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Implementation of disruptive technologies for the last mile delivery efficiency achievement

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Abstract

The last mile delivery (LMD) is one of the most tangled procedures in logistics. The reason is that it involves various uncertainties, including weather and road conditions, traffic hours and route selection, car accidents, delivery vehicle anomalies, at the same time needing to avoid parcel damages and delivery errors, while communicating with the recipient of the parcel. Above-mentioned factors cause the difficulties of successful parcels delivery to customers' doorsteps. Therefore, businesses need to search for technology solutions that will enable increase of last mile delivery efficiency. All intelligent solutions are built upon big data, as huge volumes of data allow the prediction of future behavior based on historical knowledge. In this study we propose a last-mile solution where the combination of disruptive technologies allow a better distribution without costs increasing.

Keywords: Last mile delivery; Artificial Intelligence; Optimization; Internet of Things (IoT), Blockchain, Big Data;

1. Introduction

Currently, around 55% of the world's population are inhabitants of urban areas, and the trend is moving towards increase up to 68% by 2050 [1]. Covid-19 pandemic forced new e-commerce business models as a direct effect of social distancing measures in urban centres. Like this, new consumer behaviours and shopping habits were intensified [2], putting pressure on businesses to perform more efficient and fast deliveries.

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Last mile delivery (LMD) encompasses all logistical operations and refers to the final step of the process, when the goods are delivered to final customers/consumers doors [3]. The following general trends and challenges have caused LMD high relevance is coming from challenges like increasing volume of deliveries, sustainability concerns, costs, time pressures, and an aging of staff [4].

Sustainability issues are crucial to consider in LMD, thus policy makers are developing Sustainable Urban Mobility Plans (SUMP) and Sustainable Urban Logistics Plans (SULP). These initiatives are pushed by European Green Deal 2020 strategy, as well as the National Plan for Energy and Climate NECP 2030, which foresees a reduction of greenhouse gas emissions in 2030 between 45%-55% compared to 2005, and a 20% incorporation of renewable energy in transport [5,6]. Common causes of failures in LMD modes implementation include the lack of feasible business models, reliable information systems, data and freight availability. Most of current LMD logistics initiatives are not business driven, but rather technologically driven, with the focus on the technical, environmental, and operational feasibility [7]. Novel data sources (e.g. GPS, Mobile Network Data and Satellites etc.) are able to capture the whole travel of freight vehicles, which include complex routes connected by many stops, thus enabling an advanced freight modelling. Such models have been found to be behaviourally more robust than person travel demand models, as they enable explicit representation of distribution centres, warehouses and intermodal facilities, which are used by more than half of all trucks [8]. Therefore, LMD solutions require an integrated modelling approach to counterbalance sustainable city logistics solutions, which are usually challenging, as they need public acceptability from stakeholders to achieve the desired impact [9].

Currently, urban and national policy-makers are introducing more strict policies to take an action on climate change and air pollution, restricting usage of old, polluting vehicles in favour of more sustainable alternatives. New modes of transport promise a reduction in the number of motorized vehicles, however, impact from the deployment of cargo bikes, electric vans and automated vehicles and their role in the supply chain (SC) is still unclear, as well as their limitations in respect to the topology of the city, weather and seasonality [10]. For instance, cargo bikes have been tested as suitable sustainable solutions for urban deliveries across Europe, successfully substituting cars, especially considering navigation on narrow roads and delivery of parcels in historic centres [11]. Like this, it is important to keep experimenting with various innovations towards LMD.

Therefore, the current challenge of urban planners is to find solutions that are able to reduce the impacts of urban mobility of goods without penalizing the normal life of the citizens. With a view to address the above issues in the context of city planning, the European Commission promotes the concept of sustainable urban mobility, supporting guidelines for developing Sustainable Urban Mobility Plans (SUMP) [12]. According to the SUMP approach, the guidelines for developing and implementing Sustainable Urban Logistics Plans (SULPs) were defined within the research project called ENCLOSE (Energy Efficiency in city logistics services for small and mid-sized European historic towns) [13].

This study is contributing on systematizing literature in the field of LMD and disruptive technologies that are being used to solve current challenges of efficient deliveries. Moreover, this study proposes a decentralized model for LMD, based on the example of Lisbon city, where using a combination of disruptive technologies may bring a solution to urban environments.

2. Last Mile Delivery Process

Sustainability

Increasing urban parcel demands imply a higher number of delivery vans entering the city centres, which burdens the existing infrastructure, and brings negative impacts on health and safety of citizens. Consequently, increasing customer awareness and novel governmental legislation enforce courier services to intensify the efforts for sustainable and environment-friendly operations [14]. Example of public policies directly impacting LMD could be found in such as British Columbia, which allows (single-person) electric vehicles on their high-occupancy vehicle (HOV) lanes, which are normally reserved for cars with multiple occupants [15]. Such a policy could be an incentive for courier services to electrify their delivery fleet in order to access urban areas faster via uncongested HOV lanes.

Costs

Traditional home deliveries performed by vans are costly and price increase from 2 to 6 euros depending on customer density[16.]. Important drivers for high costs are traffic jams and missing parking spaces in congested streets as well as customers not available at homes to receive parcels. [17] state that first-time delivery failures reported by courier services lie between 12 and 60% for different regions of the world. Thus, delivery concepts allowing an unattended delivery or customer self-services are a promising alternative to lower total costs.

Time pressure

The increasing volumes of parcel deliveries are mainly triggered by increased e-commerce activities in the last years. Most online retailers made next- or even same-day deliveries as one of their basic service promises, so LMD face tight deadlines and considerable time pressure. Moreover, online deliveries vary over the week, with Mondays typically having peak workloads, and over the year having peaks during seasonal sales[18]. Thus, LMD face strongly varying workloads, and new concepts are required for easier scalability on short notice.

Aging workforce

The aging workforce in many industrialized countries enlarges the problem of employers hiring the required manpower, especially in a physically demanding environment such as parcel delivery, with harsh occupational conditions and low payments. Right now, the delivery person handing over a parcel is generally the only human interaction for e-commerce customers, the performance of which influences heavily on customer satisfaction for both online retailers and courier services. In such a work environment, alternative delivery concepts less dependent on human work seem as a promising alternative for the future. Given these challenges, LMD solutions are arising, such as autonomous driving, drones, and delivery robots, which have potential to bring efficiency and increase customer experience.

Blockchain application

As is the case with other stages of logistics, LMD are often delayed due to a lack of Proof-of-Delivery documentation (PoD). This results in issues, such as payment and invoice settlement delays. Blockchain technology (BCT) has the potential to assist in resolving such issues by establishing a decentralized platform – basically a digital ledger – on which each transaction is recorded and accessible to all parties. While BCT is still in its infancy stage, its usage in the LMD would allow quicker, more transparent and secure transactions. Bringing numerous contractors together on a single, standardized platform would help improving visibility at each step of the delivery process and give real-time updates access to consumers.

3. Literature Review

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) technique [19] was used to perform a systematic literature review with the following research question: “What is the current level of knowledge of using disruptive technologies to optimize the delivery process efficiency in the context of last mile Delivery?”.

We have conducted our search on Scopus and Web of Science (WoS) academic databases during the period of February 2022. The results limited to peer-reviewed articles only, published between 2012 and 2022, written in English or Portuguese. The search technique was based on a single query in both databases. The title and abstract were used to make the first selection of articles, and in certain situations when that information was insufficient, the whole text was examined.

After performing a manual process, towards the identification of significant subjects on their research questions, identifying the outcomes and removing the duplicates, 46 documents were obtained. Figure 1 shows the PRISMA workflow diagram for the articles selection process.

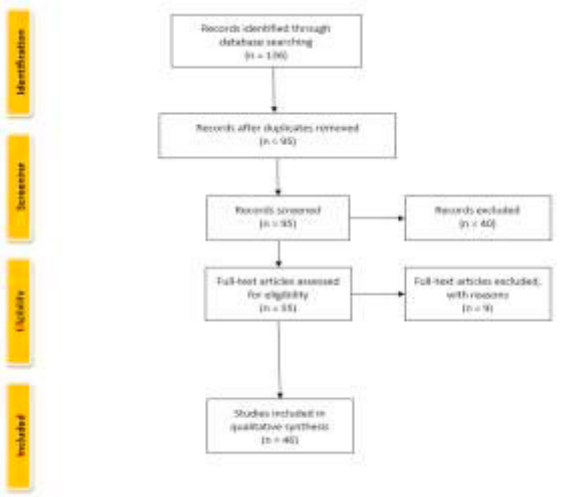

Fig. 1. Prisma methodology implemented for articles identification

A more detailed analysis of the review is summarized in Table 1, which reveals the topics mentioned in extant literature under context of LMD.

Table 1. Prisma methodology implemented for articles identification

Topic	References	№ of Documents
Sustainability	[20]–[45]	25
City / Urban Logistics	[21]–[23], [26], [28], [35], [37], [38], [40], [42], [44], [45], [50]	24
Transport System	[20]–[22], [26]–[28], [30], [32]–[34], [37], [38], [44], [47], [48], [53], [54], [56]	20
E-Commerce	[21], [22], [24], [31], [37], [39], [40], [44], [47]	9
Pick-up points	[21], [35], [44], [47]	4
Supply Chain	[25], [29], [36], [52]	4
Artificial Intelligence (AI) / Data Mining	[27], [29]	2
Smart Cities / Intelligent transportation system	[27], [35], [42], [45]	1
B2B/B2C	[35]	2
Blockchain	[36], [52]	2
Home / Urban Delivery	[21], [32], [37], [53]	4
IoT	[50]	1
Decision Support System	[42], [43]	2

4. Analysis

After assessing all the selected articles, the growing number of LMD studies across the globe in the recent years is becoming vivid. From the most popular topic, authors from [20]–[22], [26]–[28], [30], [32]–[34], [36]–[38], [44], claim that sustainability can be achieve by focusing mostly on the transport system, or by changing the paradigm. On study [21] the best location for pick-up point is analysed. For the pick-up points, is where the paradigm is changing, and authors are looking for alternative solutions. [22] proposes the metro stations to collect the parcels, [44] intends to reuse journal kiosks, [51] looks for commercial establishments for pick-up points. On data analytics, [47] tries to find the most sustainable pick-points through an analysis of the delivery performance and CO2 levels. To achieve sustainability, a common solution for Electric Vehicles is being proposed in [32, 33], cargo bikes are being suggested in [34] to achieve sustainable performance. Regarding BCT and transportation systems, [36] focuses on the installation of a BCT-enabled fleet sharing system to optimize drone operations.

In line with extant literature analyzed, we revealed a lack of studies on the topic of optimization of LMD processes through AI. In [53], authors look at how companies can use AI to improve SC resilience by strengthening visibility,

risk, sourcing, and distribution capabilities. Researchers on [29] present a unique data-and-model-driven approach for urban distribution decision-making, making the most efficient use of resources through combination of optimization, simulation models and machine learning (ML). Using Data Mining techniques authors in [53] suggest a novel method for optimization of e-grocery home delivery using customer-related data, which can reduce up to 3-20% of the total travel distance. [27] proposes an innovative and successful LMD package delivery method based on vehicle trip sharing, using available private automobile journeys to deliver parcels as they travel, based on method that predicts each road segment's journey time and fuel usage, taking into account not just traffic circumstances, but also different drivers' car fuel efficiency and personal skills.

By developing a decision support system (DSS) that allows assessing and comparing multiple scenarios, [48] presents a unique parcel delivery concept for LMD operations and build an optimization model to assist tactical planning choices. In [42] synergies and conflicts of economic implications of green vehicle adoption are discovered, proposing a simulation-optimization DSS tool for evaluation of mixed-fleet strategies for package delivery. Combining DSS and sustainability, [43] presents a sophisticated decision-making strategy for long-term LMD establishment.

5. LMD Collaborative Process

In this study, we develop and test a solution that allows the City Council to manage the process of loading and unloading (temporal and spatial management), visualizing the whole process of deliveries (real-time monitoring data of transport in the city). This solution would eventually reduce traffic in urban centres and the CO2 emissions. However, there are several challenges that need to be considered: (a) there are multiple entities and various sources of information, both local and central; (b) the high volume of data; (c) difficulties in standardizing information, hence difficulties to benchmark various agents in the sector; (d) lack of technological solutions availability in some regions.

The solution proposed in this study is built upon a centralized database with collection, processing and organized representation of the information. It foresees the availability of visual and intuitive indicators, as well as comparative and evolution analysis. It is, therefore possible to evaluate the permanent evolution of data models, with the creation of new metrics that will allow new perspectives of analysis - greater control and monitoring of activity and different layers of information according to the level of security. Data models would as well be based on automatic predictive capacity on the data (AI / ML), being able to identify trends, gaps and improvements in scalability to the universe of data / sources.

Figure 2 shows the functional architecture of the multidimensional model and respective dimensions of analysis directed to cities and transporters, operating in the urban environment in a smart city logic. In this architecture, we are seeing: (i) Collaborative solution for operators, which allows real-time management operations spatial analysis, visualization and exploration of information integrating logistics operation information systems; and (ii) Collaborative solution for municipalities, in real time - spatial analysis, visualization and exploration of information. With the availability of transport information to the Municipality (transport position within the city) and from the Municipality of Lisbon to the transporters (traffic information, reservation of unloading places), it is intended to contribute to the development of a new concept integrated with the various actors of the LMD value-chain. With this solution it would be possible to test new value-added services and reduce delivery lead-times. A study of requirements for usability of e-cargo bike deliveries in Lisbon was done using cargo bikes and electric vehicles, including home deliveries, store replenishment and reverse logistics.

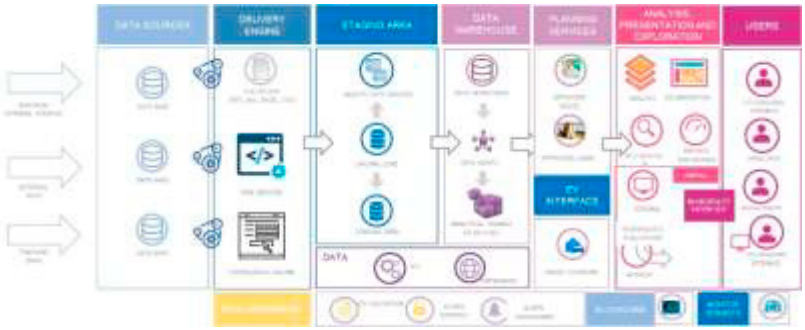

Fig. 2. Platform Architecture Proposal

The combination of edge computing and AI gives a new approach of Edge Intelligence needs for LMD process at distribution vehicles. If integrated with warehouse data, this solution would allow the implementation of several services to reduce cost of LMD, otpimize loads and routes, identify and predict behaviour patterns over past data. BCT-based platform would introduce security, traceability and interoperability among data.

6. Conclusions

New technologies endorse LMD operations on several dimensions of sustainability, including economic, environmental, and social aspects. The deployment of cutting-edge technology, innovations, and new business models requires a balance of open/closed, free/charged, and cooperation/competition solutions. These choices affect the extent and timing of the deployment of new technologies and business models, the scale and sustainability of the ecosystem, and the platform's potential to produce and utilize network effects.

These interactions become more significant in large-scale network systems. These sectors are defined by their reliance on a network technology framework. The adoption of new technologies by businesses adds value and competitiveness, when compared to competitors. When investments in technology align with the company's strategic goal, the circumstances for impacting performance and overall productivity - competitive advantage would be reached.

AI-based technologies are proven to be beneficial in LMD, as they optimize the whole delivery process, streamlining the delivery of items to clients and thus, saving money. Given the ever-increasing needs of consumers for order fulfilment, this tendency is projected to continue. However, the issue is how long will human involvement be required in such technologies. In some areas, it is predicted that workers would lose employment as a result of the advent of new technology, most notably artificial intelligence. The question is – would it happen with logistics? In principle, one may argue that although AI-based technologies simplify and streamline a variety of LMD tasks and processes, they also represent a danger to the employment of those workers, whose activities can be automated.

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