2020). Parcel lockers store parcels to be picked up by final customers who have to identify themselves via integrated terminals (Schwerdfeger and Boysen, 2020). They provide a convenient solution especially for people often not at home during the typical delivery times (Iwan, Kijewska and Lemke, 2016). CL systems can also be enhanced by using Internet of Things (IoT) solutions (Wang *et al.*, 2020) that are likely to bring opportunities in the field of the intelligent logistics, by improving the efficiency, reducing the costs and increasing the competitiveness (Fu, 2018). Indeed, IoT applications have received a lot of attention in the field of traffic and transportation (Tahaei *et al.*, 2020), since they are able to facilitate the exchange of goods and services by connecting each object to a data network and assigning a digital identity (Golpira et al., 2021). The related final aim is to create a worldwide network to connect people, things, data and processes (Malik, Dutta and Granjal, 2019).

A first list of 65 projections is developed from the literature. Then, 24 projections were excluded after a brainstorming session among the researchers participating in this study in order to avoid redundancies. The list of 41 projections has been submitted to a panel of 6 senior experts, who ensured that items were both compelling, non-trivial, clearly expressed and understandable. Moreover, the test with the panel of experts aimed at achieving the reliability of the survey by ensuring that the wording of the questions would not influence the answers (Gordon, 1992) by avoiding ambiguity and conditional statements (Rowe and Wright, 2011). Reliability ensures that “true consensus” is reached, rather than a consensus based on the absence of real debate.

The revised version of the projections was again submitted to the pre-panel to check that all changes requested were included in the final list.

The final list includes 33 projections phrased according to consolidated practices regarding the length and number of elements in each sentence (Mitchell, 1991). The projections can be classified according to the seven technologies being investigated and four categories of analysis (Table 1). These categories are traced back on how technology is traditionally assessed in literature. In particular:

i. Barriers to the implementation of technology can be referred to lack of knowledge, more focus on operations processes lack of understanding the strategic importance, and the scarcity of human resources (Yu and Schweisfurth, 2020);
ii. External factors that may enable the uptake intended as long-term process that is hard to manage given the multidimensional aspects (*e.g.* economic, user-friendliness) of a technology (Haque, 2022);
iii. Benefits of using the technology to last-mile stakeholders that often have different goals in dealing with CL (Amaya *et al.*, 2021);
iv. Impacts on last-mile stakeholders that are the drivers towards the selection and implementation of the appropriate solution in every specific case (Nathanail *et al.*, 2021).

Table 1 Final list of projections

Technology	ID	Projection	Category
Big Data Analytics (BDA)	1.1	BDA have enabled de-centralization of decision-making processes in supply networks and have supported the growth of micro-retailing, such as "nanostores".	Benefits of using the technology
	1.2	The application of BDA has increased order frequency for B2B customers.	Impacts on stakeholders
	1.3	The market share of same day delivery services is higher due to more precise demand forecasting supported by BDA.	Impacts on stakeholders
	1.4	At an operational level, Big Data is used for supporting interaction between final customers and Logistics Service Providers (LSP) – e.g. Real time coordination with drivers-.	Benefits of using the technology
Crowd Logistics	2.1	Acceptability by customer (trust, safety, and security) is one of the main barriers blocking the adoption of crowd logistics solutions.	Barriers to the implementation
	2.2	For e-commerce home-deliveries, traditional delivery vans are still preferred to crowd-logistics due to their more efficient use of the vehicle (i.e. delivery vans have higher load factors).	Impacts on stakeholders
	2.3	Crowd logistics is better suited in nonstandard non-scheduled deliveries (groceries, flowers, etc.) and in less dense (i.e. rural) environments.	Benefits of using the technology
	2.4	Crowd logistic services are economically viable only in high demand areas.	Enabling factors
	2.5	Crowd logistics does not provide environmental benefits if associated with private cars.	Impacts on stakeholders
	2.6	Crowd-logistics services negatively impacts the level of salaries for last-mile professional drivers.	Impacts on stakeholders
	2.7	Crowd-logistics ensures the same level of service even though the carriers are, usually, not trained professionals.	Benefits of using the technology

Drones	3.1	Urban drone deliveries are economically viable only if paired with centralized urban fullfilment and/or consolidation centres.	Enabling factors
	3.2	To support the adoption of drone-based delivery, how important it has been to overcome the following issues: [Lack of dedicated regulation frameworks.]	Barriers to the implementation
	3.3	To support the adoption of drone-based delivery, how important it has been to overcome the following issues: [Social acceptance -e.g. privacy, surveillance concerns-]	Barriers to the implementation
	3.4	To support the adoption of drone-based delivery, how important it has been to overcome the following issues: [Technological issues -e.g.range, capacity, resistance to extreme weather, landing capabilities, safety, advanced navigation and coordination algorithms-]	Barriers to the implementation
	3.5	Drone-based deliveries are enabled by being integrated with delivery vans (both autonomous and manned) for the first leg of the journey (Outward journey).	Enabling factors
	3.6	Drone-based delivery are better suited in limited scenarios such as rural deliveries, medical deliveries or emergency relief.	Benefits of using the technology
	3.7	The adoption of drone-based delivery reduces the size of last-mile vehicle fleets and in turn the number of required drivers.	Benefits of using the technology
Intelligent Transportati on Systems (ITS)	4.1	The number of freight delivery bays have increased, and their locations and size are optimized. In addition, delivery bay monitoring and booking systems have been deployed and enforced (i.e. ensuring that illegal behaviors are fined).	Impacts on stakeholders
	4.2	Public authorities are focusing their efforts on enforcing access restrictions such as Low Emission Zones and congestion charges through ITS systems (e.g. automated plate reading and electronic payments).	Impacts on stakeholders
	4.3	ITS implementations aim at gathering reliable, precise, deep and broad data on last-mile systems -e.g. number of vehicles, volumes transported, load factors, traffic flows etc.-.	Benefits of using the technology
Low Emission Vehicles	5.1	Adoption of EVs is still related to the implementation of public policies such as: access restrictions and economic incentives.	Enabling factors
	5.2	Only LSPs with high consumer density are able to use cargo bikes efficiently.	Enabling factors
Parcel Lockers	6.1	Parcel Lockers diffusion has reached a plateau due to the investment costs needed to reach all customers.	Barriers to the implementation
	6.2	Local administrations allow parcel lockers to be installed on public space only if they are accessible via public transportation.	Enabling factors
	6.3	Only LSPs with high consumer density are able to use parcel lockers efficiently.	Enabling factors
	6.4	Shared parcel lockers are supported by LSPs.	Impacts on stakeholders
	6.5	Parcel Locker systems have been associated with automobile dependent travel behaviour.	Impacts on stakeholders
	6.6	Parcel Lockers are more likely to be installed in urban rather than suburban areas.	Impacts on stakeholders
	6.7	Parcel Lockers are more likely to be installed in high density (i.e. urban) rather than low density (i.e. rural) areas.	Impacts on stakeholders
Internet of Things (IoT) and connected devices	7.1	The main barrier to the increase of communication and coordination mechanisms between carriers and customers is the customers' inertia to technology adoption.	Barriers to the implementation
	7.2	Acceptability by customers (trust, safety, and security) is one of the main barriers blocking the adoption of IOT-based logistics services (e.g. smart locks, digital keys for in-car delivery etc.)	Barriers to the implementation
	7.3	Real-time data from multiple sources (e.g. traffic, road disruptions) are more available and thus enable a more widespread usage of dynamic vehicle routing algorithms	Enabling factors

Regarding the relations between technologies and category of analysis, a clarification is due. In fact, technologies are not necessarily associated with projections spanning over all four categories, due to the different maturity levels achieved by such technologies and the consensus reached in the literature. For instance, ITS implementations are entangled with local enforcement and thus they are more associated with bearing impacts on last-mile stakeholders. Parcel Lockers instead have proved the value that they can bring about operational, economic, and environmental benefits, and thus the projections focus on other aspects linked with their future implementation scenarios. As for BDA, the projections are more focused on impacts and benefits to last-mile stakeholders rather than barriers and enabling factors because the adoption of BDA occurs at the supply chain level, and it is therefore outside the scope of this study. Crowd-logistics and Drones instead are less consolidated technologies, and thus more attention has been posed towards the barriers to the implementations, as well as the enabling factors.

3.2. Panel selection

Experts have been selected through a rigorous selection procedure to account for the diversity between groups of stakeholders.

A pool of 226 experts has been asked to take part to this study. These experts have been recognized as last-mile logistics experts due to their enrollment in the Urban Mobility group of ALICE, Alliance for Logistics Innovation through Collaboration in Europe, which aggregates experts of last-mile logistics and coordinates European level initiatives in this field. Moreover, representatives from last-mile companies were found through last-mile logistics special interest groups on LinkedIn.

A final number of 27 experts has taken part in the study, equally distributed across different categories of experience and work positions (Figure 1). Therefore, a response rate of 12.4% has been reached, which is deemed acceptable (Monzon, Julio and Garcia-Martinez, 2020). The respondents have been classified according to several demographic aspects (de Oliveira *et al.*, 2021), such as the number of years of experience as a proxy of the level of expertise (Arditi, Mangano and De Marco, 2015), and the role profile (De Marco, Mangano and De Magistris, 2021). Respondents have been grouped as Academics to consider the theoretical perspective, Consultants, or Managers so as to include both internal and external business points of view. Finally, the type of affiliation has been considered to identify similarities or differences between research centers and universities, companies, and other entities such as public agencies.

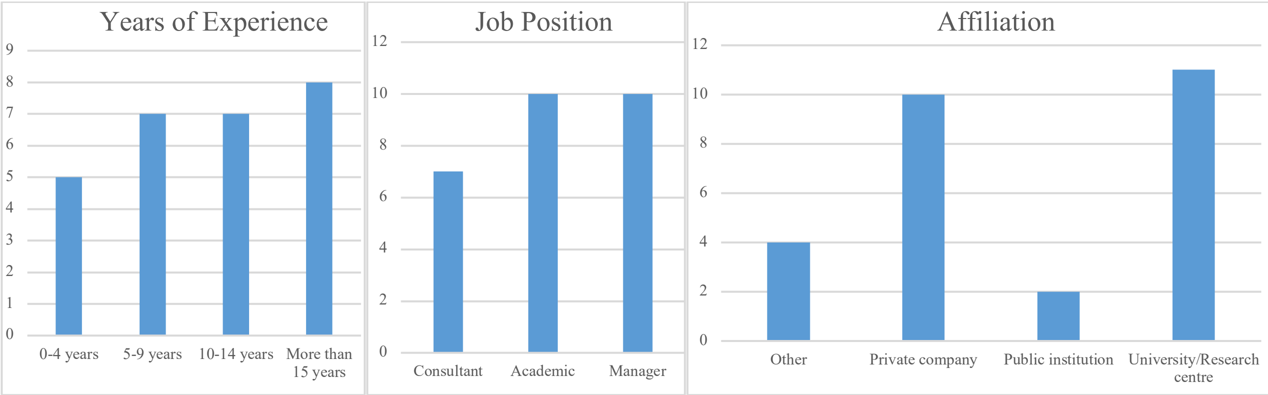

Figure 1 Distribution of panel across different demographic classes

3.3. Survey submission

The survey is composed is twofold. In the first part experts have been asked to position themselves in the stakeholder category and provide some demographic information, such as professional affiliation, job position and years of experience. In the second part, respondents have been asked to rate the future probability of occurrence for each item, on a 5-point Likert Scale where 1 = Very Improbable, 2 = Improbable, 3= Possible, 4= Probable, and 5= Very Probable. Qualitative statements were also given by the experts to justify their answers.

The projections are presented as closed-ended statements in order to achieve content and face validity of the Delphi survey (Hsu and Sandford, 2007). Moreover, the questionnaire was structured into clusters of topics to make it easy to follow.

The first round of the survey has been disseminated via e-mail and through specialized online groups on LinkedIn between 08/10/2020 and 13/10/2020.

Prior to the second round, we provide descriptive statistics for each item and a general overview of the reasons for such evaluation. Then, the second round has been submitted on 05/11/2020. During the second round, experts could change their quantitative evaluation as many times as they want, providing a reason for this change.

3.4. Data analysis and testing

In order to measure consensus, two parameters are used, namely the Interquartile Range (IQR) and the Reliability within group (r_{wg}). IQR calculates the dispersion from the median response, while r_{wg} is a measure of inter-rater agreement. Both parameters are frequently used for analyzing data non-normally distributed, as it is typical of the Delphi survey (Jiang, Kleer and Piller, 2017; Von Briel, 2018; Gossler *et al.*, 2019). A projection reaches true consensus if IQR is ≤ 1 (Gossler *et al.*, 2019) and R_{wg} exceeds 0,3 (LeBreton and Senter, 2008). Both parameters need to fall within the required thresholds in order to meet true consensus.

The obtained data are also analyzed via the Kruskal-Wallis test, with the goal of finding out whether the samples at issue belong to the same population (Guo, Zhong and Zhang, 2013). This nonparametric test is able to run when data do not follow a normal distribution and it works also in the case of small sample groups (even smaller than 25) (Kitchen, 2009). Its null hypothesis is the stochastic homogeneity, with stochastic heterogeneity being the alternative one (Vargha and Delaney, 1998). In practical terms, when the null hypothesis has to be rejected, in favor of the alternative one, a significant difference among the medians of the sub-groups exists (Ruxton and Beauchamp, 2008). The level of significance of the test is associated with the p-value. If the test shows p-value lower than the significance level (usually 5%), the null hypothesis can be rejected meaning that there is at least one difference among the groups under study. This means that at least one group has a different perception about the probability of occurrence for a specific projection. In the Delphi methodology the final goal is to obtain a general consensus about the proposed projections. Thus, the Kruskal-Wallis test highlights those items with diverging opinions. For this reason, the tests have been run for both rounds in order to understand if a broader consensus can be observed in the second round.

This test has been also carried out by splitting the respondents in two groups. The first one includes the quick respondents. On the contrary, the second group has the late respondents who also received a reminder. Reminder represents a time consuming and expensive strategy aimed at converting reluctant and hesitant participants to late respondents. These approaches assume that late respondents resemble non-respondents more than initial respondents do. Thus, on the one hand increasing response rate by converting hesitant respondents to actual participants can reduce the magnitude of response bias since the pool of respondents becomes more representative of the total sample (Studer *et al.*, 2013). On the other hand, the quality and reliability of the answer might increase since the willingness to take part to the investigation for a hesitant respondent could be lower and in turn the attention given to the questionnaire, with resulting bias (Af Wåhlberg and Poom, 2015). In order to highlight this potential effect, a Kruskal-Wallis test has been carried out between the groups of early and late respondents. The performed tests do not highlight significant differences for most of the projections. Only Projection 2.5 "Crowd logistics does not provide environmental benefits if associated with private cars" shows a median score equal to 5 for late respondents and equal to 4 for the early ones. However, since this difference is not heavily relevant it does not impact on the general consensus of the projection at issue. Also, Projection 6.1 "Parcel Locker diffusion has reached a plateau due to the investment costs needed to reach all customers." outcomes are different for the two groups of respondents. Similarly, the difference of the median scores is large enough to influence the consensus on the projection.

4. Results

In this section the main results obtained by the application of the Delphi approach are described. With the aim of achieving a more shared consensus on the projections at issue the participants involved in the research have received the questions twice. First, the consensus among all experts is evaluated with the Interquartile Range (IQR) and the Reliability within group (r_{wg}). Second, the difference between experts' groups with regards to their assessment is explored via the Kruscal-Wallis test.

4.1 Consensus among experts

The first result of the survey is the high level of consensus reached among respondents. Only 8 projections did not reach a consensus after the second round, as shown in Figure 2 that lists the median and IQR values for all projections, in descending order of consensus (i.e., ascending order of IQR).

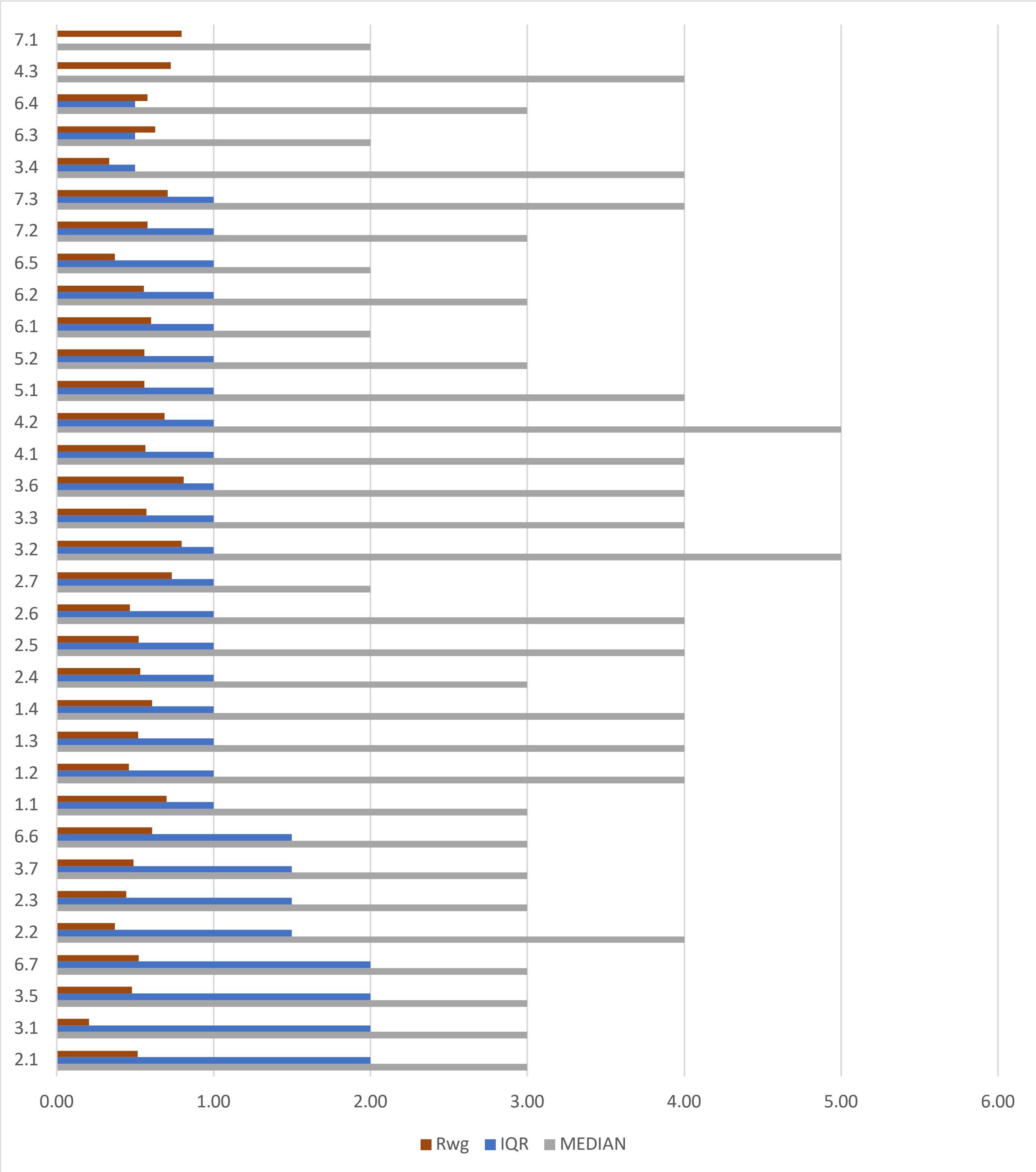

Figure 2 Results from the second round of the Delphi survey. All projections are listed here together with their median and IQR.

This is a significant improvement from the results of the first round, where scholars' evaluations did not agree on two thirds of all projections (22 out of 33) (Figure 3).

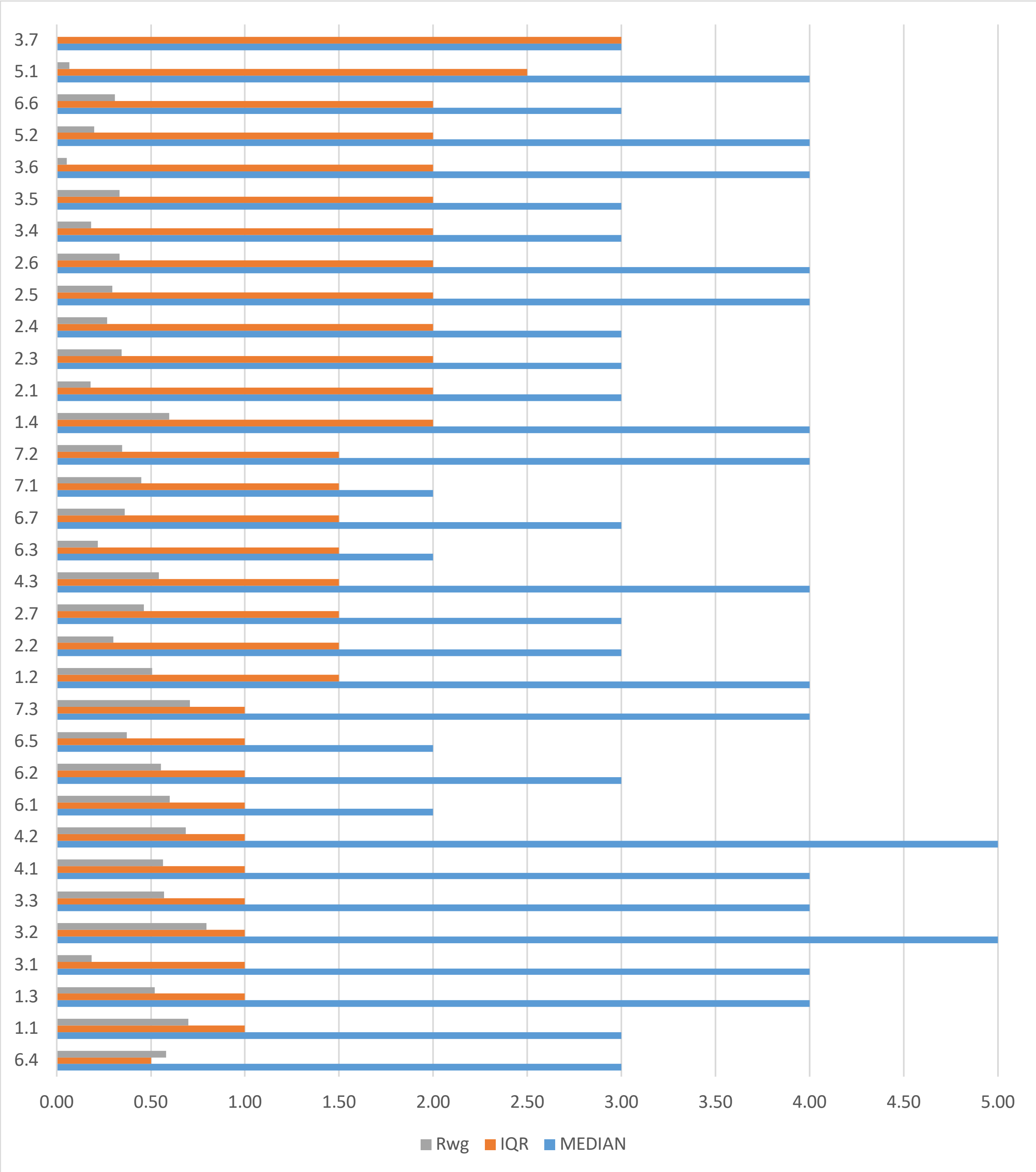

Figure 3 Results from the first round of the Delphi survey. All projections are listed here together with their median and IQR.

All projections except one have improved both criteria for consensus building (i.e., IQR and r_{wg}). In particular, IQR for projections 4.3, 5.1 and 7.1 has improved by 1.5 points while still maintaining the same median value. Overall, the median value has shifted from round 1 to round 2 in only 4 projections out of 14, and only by one scale point.

The highest consensus has been reached by projections 4.3 and 7.1: experts agree that ITS will be used to gather reliable and detailed data on last-mile logistics and that improving the communication between providers and customers will not be hampered by customers' inertia in adopting new technologies.

Projections 6.3 has also achieved strong consensus among the experts, who stated that parcel lockers will be attractive to different LSPs regardless of their customers' density. Experts therefore agree that parcel lockers will be more widespread due to their adoption by more LSPs. With regard to projection 6.4, experts agree that it is not yet possible to determine whether LSPs will adopt a shared parcel lockers configuration (Faugère and Montreuil, 2020).

In terms of drones' adoption, technological barriers are still found to be very relevant even in future scenarios (projection 3.4).

The highest median evaluations have been given to projections 3.2 and 4.2, which reflect the need for involving public authorities in last-mile logistics. As a matter of fact, experts strongly argue that the most relevant barrier for drones' adoption is the lack of regulation frameworks (projection 3.2) and that public authorities will focus on enforcing restrictions through ITS implementations.

All projections pertaining to BDA, IoT, ITS and low impact vehicles have reached a consensus. Three projections out of four regarding BDA have received a median evaluation of 4 out of 5, showing that BDA is expected to increase both order frequency for B2B and the share of same day delivery by exploiting a more precise demand forecasting. Another potential application of BDA to last-mile logistics is also represented by a better and improved interaction with the final customer (e.g. by coordinating real-time with the driver. Regarding IoT, projection 7.2 shows that experts are neutral with regards to the barrier of customers' acceptability to IoT technologies such as smart locks due to trust and safety issues. A further application of ITS, besides the above mentioned use to gather data and high impact on local enforcement, lies in the optimization and real-time monitoring and booking systems of loading/unloading areas. Concerning low impact vehicles, experts argue that cargo bikes will be beneficial to a multitude of LSPs and that public incentives will still lead the way for the adoption of another green technology, namely Electric Vehicles.

As mentioned above, the Delphi method shows its value even when disagreement among experts is found. With this regard, two technologies have provoked the highest share of projections without consensus, namely crowd-logistics and drones (3 projections out of 7 each). Therefore, it can be argued that it is too early to determine the financial feasibility of drone deliveries (projection 3.1), the best operational configuration in combination with traditional delivery vans (projection 3.5) and thus its impact on the number of traditional vehicles (projection 3.7). Similar results are obtained by the crowd-logistics, where experts do not agree on the acceptability by customers (projection 2.1), the scope of application (projection 2.3) and thus the substitution effect with regards to traditional vans (projection 2.2). Finally, the opinion of the experts is divided about the suitability of adopting parcel lockers in high-density and urban areas rather in suburban or rural areas.

4.2 Difference between experts' groups

Table 2 demonstrates that there are few significant differences among the stakeholders' groups, according to the outcomes of the Kruskal-Wallis statistical test. This test has been carried out for all projections after the final round of the survey where consensus (or lack thereof) has been reached.

Table 2 Items with significant differences among sub-groups

Projection	**Final Round**	**Years of Experience**				**Kruskal Wallis**
		0-4 years	5-9 years	10-14 years	>15 years	P-value adj for ties
		Median Score	Median Score	Median Score	Median Score	
1.1	1	3.5	3.0	3.0	3.5	0.025
3.2	1	5.0	5.0	5.0	4.0	0.007
3.4	2	4.5	4.0	4.0	3.0	0.041
		JobPosition				
		Academic	Consultant	Manager		
		Median Score	Median Score	Median Score		
1.1	1	3.00	4.00	3.00		0.049
2.4	2	2.0	3.5	3.0		0.044
		Affiliation				
		Others	Private Company	University/ Research Centre		
		Median Score	Median Score	Median Score		
1.1	1	3.5	4.0	3.0		0.022
6.1	1	3.0	2.0	2.0		0.030

In fact, only 5 out of the 33 projections have a dissimilar perspective across the identified subgroups of the sample.

In particular projection 1.1 "BDA have enabled de-centralization of decision-making processes in supply networks and have supported the growth of micro-retailing, such as "nanostores" is considered to be more realistic for the youngest and oldest professionals. On the contrary, respondents with an average length of professional experience have expressed just a medium preference, meaning that from their perspective Big Data will not necessarily facilitate the decentralization of decision making processes in the supply chain. This projection shows a discrepancy in the evaluation also by observing the Job Position, whereby the Consultant group provides a higher evaluation compared to academics and managers.

Projection 2.4 related to the feasibility of crowd logistics services in high density areas show different perceptions. The academic subsample considers this scenario less plausible thus meaning that crowd-logistics services might be useful also in other business environments. On the contrary, managers and consultants state that this technology is expected to be exploited more effectively in the specific geographical context of an urban area.

According to more experienced respondents, Item 3.2 “To support the adoption of drone-based delivery, how important it has been to overcome the following issues: [Lack of dedicated regulation frameworks.]”, is not as crucial as it is considered for the other ones, meaning that the level of awareness related to the policy framework associated with the use of drones is more significant for younger experts.

Moreover, for Item 3.4 “To support the adoption of drone-based delivery, how important it has been to overcome the following issues: Technological issues -e.g., range, capacity, resistance to extreme weather, landing capabilities, safety, advanced navigation and coordination algorithms” the alignment of opinion according to the years of experience is not achieved. Older professionals consider less important the technological burdens that impact on the adoption of drones.

Finally, Universities and Private Companies provide a low rate to Item 6.1 “Parcel Locker diffusion has reached a plateau due to the investment costs needed to reach all customers”. Thus, cost is not considered as a crucial factor for Parcel Locker diffusion for these stakeholders.

5. Discussion of results

The two projections that reached the highest level of consensus, namely the future use of ITS data and the technology adoption inertia by consumers (i.e., projections 4.3 and 7.1), are likely linked together to the extent that private companies and city administrations alike will collect a large amount of logistics data via ITS systems. Such large amount of data will probably be used to overcome the technology resistance by customers, as to achieve direct communications and better coordination with customers. For example, real-time freight data sharing and route optimization software would help operators to provide quicker logistics services and to align with the customers’ whereabouts and preferred time windows. Similarly, projection 1.4 confirms that operators will use BDA for a more effective interaction with last-mile actors (e.g.: drivers, LSPs). However, with projection 7.2 experts are not so confident that all customers will understand the value and accept the usage of IoT and BDA. Moreover, not all BDA-based applications will provide benefits to last-mile logistics processes. In fact, BDA will likely support local businesses’ ordering policies by enabling short lead times, high frequency and low volume orders. Therefore, BDA will make B2B deliveries rather similar to B2C deliveries in terms of their impact to last-mile logistics (Morganti, Dablanc and Fortin, 2014; Melkonyan *et al.*, 2020). This statement is strongly supported by consultants who are supposed to be deeply involved on BDA projects (Hughes and Ball, 2020).

As for the future of parcel lockers utilization, as stated in the results, experts foresee that this technology will likely be adopted by LSPs regardless of their customers' density, but are still uncertain over the most likely installation choice (i.e., under a single-provider or a shared configuration) and whether parcel lockers will be more adopted in either urban or suburban environments. This will open doors for studies that would highlight the potential for widespread adoption in far remote areas. The diffusion that could result from this process could generate negative impacts on public land use, unless regulated through restrictions imposed by public administrations and assets sharing policies.

Likewise, the role of public authorities is reinforced in projections 3.2, 4.2 and 5.1 that view public authorities as both regulators and major players of the technology adoption process. These findings underline the more proactive role public authorities have been playing in the last-mile logistics sector in recent years.

The missing consensus about the future of drones reflects the infancy of this technology, due to still unsolved issues, like security (e.g. thefts and damages) (Kunze, 2016), limited flight range, carrying capacity, and potential congestion around their depots (Moshref-Javadi and Winkenbach, 2021). Younger experts pay more attention to these issues than more experienced ones, and thus it is expected that solving these hurdles will be a priority for the future. In fact, the adoption of drones for delivery aims is expected to increase as a feasible way to deal with the continuous growth of e-commerce and the higher demand for speed of delivery services.

Same dissent is found among the crowd-logistics projections, which generate a mixed technology landscape for the future of such innovative solution. In fact, experts agree that crowd logistics will provide a lower level of service than traditional delivery. This will have a more negative impact on customers' acceptance than trust, safety and security issues connected to this innovative delivery service. Therefore, e-commerce B2C delivery via traditional vehicles will still be more efficient than crowd-logistics. Such projection does not achieve the consensus, even though 75% of respondents rate this projection higher than the neutral value (i.e.: 3 over 5).

Nevertheless, scholars and professionals disagree as to the profitability of crowd-logistics in high-demand environments (i.e.: projection 2.4). This might depend on their different perspective. On the one hand, academics tend to argue that lower levels of road infrastructure development in rural areas are leading to a larger use of crowd-logistics for the distribution of packages outside of the city centers (Lewis, 2020). On the other hand, managers and consultants highlight that the current ongoing urbanization, the rapid growth in e-commerce deliveries, and increasing urban traffic congestion, make crowd logistics beneficial in urban environments with high level of population density (Raj and Sah, 2019). In general, though this innovation could be profitable for operators in a wide range of contexts, it will not completely replace traditional delivery approaches. Nevertheless, a successful diffusion of crowd logistics might increase the pressure on drivers' salaries. Furthermore, most asset sharing applications might be enhanced though the integration between public entities owing traffic and infrastructure data and private companies that deal with data related to urban freight transport (Cleophas *et al.*, 2019). Private companies in charge of providing logistics services by applying Crowd Logistics or Crowd Shipping are increasingly outsourcing the logistics processes and sub-processes to individuals (Melkonyan *et al.*, 2020). These applications offer potential advantages for different stakeholders (Ermagun and Stathopoulos, 2020).

6. Conclusions

This research has explored the future scenarios for some of the most relevant innovations in CL, from an experts' perspective. To this end, this study has adopted a two-round online Delphi survey to rigorously extrapolate patterns originated from the experts' assessment of 33 projections focusing on seven technologies and four categories of analysis. Results shows that consensus among the experts has been reached through the two-round survey. This consensus is widespread across the projections (i.e., experts have agreed on 76% of the projections) and yet it does not rule out a healthy level of disagreement between experts both at the individual and group level, thus safeguarding everyone's opinion. Moreover, in the second round of the survey experts have mostly shifted their opinion towards the median evaluation achieved in the first round rather than changing their evaluation altogether, showing that the Delphi has supported the achievement of a "real" consensus rather than an artificial one. In the next subsections the main implications, limitations and future research directions are highlighted.

6.1 Implications

From a theoretical perspective this work enlarges the body of knowledge about the adoption patterns of innovative technologies in last mile operations. Thus, it might stimulate research about the most relevant technologies that are likely to have an impact on CL processes. In addition, the present study exploits the Delphi methodology that has proven to be effective and to provide robust results in different fields of applications (Von Briel, 2018; Von Der Gracht and Darkow, 2012). Finally, this research tests the outcomes of the Delphi approach by using the Kruskal-Wallis test as a way for highlighting potential misalignments among the subgroups of the sample.

From a practical point of view, the innovative technologies evaluated in this study might enable a deeper understanding of their potential future application to CL. Thus, this research might support companies to properly plan future technical choices and better address related investments. This aspect is particularly crucial, considering the high uncertainty associated with the innovative markets and the relevant level of financial engagement required for implementing new technologies (Kurata, 2019). Similarly, public authorities might be facilitated by this work in designing suitable urban policies and in turn to intervene in new contexts that are still not involved by the innovative trends in last mile.

6.2 Limitations

This study aims to identify and analyze technology patterns related to the field of CL, by adopting a structured approach intended to frame the views from a selected group of experts in a quantitative way. However, it has to be pointed out that the scope of this study might hinder the generalizability of such results. In fact, experts are drawn from a list of professionals and scholars working for European institutions, due to the relative ease of connection with the authors. Moreover, a set of technologies that appears to be more relevant nowadays for CL have been chosen. Such sub-set of technologies is deemed to be exhaustive of current implementations but does not intend to represent all technologies available for CL applications, especially in the near future.

6.3 Future research directions

Drawing from the scope limitations, future research could be directed towards applying the Delphi methodology to CL technologies after the time frame considered in this study. This future path could for instance validate the experts' opinion and enlarge the scope of technologies evaluated.

This study highlights some open questions regarding few technologies. It can be stated for instance that real-time data collection by private and public stakeholders alike will help the coordination process between stakeholders and final customers. However, an increased awareness over the value of logistics data as well as their potential drawbacks from the customers' perspective, such as an increased order frequency by B2B customers, is needed.

Regarding the drones, the future looks promising as multiple logistics companies are planning to implement such innovation and younger experts from the sample seem keener on reducing the barriers to such implementation. This stream is very promising due to the increasing number of e-commerce retailers and express couriers developing their own drones fleet and starting their pilot implementations (Roland Berger, 2020). However, future research streams should aim at solving its major issues, such as safety of the package and flight range. Parcel Lockers will expand significantly, and their success should be monitored by public authorities, who could foster and incentivize the shared configuration to decrease their impacts on land use. Finally, crowd-logistics will remain a lesser mean for last-mile delivery but may become beneficial deliveries that are outside the scope of traditional e-commerce, thus potentially increasing the pressure on the drivers' salaries. To this end, scholars are called to engage into studies that will guide LSPs towards a successful implementation of crowd-logistics without reducing their workers' salaries. This is particularly relevant considering the recent Covid-19 pandemic, which has exposed the importance of last-mile logistics for the whole population, making drivers essential workers of urban areas.

7. References

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