Socio-economic variables driving 4.0 projects in last mile logistics

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Abstract: The increasing number of people living in urban areas is determining a higher demand for logistics activities in urban environments, with consequent problems related to traffic congestion, air and noise pollution, infrastructure wear, and artistic heritage deterioration. The need of dealing with these negative impacts is fostering all the involved stakeholders of an urban logistics system to try to pursue higher levels of efficiency. In this context, the idea of City Logistics, intended as all the services aimed to better manage goods circulation throughout the cities, has been increasing its importance. In urban environments, the adoption of 4.0 technologies might play a crucial role trying to optimize the service, in terms of digitalization, automation, and interconnection not only along the supply chain but also on its last mile. The objective of this paper is to deeply investigate this topic by analysing how contextual factors could influence the investment strategies on these innovative solutions. To this end, an empirical model based on a regression analysis has been developed to investigate which socio-economics determinants had a significant influence on investment policies in 105 City Logistics projects applying 4.0 technologies. Thus, some variables have been identified, considering several crucial determinants that may affect the choice of investing in a given market, namely economic, strategic, and legal. Additionally, given the urban context, indicators which could describe the demographic aspect of cities were also included. The presented analysis shows that Gross Domestic Product (GDP), Foreign Direct Investments, R&D Expenditure, Employment rate, and Number of Inhabitants result as significant drivers of the development of 4.0 technologies in urban environments. The empirical analysis carried out introduces new observations on the enabling factors of 4.0 solutions, highlighting the most suitable socio-economic conditions for their development in the context of City Logistics.

Keywords: City Logistics, 4.0 Technologies, Regression Analysis, Last Mile

1. Introduction

The increasing urbanization has caused a significant growth of logistic operations in urban areas, with negative impacts on metropolitan road traffic and congestion, environmental pollution, and more in general quality of life (Istiqomah and Sutopo, 2020). For this reason, there is a raising need to evaluate improved and innovative solutions able to reduce emissions and optimize last mile distribution routings. As a matter of fact, more sustainable performance vehicles, adopted together with appropriate governance measures, brings environmental and operational benefits (Russo and Comi, 2018). It has been recognized that the effectiveness in the development of optimal urban logistics strategies relies on the partnership and collaboration among all the stakeholders (Rześny-Cieplińska and Szmelter-Jarosz, 2020). Thus, it is fundamental for companies trying to maximize the efficiency of urban logistics operations. Likewise, governments and local authorities seek to optimize urban logistics transports since they contribute to deteriorate the environment citizenship well-being conditions (Leyerer et al., 2019). In this context, the idea of City Logistics (CL), intended as all the services aimed to better manage goods circulation throughout the cities (Dablanc, 2007) has been increasing its importance and gaining attention. It could be referred to the optimization of logistics and transport activities with the support of performing information systems, taking into consideration the environment, traffic congestion, traffic safety, and energy saving (Taniguchi et al., 2020). In this context, the adoption of 4.0 technologies might play a crucial role in optimizing the service, thus implementing more integrated and dynamic solutions. In fact, in the era of digitalization, the use of innovative solutions in urban areas has a positive impact on goods and people flows, resulting in an enhanced life level of quality (Kauf, 2019). Additionally, a proper logistics service and technological support have direct influence on economic development of metropolitan networks, thus improving business competitiveness, supporting innovation, and encouraging investments (Yang et al., 2019). Nevertheless, few academic contributions analyse the impact of the socio-economic configuration of urban areas on the willingness to invest in innovative CL projects. In order to bridge this research gap, the aim of this work is to deepen this field, namely the application of Industry 4.0 to CL and, specifically, to determine which contextual factors drive investment programs exploiting these technologies. Therefore, the remainder of this paper is structured as follow. Literature review illustrates the research background on City Logistics concept related to Industry 4.0 and the innovative technologies applied to distribution processes in urban areas. Then the methodology adopted in this study is introduced, describing the dataset used and the empirical analysis conducted. After that, the discussion of the results obtained is presented. Finally, conclusions complete the article with the possible implications, future research streams, and the limitations of the study.

2. Literature Review

2.1 Overview of City Logistics concept related to Industry 4.0

The transport of goods is a critical process especially in urban areas. Therefore, the concept of City Logistics has been gaining an increasing attention as the activities carried out for optimizing all logistics activities in urban environments (Eshtehadi et al., 2020). It is often supported by digital systems enabling almost real-time interaction between customers and retailers for the proper handling of an order. Therefore, CL operations are expected to include Industry 4.0 technologies (Yavas and Ozkan-Ozen, 2020). The concept of Industry 4.0 was first introduced in 2011 during the industrial automation fair in Hannover (Germany) with the aim of providing products and services with the support of automation and digitalization (Hofmann et al., 2019). At an urban level, Industry 4.0 technologies are levers for enhancing new values related to the interconnectivity among buildings, grid, and mobility and to support policy makers and logistics providers in satisfying customers' expectations (Tang and Veelenturf, 2019). In particular, logistics 4.0 can be defined as networking the whole supply chain through information technology, wherein sensor and automated robots are used in operations (Jahn et al., 2018). It involves system-based planning and control of the physical movement of goods and information flow from the source to the final destination, by using front end and base technologies in order to enhance the customers' requirements (Frank et al., 2019). These technologies can significantly improve the urban logistics operations, and modelling CL by exploiting these solutions appears to be more and more promising (Taniguchi et al., 2020). In fact, the adoption of 4.0 technologies in urban areas allows to collect a huge quantity of information that in turn should be detailed and measurable so that to eliminate the barriers between the involved stakeholders. Therefore, these innovative technologies are transforming logistics functions as competitive weapons instead of cost centres (Tang and Veelenturf, 2019).

2.2 4.0 technologies applied to City Logistics

Among the innovative technologies related to Industry 4.0, Intelligent Transportation Systems (ITS), Information and Communication Technology (ICT), IoT, Big Data, Cloud Computing and Artificial Intelligence (AI) are significant for enhancing City Logistics in terms of integrated management of urban freight transport systems (Taniguchi et al., 2020). Additionally, the recent growth of urban logistics services and the emergence of sharing economy models has enabled alternative freight distribution services like crowd shipping (Simoni et al., 2019). Finally, other 4.0 solutions applied in CL are Drones and Autonomous Vehicles, Blockchain, and Additive Manufacturing (Heutger and Kückelhaus, 2016). The application of wireless communication and sensors technologies to transport field has developed ITS, which is receiving particular interest due to the increasing need for road safety and efficiency in dense road networks (Boukerche et al., 2020). In addition, the implementation of ITS seeks to relieve traffic congestion, reduce journey times, improve safety, reduce pollution, decrease energy consumption, and enhance the productivity of transport investment (Ran and Boyce, 2012). In the City Logistics arena, mobile applications assist in placing orders, planning, and choosing routes, and acquiring real-time information on traffic conditions (Iwan et al., 2014). In this context, the dramatic increase of the use of smartphone applications for the urban food delivery can be observed, and the recent outbreak of COVID-19 induced a further surge in using these apps (Smith et al., 2021). These services are based on ordering food from various restaurants through apps that is then delivered to the customers' doorstep using a fleet of bikes or electric scooters (Ortiz-Prado et al., 2021). Also, the introduction of ICT and IoT in supply chains provides a widespread information infrastructure, thus obtaining performance improvements and energy consumption reductions (Garrido-Hidalgo et al., 2019). The recent developments of ICT can be considered as the main trigger of the Fourth Industrial Revolution, which relies on the combination of various ICT tools with the ultimate goals of connecting assets and facilities, explaining data, and digitizing business operations (Peraković et al., 2019). For instance, TaskRabbit developed a platform that interconnects people from the same geographical region so that they can mutually exchange last mile delivery services. Though IoT it is possible to obtain Big Data of logistics resources and determine the best delivery route consistent with the logistics delivery requirements (Zhu, 2018). As well as, monitoring traffic congestion, parking spaces, state of roads, and traffic problems via IoT technology brings benefits to City Logistics operations (Witkowski, 2017). Furthermore, IoT enables dynamic optimization of sustainable reverse logistics (Liu et al., 2018). Generally, one of the layers of IoT architecture consists of cloud computing, which is in charge of gathering, processing, and elaborating all the data of the interconnected system, as well as managing virtualized resources in the form of service packages available to all cloud system players (Golpîra et al., 2021). Cloud computing allows a set of computing resources, namely networks, servers, storage, applications, and services, to access to an on-demand, ubiquitous, and useful network, thus supporting the opportunity to design an adaptive City Logistics infrastructure in relation to changing transport demand (Nowicka, 2014). Cloud architecture can solve the problem of increasing transport costs and in-time delivery requirements, accelerating transfers between the actors of logistics networks, providing an automated and complete solution, and increasing efficiency level (Niharika and Ritu, 2015). In this context, a better management of the urban fabric and last-mile operations is also possible through Artificial Intelligence and machine learning technologies, which provide a deeper understanding of how cities evolve, adapt and respond to various conditions (Allam and Dhunny, 2019). Additionally, by the adoption of AI, logistics networks will adopt more proactive, predictive, automated, and personalized strategies able to increase the overall performance of the distribution system (Gesing et al., 2018). Other typical 4.0 solutions applied to logistics operations are the use of Autonomous Vehicles, Drones, and Robots. The issue of Autonomous Vehicles rises particular interest in City Logistics context, since they can increase safety in freight activities and might influence urban goods movement in terms of sustainability, savings, quickness, and customers satisfaction (Baum et al., 2019). However, there are a lot of concerns on the part of consumers and public and still several open regulatory public issue that limit their adoption (Faverò et al., 2018). Also airborne Drones represent a promising technology for future growth and quality level of distribution channels (Müller et al., 2019). Nevertheless, the successful implementation of Drones programs in parcel delivery processes deals with the assessment of analysis aimed at evaluating actual economic benefits, uncertainties related to technical features and socio-environmental impacts (Kellermann et al., 2020). Additionally, City Logistics is changing thanks to the adoption of Blockchain technology. It has great potential to transform supply chain functions since it enables verification of transport sustainability performance, sustains smart and traceable packaging, and supports tracing of materials in reverse logistics operations (Dutta et al., 2020). Also Additive Manufacturing has a significant impact on urban environment logistics. Indeed, this innovative technology may play a prominent role in spare parts logistics areas and individualized parts manufacturing, allowing on demand production, new customer-centric solutions and different last-mile logistics strategies (Heutger and Kückelhaus, 2016). The overview of the literature focused on the application of 4.0 technologies to City Logistics context highlights the crucial role and the potential businesses opportunities in investing in this field. Thus, the proposed study tries to provide a contribution in this topic by investigating the socio-economic drivers that guide investment strategies of companies and public institutions.

3. Methodology

3.1 Description of dataset

In order to analyse the main drivers that guide the implementation of 4.0 City Logistics projects, a dataset made up of 105 initiatives has been built, including the principal applications of innovative solutions to urban logistic contexts. In particular, the most relevant CL projects carried out in recent years have been identified and analysed. For each observation, the main technology implemented and the economic value of the investment that has been developed have been recorded in the dataset. The data have been mainly gathered from the internet sites of the companies proposing the solutions, business reports, and investment platforms such as Crunchbase, Skift Table, Pagan Research, Tracxn, Start-up Nation Finder, TechCrunch, and Indiegogo. For example, Drone Delivery Canada reports an investment equal to 13.7M $ in an Advanced Robotics project in Canadian cities for reducing overhead costs and delivery times. Additionally, Fast Radius invested 67.3k $ in the implementation of Additive Manufacturing solutions in American urban contexts. Finally, for several projects, the adoption of more than one technology has been observed. In these cases, the technology considered was the first one shown in the description of the project per se. For instance, Makespace implemented a solution based on Cloud Computing and ICT, but only the first technology has been included in the dataset. Since the objective of the analysis is to establish the relationship between the implementation of 4.0 logistic solutions in urban areas and socio-economic factors, data related to the nation and the year of development of the project has been collected for each contextual variable included in the model, namely Gross Domestic Product (GDP), GDP growth, Foreign Direct Investments, R&D Expenditure, Employment rate, People with a Bachelor degree, Population Density, Number of Inhabitants, and Internal Private Credit. The total number of observations that constitute the dataset amounts to 105. The average amount of the investment is equal to 48 M$. The smallest project is equal to 30k$ and it refers to the installation of sensor in the mailboxes able to send notification to the receiver. The largest one is related to the development of a food delivery service finance by Uber exploiting the crowd shipping technology, and it amounts to 900M $. In America, most of the projects have been developed in the US, in Europe a certain relevance is shown by France, and in Asia Hong Kong and India show heavy interest in implementing 4.0 CL initiatives. The projects included in the dataset correspond to solutions developed in the last decade, and more than half are less than 5 years old. Regarding the geographical distribution of 4.0 City Logistics innovations, it can be observed that most of the projects operates in Asia, followed by Europe and America (Figure 1). It is worth underling that the number of implementations in Africa reflects the growing demand for logistics operations in emerging countries and the tendency of foreign promoters in investing in these promising areas of the world (Werikhe and Jin, 2016). On the other hand, Oceania is the continent that shows the least incidence of urban logistics projects.

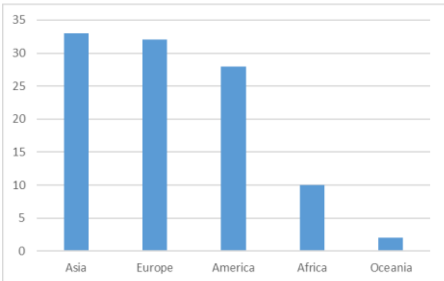

Figure 1: Geographic distribution of 4.0 CL projects

By observing the innovative technologies implemented in urban context, the dataset shows a large diffusion of smartphone user application, mostly related to food delivery projects. This result mirrors the increasing trend in the use of mobile food apps due to higher busy and dynamic routines of consumers, which more often prefer to order food online rather than cooking at home (Vinaik et al., 2019). The second most used solution is ICT, followed by Advanced Robotics, Artificial Intelligence, Cloud Computing, IoT and Big Data & Analytics. The 4.0

technologies that most struggle to take root in urban environments are Additive Manufacturing and Blockchain (Figure 2).

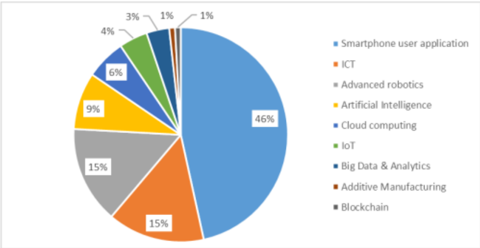

Figure 2: CL 4.0 Technologies

3.2 Description of the model and of the variables considered in the analysis

The adopted methodology is the regression model. Regression tests if the independent variables taken into account are statistically significant factors and whether they have a positive or negative impact on the response variable. A positive influence indicates that an increase (or decrease) in the independent variable determines an increase (or decrease) in the dependent variable. On the contrary, a negative effect determines opposite direction between independent and response variable variations. The level of significance for each independent variable is related to the p-value, which ranges from 0 to 1 and is obtained from the regression model. If the p-value is lower than a critical threshold, that is usually equal to 5%, the null hypothesis has to be rejected and thus the independent variable at issue can be considered as significant. In other words, the notion of significance is not related to the strength of the relationship but to its reliability. In the present study the response variable is the investment required for carrying out the project and the independent variables a list of socio-economics factors that are likely to influence the investment strategy. They are Gross Domestic Product (GDP), GDP growth, Foreign Direct Investments, R&D Expenditure, Employment rate, People with a Bachelor's degree, Population Density, Number of Inhabitants, and Internal Private Credit. GDP, used as a monetary measure, shows the market value of all the final goods and services produced in a certain period of time. Since it reflects the economic development of a country, it can be considered as a lever for fostering innovative technologies (Fan, 2011). In addition, the GDP growth is taken into account as a proxy to assess the speed of economic development (Naveed et al., 2018) Similarly, the GDP per capita, computed as the ratio between the GDP and the total number of inhabitants, is included as a factor able to support the diffusion of innovation. Thus, it is expected that the higher these variables, the higher the availability of financial resources and in turn the willingness to invest in innovation. The Foreign Direct Investments (FDI) are structured long run investments carried out between a foreign organization and a hosting country, and typically bring new technologies and know-how. Therefore, it can be assumed that broader FDI bring to increased investment in urban logistics projects. The investments in Research and Development (R&D) are aimed at creating knowledge diffusion and innovation (Jang, 2019). From this perspective, significant R&D budget are likely to lead to more financial engagement in new urban logistics initiatives. The Employment Rate is also considered in the proposed study because stronger innovation results in significant jobs creation (Aubert-Tarby et al., 2018). The Population that has gained a Bachelor's degree is another crucial variable. As a matter of fact, it is more and more considered an important pillar of technological innovation and upgrade (Wu and Liu, 2020). In urban contexts, another variable that might support innovation is the Population Density, expressed by the ratio between the number of inhabitants and the squared kilometres of the area considered. In fact, higher densities might be related to higher inclination to undertake smart innovative programs aimed at dealing with the current urban open issues such as traffic congestions and environmental pollution control (Caragliu and De Bo, 2019). The absolute number of inhabitants is considered since for high populated cities there are typically more business opportunities for promoters and project investors in new technologies initiatives. Finally, the Private Credit is included because, as it is associated with the amount of financial resources provided by private investors, it represents a potential lever in supporting the development of innovative investments (De Marco and Mangano, 2013).

3.3 Empirical Analysis

First, the presence of multicollinearity among the independent predictors is investigated. This is performed through the computation of the Variance Inflation Factor (VIF). It evaluates the relationship between an independent variable and all the other ones and it is obtained as 1/(1-R2), where R2 is the coefficient of determination of one variable on all the others and it expresses the portion of variance related to the independent variable at issue that can be referred with the other independent ones considered in the study. Variable showing a VIF greater than 5 are discarded because the regression coefficient is poorly estimated (De Marco and Mangano, 2017). Table 1 shows that multicollinearity exists in the model because Foreign Private Investment has a high VIF. Thus, this predictor is removed to avoid multicollinearity as shown in the right side of the table.

Table 1: Multicollinearity in the model

Term	VIF	Final VIF
GDP	5.62	2.85
GDP Growth	1.75	1.72
GDP per Capita	4.7	4.57
Foreign Direct Investment	**10.79**	**-**
R&D Expenditure	3.02	3.02
Employment Rate	1.15	1.15
Population with Bachelor	3.88	3.83
Population Density	1.59	1.56

Urban Population	4.04	3.90
Private Credit	4.16	3.94

After the study of multicollinearity, the regression analysis is completed. This statistical model has been applied after a logarithm transformation of records in order to obtain their normal distribution.

4. Results

Table 2 shows the outcomes of the regression analysis. Columns reports for each independent factor the coefficient together with its standard error, the T-value, and the P-value.

Table 2: Results of the Regression Analysis

Term	Coef.	SE Coef.	T-Value	P-Value
Constant	7.32	1.47	4.97	0
GDP	0.000001	0.000001	2.03	0.045
GDP Growth	0.0044	0.08	0.05	0.956
GDP per Capita	0.000041	0.0000015	2.65	0.010
R&D Expenditure	-0.643	0.302	-2.13	0.036
Employment Rate	-0.0677	0.0188	-3.61	0.00001
Population with Bachelor	0.0023	0.0325	0.07	0.975
Population Density	-0.000174	0.000127	-1.36	0.176
Urban Population	-0.0359	0.165	-2.17	0.032
Private Credit	0.00587	0.00562	1.04	0.3

In particular, the P-value underlines that GDP, GDP per capita, the R&D Expenditure, the Employment Rate and the Urban Population are significant drivers for the investment in 4.0 technologies. These results indicate that the willingness of investing is facilitated in countries with higher level of national incomes. As a matter of fact, broad availability of financial resources is related to higher level of spending for goods with a related increase of logistics processes required. As a consequence, the investments in this field become more attractive. On the contrary, the expenditure in R&D negatively influences the investments in innovative technologies in CL. This result is not coherent with the expectations previously described. However, the negative relationship might be due to the fact that businesses and governments investing in research and development are inclined to apply innovative solutions in other countries, encouraged by lower costs or increased market opportunities. Additionally, the negative influence may be related to the circumstance that although CL 4.0 is a recent phenomenon, 4.0 technologies are more established in other sectors (*e.g.* manufacturing). Thus, it is possible to exploit the knowledge already acquired and adjust it to the new field of application. Therefore, public agencies and private promoters have already been investing in the past in developing these technologies in other contexts and now their attention is lower. In fact, the notion of CL and related applications are not homogeneous at an international level. Also the Employment rate is negatively related with the response variable. This means that urban contexts with lower rates of employment are more favourable environments to carry out innovative investments in CL. This might be due to the fact that governments are trying to support weaker economic areas via different form of incentives such as public subsidies to the investments, and this could make these business contexts more attractive for promoters. Innovative technologies are often capital-intensive based programs requiring significant investment costs. Therefore, it may happen that 4.0 solutions replace human resources, with consequent impacts on the employment rate. However, in the next future it is expected a creation of new jobs resulting from the exploitation of new technologies in the digitalization field. Finally, the Urban Population shows a negative impact on the investments. This result suggests that lower populated environments are more able to manage the tests for new technologies. For example, airborne Drones are currently successfully used in countryside areas. In fact, the level of complexity associated with high populated contexts make still not effective the delivery operations carried out with such solutions. Furthermore, small urban areas could be less developed in terms of infrastructures and thus the development of new projects is expected to be more relevant.

5. Implications and Conclusions

This work originates from the need of understanding the potential environmental factors that might drive the willingness to invest in 4.0 CL initiatives. To this end, a dataset of 105 projects is here presented based on the primary collection of urban CL projects exploiting the main 4.0 technologies. The technologies considered are Smartphone user applications, ICT, IoT, Cloud Computing, Big Data, Artificial Intelligence, Advanced Robotics, Blockchain, and Additive Manufacturing. The dataset revealed a broad diffusion of Smartphone user application, followed by a considerable implementation of ICT, Advanced Robotics, Artificial Intelligence, Cloud Computing, IoT and Big Data & Analytics projects. Additive Manufacturing and Blockchain seem to struggle in confirming their diffusion in urban contexts. This might depend on their quite relevant investment cost and operations costs. In particular, Blockchain requires heavy amount of energy for the related computation and huge spaces in powered servers. On the contrary, AM is still mainly related to the effects of parts production on supply chains. Thus, AM applications in urban context are still on their infancy. After that, an empirical regression model is completed in order to identify the main relationships among the level of investments in CL 4.0 programs and several contextual variables. The results show that level of economic development positively drives the implementation of new CL projects. On the contrary, the attention posed on R&D, the portion of working population and the size of urban areas in terms of number of inhabitants jeopardize the growth for 4.0 CL initiatives. Therefore, both theoretical and practical implications can be traced. From a theoretical perspective, the present work offers a preliminary overview of the main contextual variables affecting the engagement in CL innovations. As a matter of fact, most of the literature, is focused on analysing the operational and the financial feasibility aspects of CL projects. On the contrary, the proposed research might be a first attempt to initiate a stream of literature about the role of external variables in the spread of innovative project developed in the CL field. This is supported by a quantitative analysis carried out at an international level with different structural and geographic characteristics. From a practical point of view, the proposed analysis might support private promoters in figuring out suitable business areas wherein concentrating their efforts. At the same time, public agencies might exploit this work, in order to better understand their potential to foster new CL projects and in turn to more effectively identify more favourable business environments for carrying out investments in innovative technologies. As a consequence, this could also help both practitioners and policy makers in more properly designing strategies for the innovation in existing CL systems. However, this study suffers from some limitations. First, the combined effect of the contextual drivers taken into account, together with several operational variables of the private investors is not investigated. In addition, the level of success of the projects of the sample is not assessed. Thus, future studies will be addressed in analysing the effects of 4.0 CL projects in urban areas, by including internal business factors.

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