Technological trends in last-mile contexts: A European perspective

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Technological Trends in Last-mile Contexts: a European Perspective

Anna Corinna Cagliano[1], Giulio Mangano[1], Giovanni Zenezini[1]

[1] Department of Management and Production Engineering, Politecnico di Torino, Torino, Italy
{anna.cagliano@polito.it, giulio.mangano@polito.it, giovanni.zenezini@polito.it}

Abstract. This paper presents an empirical analysis on 65 European cities where different Last Mile technologies have been implemented by both private and public operators, aiming to assess the importance of each technology involved and identify adoption trends. Results show that parcel lockers and low emissions vehicles are the most adopted technologies, while the diffusion of Intelligent Transportation Systems and dynamic routing appears limited. Finally, crowd shipping services are still scattered but show medium level of adoption. Future research will extend the analysis to international projects and include external aspects to refine the understanding of technological adoption patterns.

Keywords: Last Mile Logistics; Empirical Analysis, Europe, Technology, Cities

1. Introduction

Freight delivery in urban areas is one of the most complex processes in current supply chain environments and as such it might become very expensive if not properly managed. In fact, a number of activities accounting for up 40% of the total supply chain cost are usually related to last-mile distribution [1]. Additionally, it has been estimated that up to 20% of vehicle-kilometers travelled on urban roads are due to last mile deliveries [2]. Urban freight distribution is also a major cause for traffic congestion, noise, and pollution which might largely affect both the level of service and the costs in a production-distribution system. Recent studies state that urban logistics activities may account for more than 60% of the total CO2 emissions of distribution organizations [3].
In order to address the negative impacts of urban logistics and ultimately increase its efficiency, in the last few decades both researchers and practitioners have tackled this issue [4]. Thus, the City Logistics (CL) notion has been introduced as a comprehensive set of solutions for "totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption"[5].
As a consequence of the increased awareness towards CL themes, both public authorities and private companies have undertaken several initiatives that starting mainly from Europe are now progressively spreading all over the world. Such CL initiatives are usually referred to as CL measures. A lot of attempts to categorize and systematize the existing fragmented CL measures (e.g. low impact vehicle adoption, access regulation to limited traffic zones, urban consolidation center development, dynamic management of vehicle routings and lay-by areas, etc.) have been proposed in literature. Besides the technical papers associated with well-known CL international projects such as BESTUFS I and II, SUGAR, CIVITAS [6–8], there is a number of academic works that are worth to be mentioned. [9] are among the first authors who provided a comprehensive classification of solutions for urban freight transportation. Two different perspectives are taken: the initiative scope (e.g. public infrastructure, land use, access conditions, traffic management, enforcement and promotion) and specific groups of stakeholders (logistics operators, receivers, local authorities). Later on, [10] better detail the previous classification. First, they distinguish infrastructures into material (e.g. use of the urban transportation network) and immaterial (e.g. intelligent transportation systems). Then, they itemize governance measures into several groups such as time window

access, heavy vehicle network, and road pricing management. Finally, they add equipment, including unit loads and transportation means, as a key CL measure category. The various classifications proposed by literature are best summarized and categorized by [11]. They propose six components of CL solutions, namely infrastructure, logistics organization of transport, technologies, communications, funding, and regulations. Based on that, [12] deeply analyses technologies proposing a number of categories including vehicle propulsion systems, material handling equipment, and ICT tools supporting CL initiatives.

Among them, the classifications by [11, 12] are particularly interesting because they take a practical perspective [13]. Moreover, unlike other existing taxonomies, they explicitly take into account the technological aspect, which is a key foundation of most of CL measures.
The present work builds on [11] and [12] classifications and focuses on the technology category. Following the need for sharing best practices and providing guidelines for the effective design and implementation of urban logistics policies, there is so far a large body of literature analyzing single or groups of CL initiatives [14], [15]. Another quite debated topic is assessing the economic, environmental, and social effects of CL measures on the different stakeholders involved [16] as well as the value proposition of new CL services for selected supply chain actors [17]. However, most of the current literature, although recognizing technology as an enabling factor for the success of urban freight transportation services, addresses it just at the degree it is required in order to describe a certain initiative or discuss a given impact. There are few contributions offering comprehensive studies on the state of the art of technological applications to last mile logistics, or identifying the associated trends. Nevertheless, such studies would be beneficial to both policy makers and companies to correctly identify the best technologies to invest in when drafting new CL initiatives.
With the purpose of contributing to bridge such a research gap, this work puts forward an empirical analysis on a dataset of 65 European cities claiming to have applied technological solutions to last mile logistics. First of all, a comprehensive set of reference technologies has been defined according to literature evidence. The analysis of data that have been gathered is aimed to assess the importance of each technology at issue and to identify related several important trends in its level of adoption.
The paper is structured as follows: firstly, main CL technologies are reviewed to ground the work in the relevant literature. Secondly, the research methodology is explained and the dataset is presented. After that, the dataset is analyzed and the results interpreted. Finally, the main implications are discussed and conclusions drawn.

2. Literature review

There is a considerable number of technologies underpinning CL projects, so, as a preliminary step, a comprehensive set of them is selected in order to focus the analysis on. As already discussed in the Introduction, the main inspiring taxonomies for defining the technologies addressed in the present study are [11] and the in-depth technology analysis offered by [12]. In order to make sure to deal with a set of technologies that well represent the main ones adopted by existing CL initiatives, such contributions are leveraged with the outcomes of [18] and [19]. Both these studies investigate real-world CL implementations and classify the associated last mile logistics innovations, where most of them are technological in nature. On the one hand, [18] present three general groups: consolidation of good flows within the urban area, use of novel either low or zero emission vehicles, and regulation with particular attention to limiting activities by time or vehicle type as well as size. On the other hand, [19] distinguish CL innovations in five categories: innovative vehicles, proximity stations (also including crowd-tasking models and parcel lockers), collaborative and cooperative logistics, optimizations of transport management and routing, and innovations in public policies and infrastructures.
By combining all the categories out of these works , the following group of technologies is considered in the present research: i) Intelligent Transportation Systems (ITS) – Electronic control and access; ii) Dynamic routing and lay-by area monitoring and booking; iii) Low emission vehicles; iv) Crowd logistics; and v) Parcel lockers.
ITSs deliver value-added services (e.g. traffic management systems, route planning, etc.) to enable and control transportation operations performed by fleet of vehicles. In the CL context, they can be purposefully applied to support electronic access control, access charges, and road pricing systems by managing the interaction between freight carriers and municipalities and ensuring security and reliability of services [20]. They rely on an integrated IT platform that can be accessed by different stakeholders through both a browser

and mobile devices. ITSs help achieve a more efficient resource usage together with improved physical flows. As far as road pricing is concerned, it is paid for transiting in urban roads and depends on either the access time or the vehicle emission levels, thus discouraging the use of polluting freight transportation vehicles as well as fostering a more rational use of infrastructural resources [21].

Among the provided services, ITSs also offer real-time information about traffic and lay-by availability. The first kind of information is of key relevance to routing planning systems that can dynamically re-route vehicles based on the actual road conditions. This is a technological solution that enhances carrier efficiency and reduce negative impacts of CL activities. A lot of vehicle routing algorithms have been developed for urban freight distribution, many of them taking into account restricted delivery time windows due to either access times to particular city areas or customer needs [22]. Accurate and real time information about the availability of lay-bys is crucial to optimize logistics time and costs as well as improve environmental sustainability [23]. Moreover, it can provide reliable input data to routing planners so that freight transportation vehicles can adjust their routes according to the availability of loading and unloading areas nearby. Finally, the positive effect of lay-by management on urban freight distribution is supported by a proper design of these infrastructures in terms of location and area sizing [24].

As a third technology category, low emission vehicles applied to CL environments include a large variety of types, such as electric, hybrid or fuel cell vans, together with cargo bikes [25]. However, the required initial investment for a large-scale implementation of many low-emission vehicles is very high and sometimes not completely counterbalanced by the related benefits. For this reason, simpler and less expensive transportation means have started being considered for CL purposes. Cargo bikes are an urban distribution solution introduced in recent years to deliver parcels on bike routes, thus contributing to limit traffic congestion, enhance efficiency, and decrease negative CL externalities [26]. Despite public stakeholders increasingly promote the use of electric cargo bikes, logistics providers are still reluctant to their adoption because of a number of operational issues, like the limited parcel size, the short travel distances, and the need for consolidation centers acting as departure points [27].

The fourth technological class addressed in this work, namely crowd logistics, is relatively new and is related to the notion of sharing economy. It has been introduced as a consequence of the more and more widespread diffusion of the online B2C commerce and the need for finding competitive ways of performing last mile and same day deliveries. Big players such as Amazon and Walmart are already adopting such a logistics approach. According to crowd shipping, deliveries are outsourced to private individuals that might be themselves customers of retail business [28]. At least two organizational models exist. According to a first one, individuals might be paid to pick up parcels from dedicated stations and delivery them to final customers, for example during their daily trips to and from work. In a second solution the customers of a logistic service provider are in charge of delivering goods for others for a sum of money [29]. Crowd shipping services usually rely on an electronic platform to connect senders and shippers. Benefits include economic savings due to shipper costs that are less than the average wages of traditional drivers, a reduced need for logistics infrastructures, delivery flexibility to changed time windows, and low environmental impacts since shippers can also sometimes use the public transportation network according to the size of delivered parcels. Moreover, it has been proved that integrating crowd logistics with traditional delivery methods can help containing last mile logistics costs [30]. Crowd shippers might pick up and deliver goods not from/to a private location but a parcel locker [31].

Parcel lockers are sets of unattended lockers located in residential areas, work places or public utility places, such as shopping malls or railways stations. They are opened thorough an electronic code and used by different customers to drop off or pick up goods 24 hours a day, 7 days a week. They can be property of a single B2C company or shared among a group of companies [32]. Similarly to crowd logistics, parcel lockers provide an efficient solution to the fast growth of e-commerce and the associated increase in parcel delivery and return volumes. In particular, they are able to improve the consumer service satisfaction while ensuring a high level of logistics performance as well as competitive advantage to companies [33]. However, one of the relevant efficiency factors for this solution is an appropriate locker site: the area should be considered beneficial for self-collection by potential customers [34]. For this reason, many recent studies are concentrating on the determination of the best location, number, and size of parcel lockers (e.g. [32], [35]).

The performed review reveals that there is quite a large body of literature discussing the various CL technologies. However, most of the contributions on this topic are focused on either a single or a group of implementation projects or study the impacts of one or few technologies. There is a substantial lack of works taking a broader perspective and investigating the current general state of the art of technological measures in CL. Such a comprehensive analysis would provide both researchers and practitioners with many benefits, including the possibility to trace evolution trends and to offer guidelines for setting effective CL strategies. This is where the present research seeks to contribute to the current state of the art.

3. Methodology

In order to identify the main trends in the use of the innovative technologies able to support logistics activities in urban environments, a sample of 65 European cities where such technologies were implemented is extracted. The cities have been selected, since they have claimed to be involved in the development of CL projects based on most recent technologies. Data on technological implementation are retrieved from project documentation, national and regional reports and scientific literature. The decision of considering only European cities is based on their high demand for technological initiatives and programs aimed at improving urban logistics systems. In this context, the European Commissions' Transport 2050 Strategy proposes a strong reduction of greenhouse emission and sets different modes of transport including CO_2 free logistics in major city centres [8]. Also, more recently the European Digital Agenda has a significant impact of the organization of CL programs [36]. In the sample under study both small (Regensburg, Germany; Vicenza, Italy) and big cities (London, UK; Paris, France) are considered. A value equal to 1 or 0 is related to each technology whether a city reports a CL initiative or not for that specific technology. In other word, the assignment of 1 in a given technology means that a city has at least one project exploiting that technology.

3.1. Sample description

As previously mentioned, the sample is composed by 65 European cities, belonging to 15 countries (Figure 1). The cumulated population of the cities equals roughly 50,1 Mln inhabitants, with an average density of 3'080 inhabitants/km^2. The weighted average GDP per capita of the sample equals 36'276 €, slightly higher than the GPD per capita of the European Union (i.e. 32'672 €).

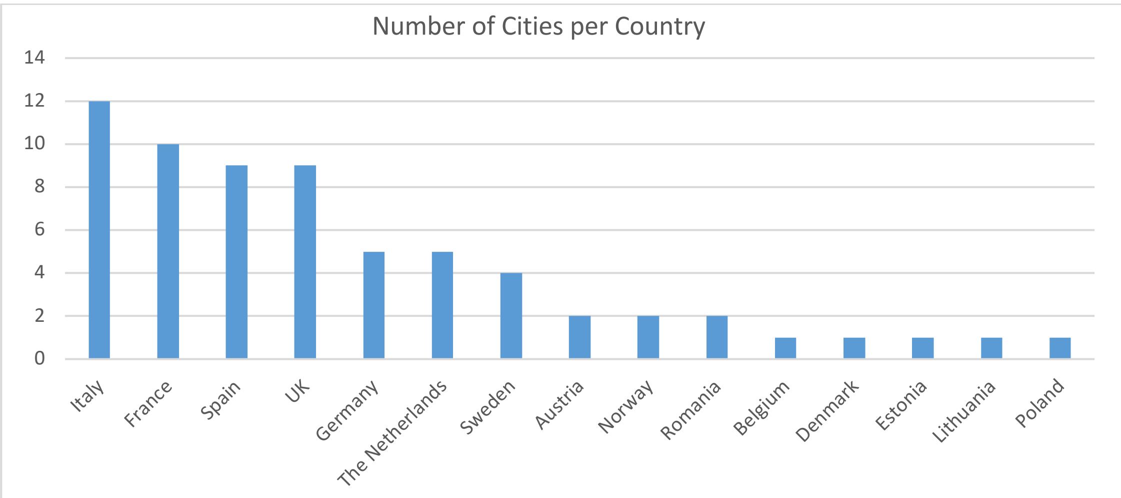

Figure 1: Number of Cities per Country

4. Results

4.1. Coverage of technologies in the sample

Figure 2 shows the number of applications for every technology at issue and for the cities of the sample taken into account, together with the related percentage level. First, almost 100% of the cities are now using parcel lockers in urban logistics processes. This result demonstrates a relevant interest associated with this solution and a certain level of maturity. This phenomenon is related to the broad use of e-commerce that has imposed new challenges in last mile delivery processes [24]. In particular by moving from business to business (B2B) to business to customers (B2C) companies have to deal with an increasing number of smaller parcels [37]. In this context, parcel lockers can play a crucial role, since they can enhance the level of efficiency of urban logistics, by avoiding the missing delivery issue as already stated in the literature review section [33]. Also, in most of the cities the use of environmentally friendly vehicles can be observed. This aspect can be related to the increase awareness of public policy makers about the environmental issue, especially in urban areas. As a matter of fact, low emission vehicles are an effective response for reducing pollutants in city contexts in both terms of emissions and noise levels. In particular, the implementation of cargobikes is proving to be cheaper and more efficient than vans under certain circumstances such as very congested areas or with small parcel delivery [26, 27]. The application of crowd logistics is lower. This might be due to a relative more recent development of such a measure that has been often associated with the adoption of applications based technologies that support the connection along the supply chains [38]. Finally, the implementation of ITS and Dynamic Routing projects is still limited. In particular, only 10% of the cities of the sample are using algorithms for the optimization of the routing and for the management of the lay- by areas. This result might be explained by two main elements. First, a lot of stakeholders are typically involved in the design of these kinds of projects. Since the objectives of every stakeholder are often not perfectly aligned, it could be difficult to set an effective coordination among them. Then, these initiatives require relevant investments in both physical infrastructures and software licenses. Due to the level of uncertain returns, private sponsors are still hesitant in promoting this kind of initiatives, that can only rely on the public support.

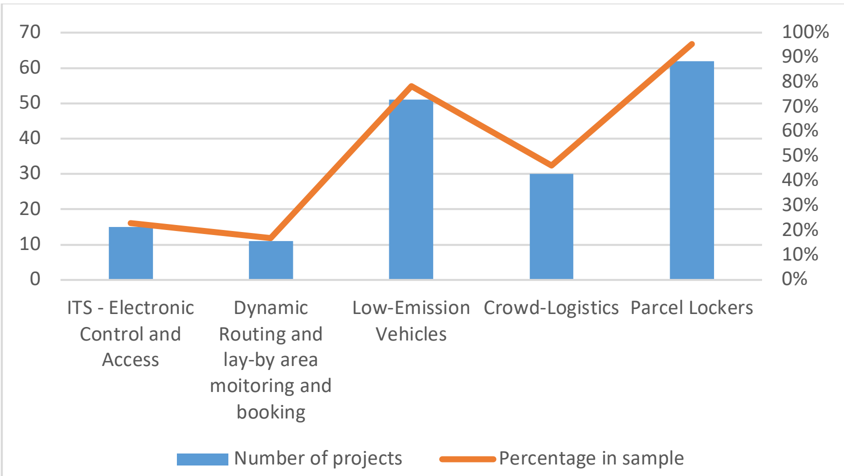

Figure 2: Adoption of technologies

4.2. City Coverage Index

Each city is associated with a coverage index that represents the number of last-mile technology projects implemented in that city. This index is computed as the ratio between the number of technologies used by each city under analysis and the total number of technologies taken into account in the study. It can be considered as an expression of the ability of a city to exploit the new technological solutions that can be used in urban environments for supporting logistics activities. The coverage index takes values from 0.2, meaning that only one project is present, to 0.8, meaning that none of the cities in the sample has adopted all the last-mile technologies at issue. The distribution of cities among the coverage index is quite balanced, with a large majority of cities showing coverage indexes of 0.4 or 0.6. Moreover, a very large share of the cities in the sample cover both Parcel Lockers and Low Emission Vehicles, as shown in Figure 3. The most "technological" cities in the sample are Lyon, Berlin, Rotterdam and London. Such cities are able to combine the efforts by public authorities in managing and controlling urban freight by means of ITS systems or planning algorithms with new delivery solutions used by private companies, such as cargo bikes or crowd shipping. These four cities belong to different countries. This result demonstrates the widespread adoption of last-mile solutions by European cities. Such outcomes also show that large markets are leading the way of technological improvements in last-mile processes, as three out of four cities come from the three largest economies in Europe [39]. Furthermore, Rotterdam implemented a planning tool for delivery trucks due to the large traffic generated by its port[1], which is the largest cargo port by tonnage in Europe [40].

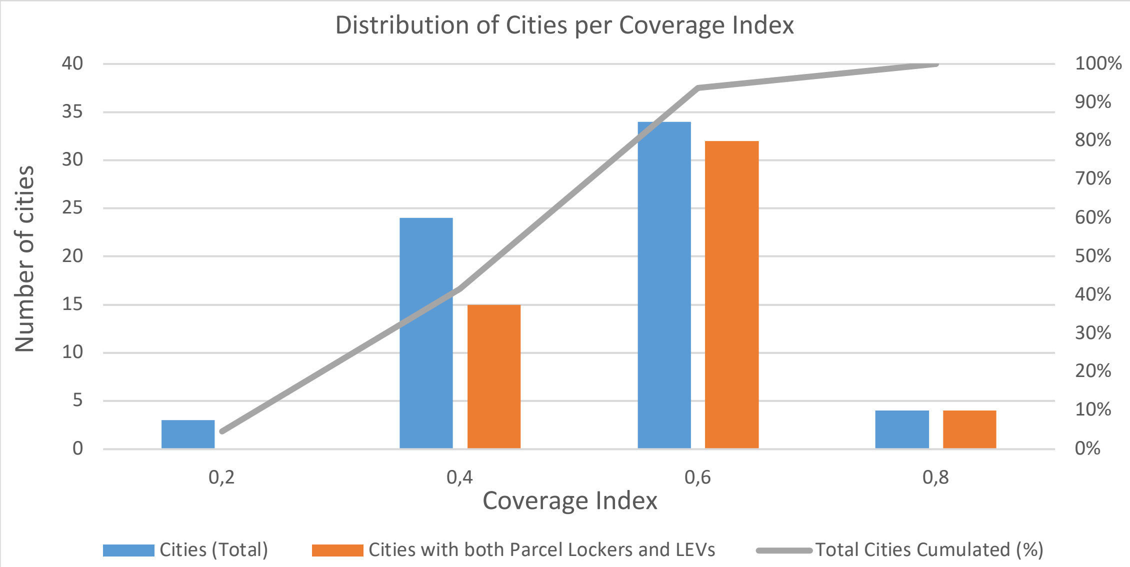

Figure 3: Coverage Index for the sampled cities and the cumulated percentage of the distribution

4.3. Private endeavor or joint private-public effort?

The larger group of cities in the sample (i.e. 34 out of 65) show a coverage index of 0.6. Nevertheless, the cities belonging to this group achieved this result by taking different path towards technological improvements in last-mile contexts. As a matter of fact, we can divide the 34 cities with a coverage index of 0,6 into two subgroups.

The first sub-group, composed by 21 cities, has experienced the adoption of various market solutions, such as cargo bikes or electric vehicles, crowd-shipping platforms and parcel lockers. Hence, in those cities the surge of last-mile technologies can be attributed mostly to last-mile private operators. In particular, we can distinguish three countries that account for 71% of the cities in this sub-group, namely France, The Netherlands and UK. These countries lie at the forefront of last-mile deliveries because they could integrate the efforts brought by small innovative companies with the large-scale adoption by international logistics service providers. For instance, the French courier Le Group La Poste acquired the crowd shipping company Stuart in 2017, which expanded its operations to several cities in France and the UK[2]. Furthermore, in The Netherlands the last-mile delivery with cargo bikes has become widely adopted, as a company such as Fietskoeriers is able to deliver goods in 30 Dutch cities by employing 600 bike messengers [41]. These findings are consistent with previous results by [13], who state that technological implementations do not depend on the specific structure of a city, but rather on the maturity of the technology and on the adoption by private players.

On the other hand, the second sub-group is composed by 13 cities that decided to implement at least one technological project at a urban planning level, either in terms of ITS or freight planning algorithm. Such cities couple an average level of adoption of market solutions, i.e. the most common ones, with a greater interest in urban freight issues by local authorities. Among these cities there is a predominance of Italian ones, which compose 58% of the sub-group (7 cities out of 13). Another geographical area vastly represented in this sub-group is composed by the Baltic and Scandinavian regions, which comprise 4 cities (i.e. Tallinn, Stockholm, Gothenburg and Copenhagen).

5. Discussions and Conclusions

[1] https://www.portbase.com/en/services/road-planning/
[2] https://www.ipc.be/en/News-Portal/operations-logistics/2018/05/08/07/38/crowd-sourced-delivery

This paper is intended to propose an analysis on the adoption of innovative technologies in carrying out logistics activities in urban environments. To this end, a set of technologies has been identified, and a sample of European cities that have claimed to adopt such technologies has been created.
The results show that parcel lockers together with low emissions vehicles are the most adopted technologies in the cities under study. This might be due to the fact that big players operating at international levels, such as e-commerce companies and logistics service providers, are involved in these projects. On the contrary, the limited diffusion of ITS, or dynamic routing initiatives, is based on the significant support of public authorities that have also to align the different objectives of the stakeholders that are involved. In addition, it is important to underline that a lot of Italian cities have carried out these services. As a matter of fact, Italian cities, especially in city centers, often suffer from problems of congestion related to their narrow and ancient streets that were not originally designed for the transit of cars, vans etc. Therefore, in these urban areas a structured control of the accesses and a more strictly monitoring of the flow acquire a particular relevance. Finally, crowd shipping services are more diffused in countries such as France, United Kingdom, Norway and Belgium, wherein logistics startups have experienced a more favorable business environment.
The present study gives rise to both theoretical and practical implications. From a theoretical point of view, it can be considered a contribution in the research stream focused on the classification of last mile technological projects. In addition, it might provide a big picture related to the level of adoption of the technologies supporting CL processes at a European level. Finally, this work could be suitable in assessing the level of adoption of the different kinds of services that have been taken into account. From a practical point of view, this paper might give a support to public policy makers to evaluate their technological maturity in their last mile systems and then design coherent future objectives. In such a context, the present research could drive a more thorough assessment of the impact of public investment against the initial goals, in order to evaluate the success of urban freight planning strategies. However, this work suffers from some limitations. In particular, the sample is limited to the European contexts and it is not at a worldwide level. Actually, last mile appears to be a typical European issue and a low number of municipalities are significantly promoting CL initiatives in other international regions. In fact, European cities have been facing all the problems related to traffic congestions and related pollution for a longer period of time compared with cities of other continents. Also, this work does not take into account the effect of factors that might facilitate the introduction of last mile services such as the number of start ups per inhabitants, or the venture capital funding. Future research will be addressed to overcome these limitations, by gathering international city projects for enhancing urban logistics systems and by including external aspects that may more precisely explain technological adoption patterns. In particular, such a research will be a support in the evaluation of the proposed preliminary results through a more quantitative assessment.

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