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Improving Last Mile Delivery Efficiency with Advanced Machine Learning Models

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ABSTRACT

Because of its wide range of applications and possibilities, artificial intelligence (AI) is becoming more and more significant in many sectors. Particularly in logistics, rising consumer expectations and rising cargo quantities are making it more difficult to predict delivery timeframes, particularly for the last mile. Efficient delivery systems increasingly need third-party logistics, which allows businesses to buy carrier services rather than a costly fleet of vehicles. Attended Home Delivery, the most popular e-commerce business model, is the most costly and time-consuming when a small delivery window is mutually agreed upon with the consumer, reducing potential and maximising flexibility. However, last-mile logistics is evolving as choices need to be made instantly. Due to its complexity, the last-mile delivery phase—the last step in which items travel from a distribution centre to customers—faces considerable inefficiencies and high prices. New developments in Edge AI, also known as Edge Intelligence (EI), provide encouraging answers to these problems. This research investigates how EI, real-time data processing, and AI-driven technology might improve last-mile delivery operations. A comprehensive literature analysis was carried out to evaluate technical developments, and the effect of EI solutions on operational efficiency and customer satisfaction was systematically and experimentally evaluated using the Delphi technique. Despite the significant advantages of EI technology, EU businesses are reluctant to embrace these advancements because of the hefty implementation costs. Businesses who have used these technologies, however, claim significant gains, such as improved service dependability, shortened delivery times, and better route optimisation. These results emphasise the need of hiring professionals with advanced degrees and fostering an innovative culture in order to propel technical improvement in last-mile logistics. An important step towards last-mile delivery systems that are more effective, economical, and customer-focused is the integration of EI. Subsequent studies have to focus on improving these technologies and investigating their long-term effects on the logistics sector.

Keywords: -Artificial Intelligence (AI), Customer Satisfaction,Last-Mile Logistics, Logistics Industry, Logistics Industry, Cost-Effective, Edge Intelligence (EI), Delivery Systems, Technological Advancements, Optimizing Flexibility.

INTRODUCTION

The travel of the package from the last delivery base to the ultimate destination, or last-mile delivery, presents a unique logistical problem [1]. This segment of the supply chain is thought to be among the most costly and challenging to organise. The variety of delivery circumstances, pertinent characteristics, and the increasing sway of a package's destination are all challenging issues. These days, for instance, [1, 2], the receivers would want to specify that they are available for a cargo to be delivered to a preferred neighbour or at a preferred hour. The final mile incurs the largest portion of delivery expenses when a receiver is not present. Inaccurate delivery time forecasts often result in the absence of a recipient. Using the First-Time Hit Rate (FTHR), the failure delivery scenario [2, 3]. The average number of successful delivery attempts to recipients is shown by this percentage rate. This rate is unavoidably low in the absence of more precise last-mile data [3].

To reach the required degree of efficiency and protect against the risks arising from real-world unpredictability, a number of management solutions have been created [3, 4]. Third-party logistics (3PL), which is the practice of an organisation employing third-party companies to outsource aspects of distribution, storage, and/or fulfilment services, is the most significant [3, 4]. The benefit of using 3PL is that fleet expenditure may be decreased without sacrificing service quality. The use of 3PL for logistical activities is the main emphasis of our study; specifically, we look at a business that rents containers from a third-party logistics provider in order to convey commodities [4]. Securing long-term distance contracts with the carriers is a real-world example of such a choice [4, 5]. The main choice in this situation has to do with how many bins to reserve for transit. Uncertainty about demand and potential supply delays have a significant impact on this choice [5]. Consequently, a number of stochastic models have been created by academics to aid with decision-making. The Variable Cost and Size Bin Packing problem with Stochastic Items (VCSBPPSI) is the most pertinent of them. A two-stage stochastic optimisation issue with a tactical and an operational phase is examined.

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Our present research is motivated by this growing commercial requirement. Accurate delivery time prediction is necessary to improve supply chain process planning and prevent excessive expenses [5, 6]. Our study examines how Artificial Intelligence (AI) and Machine Learning may be used to forecast a shipment's delivery time at the last stage of the supply chain, taking into account the technology's present significance and potential [6, 7]. A matching process and information system architecture was also created by us. We provide a broad framework for last-mile logistics in order to achieve this [4, 6].

A company's success is determined on how satisfied its customers are; it costs more to lose a devoted client than it does to attempt to get a new one. As a result, businesses have been attempting to stay ahead of the competition by innovating and providing solutions for issues that rapidly worsen [6]. In particular, consumers are choosing to purchase things online due to the e-commerce sector and the rapid advancement of technology. Due in large part to online mobile buying, e-commerce has expanded five times faster than retail commerce [6, 7]. Organisations are compelled by this need to implement an Omni channel strategy that expedites product delivery and enables online sales. But with e-commerce, what does "customer satisfaction" mean? What must a business do to be successful in the sector? The following assertion may be found in the book Approximate Dynamic Programming for Dynamic Vehicle Routing [7]:

"LSP (Logistic Service Provider) parameters are … shifting. Specifically, shippers' and consumers' expectations are rising. [...] Customers and shippers, on the one hand, want services that are affordable [5, 8]. However, they anticipate dependable and quick services. LSPs must take constraints and criteria into account in order to provide dependable services and maintain the loyalty of their clients".

From known deterministic information, like the number of customers to visit, to stochastic information, like new orders, same-day delivery, [5], shifting traffic patterns, weather changes, etc., these conditions and requirements can take many forms. According to a survey, customers regard the quality of online information and online services as two of the most crucial aspects of online buying [5, 6]. They contend that these qualities must be included into their website, rules, and plans in order for the company to be sustainable [6].

Channel Modelling for Last Mile

Using LAP for connectivity Despite their many advantages, such as their capacity to provide a regional footprint and their extended deployment durability [6, 7], HAPs are still a costly choice when it comes to wireless communications delivery in distant locations. Because LAPs can cover a large area with a radius of tens of kilometres fairly quickly [6], depending on configuration and communication payloads [6, 7], they are therefore preferred for providing dynamic and scalable networks in the event of short-term large-scale events or during and immediately after natural disasters. Whether they are tethered platforms that rely on ultra-strong but lightweight tethers for power and communications, or autonomous solar-powered airships, LAPs can be deployed up to a maximum height of 5 km above the earth. The six main criteria that are said to influence last mile connection with LAPs are highlighted in the ensuing subsections, as shown in Figure 1 [5, 7].

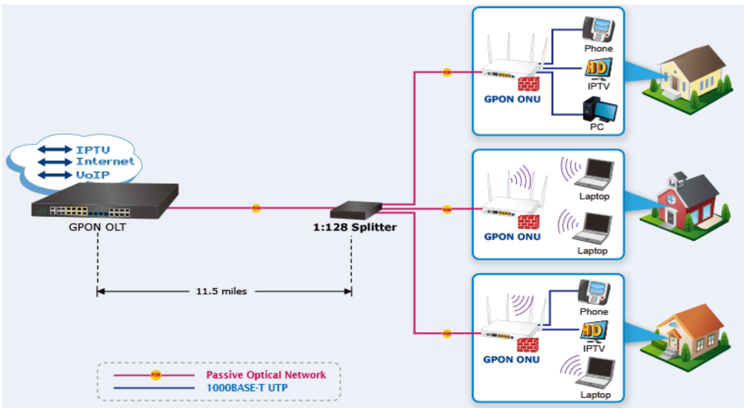

Fig. 1 Last mile connectivity issues with using LAP. [11]

Customers will always choose the best choice, which is typically the fastest and most dependable service, and the sector is expanding quickly for both B2B and B2C e-commerce businesses.

This presents a significant problem for management. In particular, last-mile delivery is driven to provide high-quality service, which often results in low truck utilisation and service duplication [11, 13]. As a result, they enumerate the difficulties that last-mile delivery providers encounter, including;

(1) Demand trends and peak periods, when operations are driven almost to the breaking point;
(2) Businesses that optimise fast reduce the time between placing orders and receiving the goods; [10],
(3) Time limitations and constraints that are too complicated for the provider to provide high-quality service; [11,12],
(4) Delivery failures for residential addresses;
(5) High return rate as a result of unsuccessful efforts to address the issues raised; and
(6) Insufficient logistics to meet the demand pace, including distribution centres, funding, [12], cars, drivers, etc.

Weather and historical traffic data can be used to estimate traffic, however the accuracy is not high enough for more residential regions. Furthermore, traffic sensors are mostly located on highways and motorways, where most accidents occur because of the higher speed restrictions, and are not often put in urban areas owing to their expensive cost [12,13]. This presents another financial hurdle for ITS. Therefore, independent of the delivery location, logistic enterprises still need a framework that can be utilised for successful traffic forecast and won't interfere with ITS intended resources [11]. Online shopping is rapidly expanding because it allows consumers to avoid lugging products to their homes and travel to stores [12, 13]. The online shop is available twenty-four hours a day, and customers may choose the optimal time for delivery [13, 15]. On the other hand, every advantage for the client has unique difficulties in achieving effective and efficient logistics, where the sustainable side impact must also be taken into account. Greenhouse gas emissions (such as CO_2), traffic jams, accidents, noise pollution, and direct impacts on human health and the quality of urban life are some of the detrimental effects on the environmental and social aspects of sustainability.

Although traffic may be estimated using weather and historical traffic data, the precision is insufficient for more residential areas. Additionally, due to their high cost, traffic sensors are seldom installed in urban areas; instead, they are mostly found on highways and motorways, where the majority of accidents occur due to the stricter speed limits [12,13]. For IT'S, this poses yet another financial challenge. Therefore, logistic companies still need a framework that can be used for effective traffic forecasting and won't interfere with ITS targeted resources, regardless of the delivery location [11]. Because it eliminates the need for customers to go to shops and haul items to their homes, online shopping is growing quickly [12,13]. Customers may choose the best time for delivery from the online store, which is open twenty-four hours a day [13, 15]. However, every benefit for the customer comes with its own set of challenges in creating efficient and successful logistics, where the long-term effects must also be considered. Some of the negative repercussions on the environmental and social elements of sustainability include greenhouse gas emissions (such CO_2), traffic congestion, accidents, noise pollution, and direct effects on human health and the standard of living in cities.

Numerous topics discussed in the environmental dimension, such as creative depot stations where goods can be stored when customers are not at home until they can pick them up, collaborative and cooperative urban logistics where resources are shared between various LML actors, and innovative vehicles like electric vehicles and drones, are frequently linked to the support of advanced decision systems that use real-time data optimisation techniques and prediction methods [14]. Various factors are used to assess the external and operational expenses of delivery in Antwerp using vans vs e-bikes [15, 16]. They made use of driver labour expenses, external pollution costs for emissions, noise, congestion, and vehicle attributes such as capacity limit, operation charge, driving speed, and average time per delivery [11]. Improving sustainability requires a deeper understanding of the final mile. Growing urbanisation, the sharing economy, the growth of e-commerce, consumer demand for faster delivery, and heightened awareness of sustainability are the primary forces behind city logistics [11, 12].

Attended Home Delivery with Time Window and Time Slot

As the most difficult aspect of last-mile logistics, attended home delivery, or AHD, is now the most popular business model in e-commerce [13]. A time window (TW) is a period of time that an action may or must take place in. It refers to the time frame in which a cargo is delivered or picked up in the logistics industry [13, 14]. A time slot (TS) is a period of time designated on a schedule or agenda during which an event may occur or is scheduled to occur [13, 14], particularly if it is one of many potential times. Typically, the time frame is made up of many time periods. While time slots have a set duration, time windows change based on the task being done. A time frame often comprises many time periods [14].

Machine Learning Forecast

Real-time creation or computation of a viable offer, even if achieving the "absolute optimum" is an NP-hard issue—a task that cannot be solved in polynomial time. To extract potential TW, an accurate method should identify all feasible route combinations and permutations and compare them [14]. Therefore, creating a "near optimal" solution using a machine learning prediction is an additional approach that may be used. The study of techniques that enable computer systems to learn from experience and automatically deduce general rules from particular data is known as machine learning. Machine learning is a crucial part of the expanding area of data science [15], as later understood [14, 15]. In data mining projects, algorithms are trained using statistical techniques to create predictions or classifications and to reveal important information. For predictive analysis, a variety of learning techniques and algorithms might be used. When a model is specifically trained on historical data and then used to forecast the target variable, supervised learning techniques are appropriate [16].

Using various data mining techniques to extract the meaning variables, the objective of the modelling phase is to learn about the predicted behaviour from the past data [16, 17].

METHODS

This study uses two qualitative typology methodologies as part of a multi-method approach. The first approach is a systematic literature review (SLR), which makes use of two well-known scientific databases: the US Clarivate Web of Science (WoS) Core Collection and the EU Elsevier Scopus.

These databases were selected because of their abstracts, citations, source-neutral collections, and independent subject matter experts who are acknowledged leaders in their domains [16, 17]. Because Google Scholar and other academic search engines do not guarantee blind peer review, they were omitted [16, 17]. We utilised the phrases "Edge Intelligence" or "Edge Artificial Intelligence" and "Logistics" in the paper Title, Abstract, and Keywords (Topic in WoS) [16] for our searches, which were carried out on July 7, 2024.

Table 1 State-of-the-art of EI in Logistics

Data base	Documents Types	Documents Title	Source	Year	Ref.
Scopus WoS	Journal Article	Delivery route planning was enhanced by edge intelligence to handle changes in an unpredictable supply chain environment.	Journal of Cloud Computing	2024	**[31]**
Scopus WoS	Journal Article	Using block chain to secure clustered edge intelligence.	IEEE Consumer Electronics Magazine	2022	**[22]**
Scopus	Conference Paper	Temporal Encoders for Neuromorphic Keyword Detection with Few Neurones: A Comparison.	International Joint Conference on Neural Networks	2023	**[26]**
Scopus	Conference Paper	Investigation of Edge Intelligence-Based Fast Adaptive Transmission Models for International Inland Ports.	International conferences on Cyber Security and Cloud Computing	2023	**[11]**
Scopus	Journal Article	The architecture, developments, and difficulties of edge computing in the industrial Internet of things.	Computational and structural Biotechnology Journal	2024	**[29]**
Scopus	Conferences Paper	IoT-Powered Drones: A Machine Learning-Based Intelligent Cybersecurity Framework.	International Conferences on New Frontiers	2023	**[30]**

The two most popular and globally renowned scientific databases include very few papers on this subject, according to an initial examination [17, 18]. In particular, the topic is very fresh, since the most current publication was published in 2020. A substantial interest in journals and the need for more thorough academic and scientific debate on this subject are shown by the fact that 64% of the recognised manuscripts are scientific articles and 36% are conference papers [18].

The Delphi technique is the second strategy we used. The main purpose of this approach was to verify the technical developments noted in the literature study. Using this approach, a pre-selected group of specialists was consulted [18].

A sample of different businesses operating in Portugal, a member of the European Union (EU), as well as global corporations from a variety of industries, including the automotive sector, the electrical grid, healthcare, multinational technology conglomerates, and retail, were included in the broad data collection [18, 19].

Additionally, it was focused, with the goal of obtaining opinions from highly qualified people who were knowledgeable in both management logistics and IT [20]. Seven of the 28 experts who were contacted to participate responded and agreed to be included in the research. Refer to Table 2 for more information [19, 20].

Table 2 Element of the Delphi Study

ID	Job Title	Company	Rounds
P1	IT support specialist	Multinational Automotive Company (A)	5
P2	Director of Logistics	National electric Grid Company (B)	4
P3	Chief Technology Officer	National Health Company (C) Multinational Technology Conglomerate (D)	2
P4	Head of IT		1
P5	Director of Logistics	Multinational Retailer (E)	2
P6	IT Director/IT Manager		1
P7	Director of Logistics		2

RESULTS

This section is organised into three main sections, as previously mentioned. First, we define emotional intelligence (EI) in the particular context of management and business [20, 21]. Following the establishment of this concept, we examine how Emotional Intelligence (EI) affects Last-Mile Delivery logistical, examining how EI might enhance these logistical procedures and resolving theoretically contentious areas [22]. A summary that summarises the key conclusions and ramifications of our investigation concludes this section [22, 23].

EI Broad Conceptualization

We realised the significance of briefly conceptualising EI before moving on to the fundamental examination of the findings [23]. In order to do this, on July 7, 2024, we searched Scopus using the phrases "Edge Intelligence" or "Edge Artificial Intelligence" in the publications' titles, abstracts, and keywords [24]. In general, we found that the number of articles on EI increased exponentially between 2017 and 2024 [24, 25]. With 915 manuscripts, the PRC is in first place, followed by the USA (357), and India (217). The PRC and the US are quite different from one another. Although EU research tends to concentrate on the national interests and particular concerns pertinent to each member state, EU nations show statistics comparable to the US [25]. With notable contributions from engineering (26%) and mathematics (7%), computer science accounts for 41% of the recognised articles [26, 27]. This suggests a comparatively low level of interest in the business and management sector (1%), with a high emphasis on applied sciences. Journal articles make up 52% of publications, [27], while conference papers make up 35%. Table 3. Since the "Business, Management, and Accounting" domain is the most relevant to our study, we utilised scholarly publications from English-language journals to conceptualise the EI term [28]. 14 scholarly papers were found by this search.

Tables 3 Conceptualisation of Emotional Intelligence in Business and Management Domains

Author (S)	Definition (S)
[1]	"Edge Intelligence is a methodology where the embedded processor connected to the device's actuator and sensors processes the AI algorithm's prediction for a faster response by the architecture."
[22]	Edge AI brings processing and computational duties closer to the point of contact with the end-user, whether that be a smartphone, single board computer (SBC), home appliance, Internet of Things device, or edge server. Edge AI is defined as the local processing of AI algorithms on edge devices.
[3]	A new paradigm called fog computing, also known as edge computing, has been proposed to reduce bandwidth requirements and provide real-time, low-latency applications. By allowing calculations to be performed at the sensors and devices that generate and respond to IoT data, the fog nodes allow the cloud to reach closer to the edge.
[19]	"A favourable paradigm for facilitating efficient and immediate data processing at the network's edge is edge intelligence (…)." With the goal of redefining and changing the parameters of data analytics and decision-making, Edge Intelligence has become a crucial computational paradigm.
[15]	"A novel paradigm called fog computing brings computing resources closer to end users by extending the capabilities of cloud computing to the network's edge."
[30]	"The Internet of Things (IoT) revolution has advanced towards next-generation operational efficiency and huge connectivity thanks to intelligent edge (...) Edge intelligence (EI), which combines edge computing with artificial intelligence (AI), enables the deployment of machine learning algorithms to the edge.

EI in Enhancing Last-Mile Delivery Logistics

We were able to examine EI technologies and their effects on Last-Mile Delivery Logistics by extracting pertinent material from seven of the eleven publications that were chosen [29]. Table 4 makes it clear that last-mile delivery is being revolutionised by the confluence of developing technologies [30]. Improvements in risk mitigation, speed, and prediction characterise this shift. A review of the literature reveals that these developments are being driven by physical networks of things, like UAVs, as well as technology that are integrated with sensors, complex software, and algorithms. The combination of IoT, EC, [22, 29], AI, and blockchain has been one of the most significant developments. When combined, these technologies allow for very accurate forecasts that support in-the-moment decision-making. Consequently, last-mile delivery accuracy and dependability have been significantly improved by integrated systems that combine these technologies with tangible items [29].

Empirical Validation

We examined new technologies found in the literature and their implications for the last stage of logistics in the Delphi Study [30, 31]. We were unable to thoroughly investigate the whole technical spectrum shown in Table 4 because to the small number of businesses in a single EU nation, and they are now being investigated in the PRC and the USA. It is doubtful that we would have come close to the degree of progress seen in the PRC and the USA, even if we had tried a more comprehensive examination [31, 32]. This is mostly due to two factors. First off, compared to these two nations, the EU has far less research in this area. Second, [32] the US and PRC's strategies may not necessarily be the same as the EU's. The generalisability of our study results is challenged by this constraint [32]. However, the focus of our research was on a few technologies that are actively changing Portugal's commercial and industrial processes. According to Table 4, our research shows that businesses agree that the technologies listed below have a major influence on the logistics industry, which supports the applicability of the subject matter covered in this article [33].

Table 4 The Delphi Study's Findings on EI Technologies and Their Effects on the Last Mile.

ID-Company	Technologies	Consensus	Participants Comments (Samples)
P1-A	IoT-edge-AI-block chain	86%	"In my perspective, the IoT-edge-AI-blockchain technology can significantly enhance forecasting abilities and runtime efficiency, therefore enhancing overall logistics" . The IT professional claims that Company A gathers data in real time by using IoT sensors in linked cars. Edge Intelligence helps by supplying data in real time. Blockchain integration is being worked on to handle transactions between cars and infrastructure and guarantee the security of vehicle data.
P2-A	IoT-edge-AI-blockchain	80%	"Our consumers' mobile phones are equipped with a gadget that links to our company's application. This enables us to access data from our clients' cars over the internet. We make judgements downstream, whereas EI evaluates the data at the source. Practically speaking, the EI enhanced resource allocation and demand forecasting. We are still in the early stages of a blockchain project, which I think is fascinating, but there is still a lot of work to be done in that area.
P3-B	IoT-edge-AI-blockchain	79%	"We can now analyse data at the source, optimising electricity generation and anticipating breakdowns thanks to IoT-edge-AI integration. We use sensors to keep an eye on solar panels and wind turbines. Even though Company B simply intends to include blockchain, they understand that this technology may be used to develop a decentralised energy management system that safely and openly records energy output and consumption.
P4-C	IoT-edge-AI-blockchain	85%	"Especially in our industry, the integrated system greatly improves logistical accuracy and efficiency. To make the systems we use better, some of our colleagues carry out scientific study. In practice, we use IoT devices to remotely monitor our patients. Blockchain controls access and protects critical data, while Edge Intelligence offers real-time analytics and alarms. This company's technological development was shown by a number of instances. Using Edge Intelligence, which processes data locally rather than sending it to a central server, is one example. By lowering latency, this method allows healthcare practitioners to use the Internet of Things (IoT) to make decisions more quickly and get real-time notifications. For example, advanced AI algorithms enable a smart insulin pump to continually monitor blood glucose levels and modify insulin dosage in real time. Additionally, by monitoring and confirming medical information, blockchain technology is essential to preserving data integrity

			and access control.
P7-E	Mixed-integer Programming model & Cloud-edge collaborative mode	79%	Our business has a varied network of supermarkets, clothes shops, and shopping malls, making it one of Portugal's biggest retailers. We can examine real-time data from a variety of sources, such as traffic, weather, and product availability, thanks to the EI application. This makes it possible to modify delivery routes on the fly, increasing efficiency. Unexpected shifts in product demand across several shops are another difficulty we encounter, although they are very precise and controllable.
P1-A	IoT-edge-AI-blockchain	93%	"By using IoT and edge AI to monitor energy systems, we have improved performance and increased the accuracy of our equipment breakdown predictions. The next development in energy management system security and decentralisation is blockchain. We discovered that blockchain is an area that requires further research in the organisations we examined. Nonetheless, most businesses agree that IoT-edge-AI has brought about significant and disruptive developments. Without this technology, Company A and Company B would not be able to more quickly and precisely estimate demands, which would allow for more resource allocation in record time.

The improvement of predictability is one important effect of EI (IoT-edge-AI) technologies on Last-Mile Delivery at Company A, as shown in the above table [34]. This development has resulted in shorter delivery times and lower expenses related to accumulated inventory. The business uses Internet of Things sensors to gather data in real time, which is then analysed instantly using EI technologies [34, 35]. The integration of IoT and cutting-edge AI technologies has already produced significant improvements in operational efficiency, cost reduction, and customer satisfaction, even though the block chain initiative for vehicle data security and transactions management is still in the exploratory stage [35].

For dynamic delivery route modifications, Company E used a cloud collaboration mode in conjunction with a mixed integer programming model [36]. This method has allowed for quicker route modifications, decreased delivery costs and times, and enhanced predictive capabilities. Our study is summarised in Table 5, which highlights the EI technologies we looked at and how they affect last-mile logistics [36, 37].

Table 5 The Effects of Emotional Intelligence Technologies on the Last-Mile-Combined Summary.

Technology	Impact on Last-Mile Delivery
IoT-edge-AI-block chain	Increases runtime economy and predictive power. Lowers business expenses and delivery delays. Enhances resource allocation and demand predictions. Boost client happiness while cutting expenses.
EC in IIoT	Makes choices and takes action based on predetermined standards. Reduces downtime and latency. Cut expenses.
Mixed-integer Programming model & Cloud-edge Collaborative Mode	Make judgements and route changes more quickly.

DISCUSSION

Theoretical Contributions

This study adds to the theoretical knowledge of emotional intelligence in a number of ways [37]. First of all, it broadens the scope of EI by integrating it with last-mile logistics, an area that has received little attention in relation to EI. Second, the analysis shows that businesses in the European Union are still reluctant to completely adopt EI, even in the face of significant progress made by the US and the PRC [37, 38].

The major causes of this hesitancy are worries about the high expenses of adoption and upkeep. Our study specifically shows that Portuguese SMEs have significant obstacles when it comes to implementing these technologies because of a lack of funding and experience [35].

Managerial Contributions

From a management standpoint, this research offers useful information to logistics managers across a range of industries, such as retail, healthcare, and automotive [34]. By cutting delivery times, allocating resources optimally, and raising customer satisfaction, the results demonstrate how EI may greatly improve last-mile delivery performance [37]. Despite the need for large upfront investments in financial and human resources, managers may use these findings to use EI technologies like IoT-edge-AI-block chain to optimise processes and save costs [36].

Limitations and Future Research Avenues

Notwithstanding its merits, this study contains a number of shortcomings that point to potential directions for further investigation. One major drawback is the sample's coverage, which is restricted to a small number of industries and a particular geographic area of the European Union (Portugal) while being diversified [37]. To improve the results' generalisability, future research should increase the sample size and include a wider variety of sectors and regions [36]. The dependence on qualitative approaches, which, while they give depth, may be supplemented by quantitative studies to provide a more thorough viewpoint, is another drawback [38, 39]. The integration of EI with other cutting-edge technologies and its consequences for supply chain management and logistics also need further investigation [40]. A more comprehensive knowledge of EI and its revolutionary potential in the logistics sector may result from these future study avenues.

CONCLUSION

In conclusion, supply chain management and logistics may greatly benefit from increasing last-mile delivery efficiency using cutting-edge machine learning models. These models may cut down on delivery times, save fuel, and improve customer satisfaction by using real-time data processing, predictive analytics, and route optimisation. While deep learning and reinforcement learning may improve decision-making, methods like demand forecasting and dynamic route planning enable businesses to adjust to changing circumstances and delivery requirements. Businesses can keep refining their last-mile tactics with the help of continuous machine learning improvements, which will eventually lower costs, improve service quality, and help create a delivery infrastructure that is more competitive and sustainable.

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