Start-up-driven innovation for logistics: a classification framework

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Abstract: Start-ups are often frontrunners to foster innovation, contributing to developing and spreading original thinking and solutions. In recent years, start-up ecosystems have experienced significant growth worldwide, and many start-ups have also emerged in the field of logistics. Despite this rising trend, the academic literature has underestimated start-up-driven innovation in the logistics industry so far. To act as a bridge between theory and practice, the purpose of this study is to investigate and formalize the main directions of innovation brought by start-ups operating in the logistics field. First, both available academic literature and secondary sources were examined, along with financial-reporting data retrieved from commercial databases. As a result, 501 start-ups founded after 2015 and having logistics services within their core business were identified worldwide. Then, a classification framework was developed, according to start-ups' value proposition. Four macro-categories were drawn – new logistics players, logistics platforms, software developers, and hardware developers – and further subdivided into sub-categories to better acknowledge specific peculiarities. Funding received and the number of start-ups per each category were considered as proxies for the value of and potential for innovation. New logistics players and hardware developers emerged as the start-ups categories offering the widest opportunities. The study offers an original approach to map and classify start-up-driven innovation in logistics, simultaneously allowing for identifying the most promising directions for future developments, also in the wake of the increasing concerns about environmental and social sustainability. On the one hand, the growth of hardware solutions such as electric or self-driving vehicles calls for additional exploration of the related managerial implications. On the other hand, further research could investigate how logistics service providers could introduce innovative solutions in their daily operations, such as for urban deliveries.

Keywords: logistics, innovation, start-up, classification framework

1. Introduction

Start-ups are companies designed to grow fast, acting as incubators of ideas and proposals to create new products or services in uncertain business environments (Katila et al., 2012). Start-ups are frontrunners to foster innovation, and a dashing growth of start-up ecosystems occurred worldwide in the last decade (McKinsey, 2020a). The logistics industry, despite being usually described as static and not prone to innovation, is also affected by this ferment (Grawe, 2009; Chichosz et al., 2020). The last decade, characterized as "the digital age", has changed its competitive dynamics (Hofmann and Osterwalder, 2017). In addition to players such as Amazon and Alibaba, a host of innovative newcomers have entered the logistics market and challenged current business practices and future prospects of incumbent logistics service providers (LSPs), including digital start-ups (Castillo et al., 2018).

Start-ups' relevance is thus increasing rapidly for practitioners (McKinsey, 2020b). Broader investigations have been recently recommended, but the academic literature has not provided adequate attention towards start-up-driven innovation in the logistics industry, nor offered a structured approach to classify logistics start-ups according to the proposed innovation degree (Wang et al., 2020). To act as a bridge between academia and the current practice, the purpose of this study is to investigate and formalize the main directions of innovation brought by start-ups operating in the logistics field. Two research questions (RQs) have been identified:

- *RQ1: What start-ups are offering solutions for logistics?*
- *RQ2: What are the most promising areas of innovation?*

To address these RQs, two main research phases were conducted. First, both academic literature and secondary sources were reviewed on the topic of logistics start-ups, along with financial-reporting data retrieved from commercial databases. For this study, the scope was limited to logistics as defined by the US Council of Supply Chain Management Professionals (CSCMP), that is "[…] that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the points of origin and consumption to meet customers' requirements" (CSCMP, 2016).

Second, a census of logistics start-ups operating worldwide was performed, and 501 start-ups having logistics services within their core business were identified. A classification framework was then developed, according to start-ups' value proposition. Four macro-categories were drawn and discussed: new logistics players, logistics platforms, software developers, and hardware developers. Funding received and the number of start-ups per each category were considered as proxies for the value of and potential for innovation. Results were then validated by comparing the emerging insights with the available literature and by involving expert practitioners. The paper is organized as

follows. Related literature is first presented, followed by the methodology description and the illustration of the results relating to the two identified RQs. Results are then discussed, and conclusions are lastly drawn along with proposals for future research.

2. Literature review

2.1 Start-ups and innovation in logistics

Start-ups can play a wide range of roles along the logistics chain (Cassetta et al., 2017; Chichosz et al., 2020), replacing existing LSPs in their offer of access to new markets, service level improvements, and capability to adapt to changes in customers' needs (Selviaridis and Norrman, 2015). Consequently, start-ups are proposing themselves as innovative LSPs, entering market niches with novel technologies or business models (Hofmann and Osterwalder, 2017; Spadoni et al., 2019). In more detail, logistics innovation concerns any product/service related to logistics that is seen as new and useful to a particular target audience (Flint, et al., 2005). It can relate to a wide range of original cutting-edge solutions, affecting internal operations as well as services with business partners (Chapman et al., 2003; Grawe, 2009). Recently, the logistics industry has been shaken by several trends and technological innovations, including Logistics 4.0, Internet of Things (IoT), Data Analytics, Artificial Intelligence tools, and Physical Internet (Sternberg and Norrman, 2017; Cohen, 2018; Govindan et al., 2018). Digital technologies specifically had a major impact in facilitating transactions and exchanges among companies and between companies and customers, eventually leading to lowering costs and improving efficiency (Wang et al., 2020).

2.2 The role of technology

Technological advances are creating new opportunities, and a key emerging concept is the so-called Logistics 4.0. It represents the crossing between logistics processes and Industry 4.0 paradigms and can be defined as the combination of logistics with applications enabled by new digital technologies (Barreto et al., 2017). Logistics 4.0 often leverages IoT or Radio Frequency Identification (RFID) technologies, entailing opportunities related to automated information flow management and the interconnection of multiple devices (Winkelhaus and Grosse, 2020). IoT and RFID can be instrumental to increase supply chain visibility on data at different managerial levels, enabling improvements in both transportation and warehouse management (Lee et al., 2018). Smart packaging solutions that include temperature or geo-localization sensors are increasingly widespread, allowing for collecting a huge amount of data, or Big Data (Wang et al., 2016). Big Data analytics is a new generation of techniques designed to extract value from very large volumes of a wide variety of data (Govindan et al., 2018). Market opportunities concerning better transportation operations management can emerge, related to traffic data collection, arrival times predictions, alternative routing algorithms, and fares comparison (Lai et al., 2018; Winkelhaus and Grosse, 2020).

Also, the Physical Internet concept refers to the Digital Internet as a design metaphor for the development of sustainable, interoperable, and collaborative logistics. As the internet moves data by standard protocols that encapsulate data, the Physical Internet would move freight as globally standardized packaging (Sternberg and Norrman, 2017). If Physical Internet can revolutionize long-haul freight transportation, major innovations are also characterizing last-mile or urban logistics (Chichosz et al., 2020). Start-ups can offer solutions as autonomous vehicles, including drones and ground delivery robots, but also real-time route optimization or fleet management software tools (Cassetta et al., 2017; Lai et al., 2018). Autonomous vehicles could support new value networks concerning both warehousing and transportation operations (Hofmann and Osterwalder, 2017). Two major technological trajectories can be outlined. On the one hand, the enhancement of conventional vehicles through the development of automated driving systems to improve safety and reduce congestion. On the other hand, a more radical shift is driven by the development of alternative vehicles and new transportation services (Fagnant and Kockelman, 2015; Perboli and Rosano, 2019). For example, drones could quickly deliver packages, offering adequate flexibility to meet strict time windows with good accuracy (Yoo et al., 2018).

2.3 Logistics innovation and sustainability

Alongside these perspectives, increasing concerns are rising about the environmental impact of logistics (McKinnon, 2016). Hybrid and electric vehicles are gaining traction for transportation services (both last-mile and long-haul) (Speranza, 2018). They could determine substantially improved environmental performance, and their usage has spread along with increasing research activities to bolster their development and adoption (Davis-Sramek et al., 2020). Lastly, not only environmental but also social sustainability is increasingly under scrutiny in the logistics industry (Nikolaou et al., 2013), especially regarding urban logistics and last-mile delivery (Lagorio et al., 2016). Cost efficiency is often achieved at the expense of workers, and this phenomenon is raising a huge debate among both researchers and practitioners (Ignat and Chankov, 2020). With crowd logistics becoming a crucial part of the last-mile delivery challenge in many cities, the working conditions of riders represent an important issue for logistics platforms (Macharis and Kin, 2017). Platforms match the demand and the supply of transportation or storage services, acting as marketplaces that disintermediate the process with faster processes and more customized services (Castillo et al., 2018). Also, these platforms often provide IT services such as real-time tracking and features for transportation supervision, increasing the overall supply chain transparency (Kafle et al., 2017).

3. Methodology

To address the RQs a multi-method approach was adopted. First, a review of the related academic literature was performed about start-up-driven innovation in logistics. A search strategy was defined in advance to guarantee rigor and trustworthiness (Tranfield et al., 2003). Electronic sources were selected, and research keywords and strings were defined (Seuring and Gold, 2012). Two search engines (i.e. Elsevier Scopus and Google Scholar) were used, as they

are quite complementary to each other (Chapman and Ellinger, 2019). The following keywords and related combinations were considered: logistics, innovation, and start-up. While reading previous contributions, further relevant terms were identified, and the list of keywords was progressively updated. Backward and forward cross-referencing was then applied, and additional sources were considered, including conference papers and book chapters. Besides, literature-based insights were integrated with secondary sources including articles, websites, and research reports (e.g. DHL, 2020; McKinsey, 2020b).

Second, an empirical analysis of logistics start-ups operating worldwide was performed through the creation of an appropriate research database. For this purpose, data were retrieved from Crunchbase, a commercial database collecting information about start-ups worldwide, including foundation date, concept description, website, founders, and amount of funding received by start-ups. To build the research database some tags were first defined to identify and retrieve start-ups that were connected to the logistics sphere, e.g., "supply chain" and "logistics". Based on the results of this preliminary extraction, more specific tags were added such as "transportation", "delivery", "delivery service", "warehousing", "packaging", "courier service", "shipping", "autonomous vehicle". This process was repeated several times, until achieving a convergence around a stable number of resulting companies. Once the tags necessary for the extraction were defined, two main parameters were introduced to determine what companies could be considered as start-ups, i.e. i) founded in the last 5 years (foundation date later than 01/01/2015), and ii) having received funding in the last two years (last funding date later than 01/01/2018) (Sanasi et al., 2020). Only companies that met both criteria were considered, and corresponding data were retrieved on March 16th, 2020. All start-ups were manually skimmed to consider only those having logistics within their business purposes. This second stage of research was completed by integrating the results with secondary sources, including companies' websites. For example, a group of 77 companies that mainly focused on e-commerce sales, not having logistics within their core value proposition, were removed. Out of the 1,510 start-ups initially detected, 490 remained.

Third, to improve the research rigor, as well as to increase its completeness, 12 direct interviews were carried out with a group of experts, through contacts activated by two Italian universities. Experts were selected based on their experience in the logistics industry (more than 10 years) and their involvement in innovation practices or practitioners' discussions. Personal e-mail invitations were sent out including information about the research project, and 7 interviews were carried out in April 2020 (average duration: 40 minutes). Such interviews led to identify additional 11 start-ups that had not retrieved initially from Crunchbase. They were manually added to the research database, integrating the related financial data when available. Overall, 501 start-ups thus constituted the final sample, being each company characterized by a brief description, funding received, and other descriptive data. Each start-up was singularly examined to identify common patterns and track relevant differences, to infer a classification framework for start-ups in the logistics field. According to their value proposition, the 501 start-ups were classified into four macro-categories: "new logistics players", "logistics platforms", "software developers" and "hardware developers". All the start-ups were mapped in the framework. When a start-up could be potentially belonging to more than one macro-category, further web-based sources were examined. The assignment was then discussed among the researchers to come to an agreement that considered the main activity performed by the company in focus. It was then assumed that the number of start-ups and the funding received per category could approximate the innovation potential, to identify the most promising directions for future developments. However, it must be noted that not all start-ups provided full financial data. Out of the 501 start-ups identified, 381 exhibited the total amount of funding available, and 337 made the last funding received available. Nevertheless, undisclosed funding is quite unusual for large transactions, and financial-data available from Crunchbase were assumed to be a reasonable proxy for the interest towards each category.

Finally, to check the results' validity (e.g., start-ups macro-categories and the related classification), as well as to triangulate their consistency, they were later compared to the previous literature. To increase the study's practical relevance, the framework was also discussed with the previously interviewed expert practitioners, who took part in an additional round of 8 interviews between June and July 2020 (average duration: 30 minutes).

4. Results

The macro-categories identified through the empirical analysis are defined in Table 1, while the distribution of funding per each macro-category is offered in Table 2.

Table 1: Macro-categories' definition

Macro-category	Definition
New logistics players	Start-ups offering innovative logistics services in terms of geographical scope, type of business, vehicles used, data usage, or logistics process design, eventually leveraging new technologies.
Logistics platforms	Start-ups acting as marketplaces for the crossing of transportation and/or storage supply and demand, providing innovative approaches for data usage and crowdsourcing applications.
Software developers	Start-ups developing software to monitor and analyze logistics activities, including e.g. logistics planning and route optimization, enabling stronger visibility and control along the entire supply chains.
Hardware developers	Start-ups designing hardware solutions to support logistics activities, to improve their efficiency as well as their environmental impacts.

Table 2: Funding received per macro-category

Macro-category	#start-ups identified	#start-up (total funding available)	Sum of total funding [M$]	Average total funding [M$]	#start-up (last funding available)	Average last funding [M$]
New logistics players	160	125	2,986.2	23.9	108	14.6
Logistics platforms	88	67	1,423.4	21.2	58	12.4
Software developers	168	122	1,894.2	15.5	111	7.9
Hardware developers	85	67	3,283.9	49.0	60	36.2
Total	501	381	9,587.8	25.2	337	15.8

Macro-categories were furtherly detailed, and categories with higher granularity were identified to better acknowledge specific peculiarities (Figure 1). Macro-categories and related categories are characterized as follows.

New logistics players have been classified according to two dimensions, namely the type of channel they address (B2B or B2C), and the type of logistics service offered (complete or specific). Crossing the two dimensions, four categories can be identified. The first (B2B – complete service) includes start-ups that offer logistics services while extensively adopting innovative technologies to digitize processes, acting as digital freight forwarders, carriers, couriers, or 3PLs. They. For example, one start-up applied Physical Internet through the "modularization of transportation units". A second category (B2B – specific service) includes few examples, mainly related to offering warehouses' excess storage capacity to spot customers. Third, the "B2C – complete service" category includes start-ups offering end-to-end logistics solutions for e-commerce, improving cross-border e-commerce or developing omnichannel synergies. Lastly, the "B2C – specific service" category includes start-ups that are not providing end-to-end solutions, but focus on specific elements of the value chain. For example, some start-ups offer only last-mile transportation services, while other focus on storage to provide customers with flexible on-demand warehousing or created a network of pick-up points to facilitate return management.

Logistics platforms have been categorized according to the main activity targeted (transportation or warehousing), and whether the supply side is represented by structured players or by individuals involved in crowdsourcing operations. According to the type of activity and the type of actors involved, four categories have been identified. Transportation marketplace platforms aim at helping shippers connect with professional hauliers with empty or unsaturated vehicles. Similarly, storage sharing platforms connect businesses that need storage space with suppliers willing to transform their available assets into profitable entities. When introducing crowdsourcing operations, they could refer to transportation (i.e., drivers optimize the space usage of their vehicles obtaining compensation, while shippers could get transportation options that would have otherwise been unavailable) or storage (i.e., companies can temporarily increase their storage capacity by flexibly renting private spaces such as garages or small warehouses).

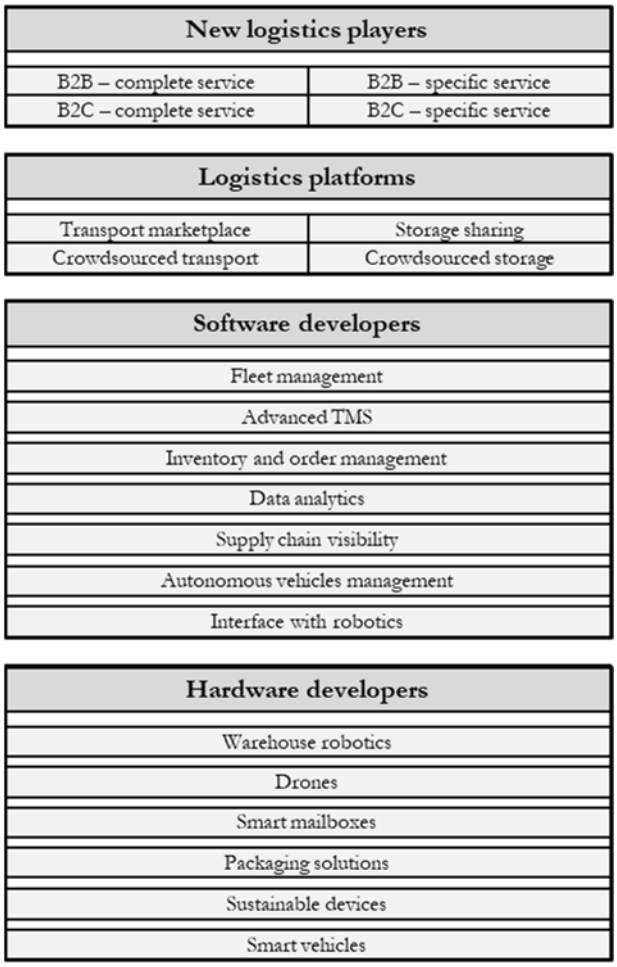

Figure 1: Identified start-up categories for each macro-category

Software developers offer tools and instruments that simplify logistics operations by helping customers manage different logistics processes, and facilitating smooth access to important information. Seven categories were identified. "Fleet management" start-ups develop software to pursue fleets' performance optimization by minimizing maintenance and fuel costs. If these start-ups mainly provide support to manage their fleets, "advanced Transportation Management Systems (TMS)" start-ups use technology to improve planning and execution of logistics activities by integrating information to be shared among different players. "Inventory and order management" start-

ups offer solutions and tools to improve replenishment processes, including customs clearance operations. Moreover, they look towards offering real-time visibility over inventory positioning and availability. Then, "data analytics" start-ups propose solutions to develop knowledge upon Big Data exploitation, to pursue alternatively descriptive, predictive, or prescriptive purposes. Additionally, in today's increasingly complex and demand-driven landscape, end-to-end visibility into the supply chain is crucial. "Supply chain visibility" start-ups aim at providing customers with tools that increase real-time visibility along the entire chain, smoothing information exchange processes and enabling timely actions whenever adverse events occur. As self-driven vehicles are quickly gaining market shares, "autonomous vehicles management" start-ups offer specific solutions to enable real-time control management of autonomous fleets. Automation is increasingly considered also for warehousing, and "interface with robotics" start-ups are developing software to optimize the interface and integration with the robots used inside logistics facilities.

Finally, hardware developers encompass six categories. The first one, "warehouse robotics", embraces start-ups that develop multi-purpose programmable robots for warehousing operations, including materials handling and increasingly complex picking operations. Conversely, when looking at robots for air transportation, "drones" start-ups come into play. They develop and commercialize unmanned aerial vehicles (UAVs), including a ground-based controller and a system of communications. UAVs can operate with various degrees of autonomy, either under remote control by a human operator or autonomously by on-board computers. UAVs might eventually land onto "smart mailboxes" that some start-ups have been developing through revising traditional mailboxes, to respond to unattended deliveries. Some start-ups are proposing innovative ideas for packaging ("packaging solutions"), e.g. by developing systems that customize packaging for every single item, thus minimizing space and waste during transportation and also improving the environmental impact. Others are proposing innovative sensors for packaging, to achieve more effective shipments' monitoring. Similar ideas are propounded by "sustainable devices" start-ups, which propose tools based on innovative technologies to address increasing concerns about environmental sustainability. Regarding freight transportation, "smart vehicles" start-ups are developing autonomous vehicles for long-haul transportation and robots for urban deliveries, or propose alternative power supplies for traditional vehicles (e.g., hydrogen, electricity, or hybrid).

5. Discussion

The identified four macro-categories highlight that start-ups are offering logistics solutions covering a wide range of different needs and areas (RQ1), including the development of original software and hardware solutions. Macro-categories and the more granular related categories were compared to analyse the received funding and highlight the most promising areas of innovation (RQ2). Overall, new digital technologies can support logistics innovation, and start-ups can concretely leverage them. The progress of technological innovations has been dashing in recent years, and the digital revolution is having a significant impact on the logistics industry.

"New logistics players" can exploit cutting-edge technologies to offer original products/services to their customers. Digital transformation in logistics entails the integration of technologies like Big Data analytics in areas such as storage, order management, or transportation. The most important categories in terms of number and investments are "complete B2B services" and "specific B2C services", which bring various innovative elements into traditional operations. The related start-ups offer original solutions for last-mile delivery introducing delivery planning algorithms and software for information integration, using a variety of transportation vehicles (e.g. bicycles, electric vehicles, or drones). Automated solutions for urban distribution are redefining the way goods are moved inside cities. For example, fully automated micro-fulfilment centres are gaining rapid traction, where picking operations are seamlessly integrated with last-mile transportation. Through operations digitalization, start-ups can also design transportation to optimize goods' loading. Some start-ups concretely introduced the modularization of transportation units, following the Physical Internet paradigm (Sternberg and Norrman, 2017).

As concerns platforms, marketplaces help connect companies that need to ship goods with professional hauliers having empty or under-utilized vehicles. This could happen both at a global or local level, and could also relate to crossing demand and supply of containers, which allows users to find unused third-party containers and to reduce the overall handling of empty containers. In the wake of the increasing imbalance of global flows that has been characterizing 2020, it could help address a crucial drawback for logistics. Also noteworthy are start-ups offering crowdsourced services. Crowdsourcing enables anyone to easily exchange products, services, or other resources with their peers. Matching demand and supply through marketplaces accessible to a wide variety of people allows for increasing the level of utilization of resources. However, working conditions for riders deserve to be properly addressed (Ignat and Chankov, 2020), as exploitation phenomena are increasingly registered.

Start-ups that develop software solutions mainly aim at improving order management operations, including the interface with the end customers. "Supply chain visibility" and "Inventory and order management" are the most significant areas. The first includes start-ups that offer tools for real-time tracking of vehicles and shipments. The second group of solutions mainly addressed to e-commerce firms or related to customs documentation management, simplifying exchange procedures and integrating information into a single tool. In the light of the erection of trade barriers worldwide, along with the significant increase in cross-border flows management (Prataviera et al., 2020), start-ups look towards streamlining customs clearance processes, e.g. automatizing goods classification and the related duties calculation. Other start-ups develop algorithms for fleet performance optimization, introducing

the possibility of dynamic re-routing depending on real-time transportation conditions. Smart maintenance and monitoring leveraging cloud-based Big Data analytics can be combined with sensors on-board. However, this is not just the matter of having more sensors, but also improving information technology analysis and decision making based on richer data. Blockchain technology adoption is also increasing, as it enables mechanisms for data storage and sharing between several network nodes characterized by transparency, transaction traceability, and security (Pornauder et al., 2020).

Smart vehicles and warehouse robotics emerge as the most important categories among hardware developers. Given the growing attention towards environmental sustainability issues (Macharis and Kin, 2017; Speranza, 2018), start-ups that are developing electric trucks, bikes, and trailers are rapidly gaining traction. If an acceleration in the shift from fossil fuel to electric vehicles is imminent (McKinnon, 2016), the elimination of the cost difference between electric and internal combustion engines could probably mean a turning point for the transportation industry in the next future. Moreover, the literature presents the adoption of drones or electric robots as possible alternative solutions for last-mile delivery (Hofmann and Osterwalder, 2017). There is wide empirical evidence of this pattern within existing logistics start-ups, also concerning deliveries towards rural and isolated areas.

6. Conclusions

Although start-up ecosystems have experienced significant growth worldwide, even in the logistics field, the academic literature has explored start-up-driven innovation in the logistics industry only to a limited extent, and broader investigations have been recently recommended. This research schematizes start-up-driven innovation in the logistics industry, offering a classification framework mapping different initiatives into four macro-categories and further embedded categories. Therefore, it offers a pragmatic but robust lens to approach the innovation phenomena in the logistics industry, further detailing the macro-categories into more granular categories that reflect the singular characteristics of smaller groups of companies. Moreover, the study identifies categories that are raising more funding, thereby illustrating the most promising directions for future research and practical applications.

New logistics players and hardware developers are the two macro-categories that collected the highest funding. New technological solutions, and the related embracing by LSPs, answer to the growing attention of public opinion towards sustainability. For example, hardware solutions such as autonomous and electric vehicles are increasingly adopted, but the related managerial implications deserve to be further explored. Also, significant efforts are currently in place concerning shifting freight from road to rail, improving vehicle utilization, and switching transportation operations from fossil fuel to renewable energy. An investment boom in technology is occurring, in particular for urban deliveries. In this regard, social sustainability should be pursued as well, and last-mile delivery implications should be better investigated also concerning workers' well-being.

The present study presents some limitations and offers interesting directions for future investigation. Despite the large sample collected, and having triangulated data with secondary sources, the considered start-ups did not all have the same data available. Although this does not negatively affect the outcomes related to RQ1, it represents an obvious limitation regarding RQ2 and additional analyses concerning what categories received more funding could be developed. Also, the start-up landscape is in turmoil and evolves rapidly. Monitoring the evolution of the various macro-categories over the next years could be relevant, to explore the directions of logistics innovation and where the investors' interest could move. Indeed, new categories will probably require to be identified and defined, while others might experience a significant reduction in funding until even disappearing. Lastly, case research could be recommended to deepen how start-ups manage to bring their solutions to the logistics industry, and investigate the relationships they might develop with incumbent LSPs.

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