Last-Mile Logistics Innovations for Consumer Goods

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* AI-driven route optimization, drone deliveries, and autonomous vehicles.

Abstract

Last-mile delivery is the final link in the supply chain. It serves as a vital connection between upstream supply chain operations and the end customers. The outbreak of COVID-19 in 2020 substantially affected the supply chain management of different companies. The pandemic has hit all the fronts of supply and demand, as well as the entire infrastructure of transportation and distribution. Consumers predominantly made their purchases through collection points and crowd logistics during the pandemic, making product delivery a hassle in the supply chain.

During the pandemic, last-mile delivery was a big challenge for logistics performance. Traditional delivery methods were costly and time-consuming. The latest innovation in last-mile delivery through drone deliveries, autonomous vehicles, and AI-driven route optimization helped to bring down the cost of logistics. These initiatives also quickened up the delivery time and made last-mile delivery service much more effective. The paper studies smart solutions such as the use of smart lockers, drone deliveries, autonomous vehicles, and AI-driven route optimization in last-mile logistics.

Keywords: Last Mile Logistics, Supply Chain Optimization, AI-Driven Route Optimization, Drone Deliveries, Parcel Lockers, Autonomous Vehicles

Introduction:

Logistics is the process of moving goods from the point of production to the place of demand. Logistics planning integrates manufacturing, transportation, and sales to meet the needs of the clients (Qu et al.,2015). Logistics is basically the backbone of any company's buying, transporting, and storing activities. Its optimization will cost-effectively reduce customer service and cost levels, as well as achieve economic efficiency. The entire world was struck with a new type of virus in 2019, bringing the whole economy down. All the sectors, from tourism, consumer goods, and transportation-witnessed devastation.

Pandemics and epidemics render all production and logistics activities suspended (Singh et al., 2020). The COVID-19 rapid spread has shown the world that natural events such as pandemics and epidemics can heavily disrupt global supply chains (Queiroz et al., 2020).

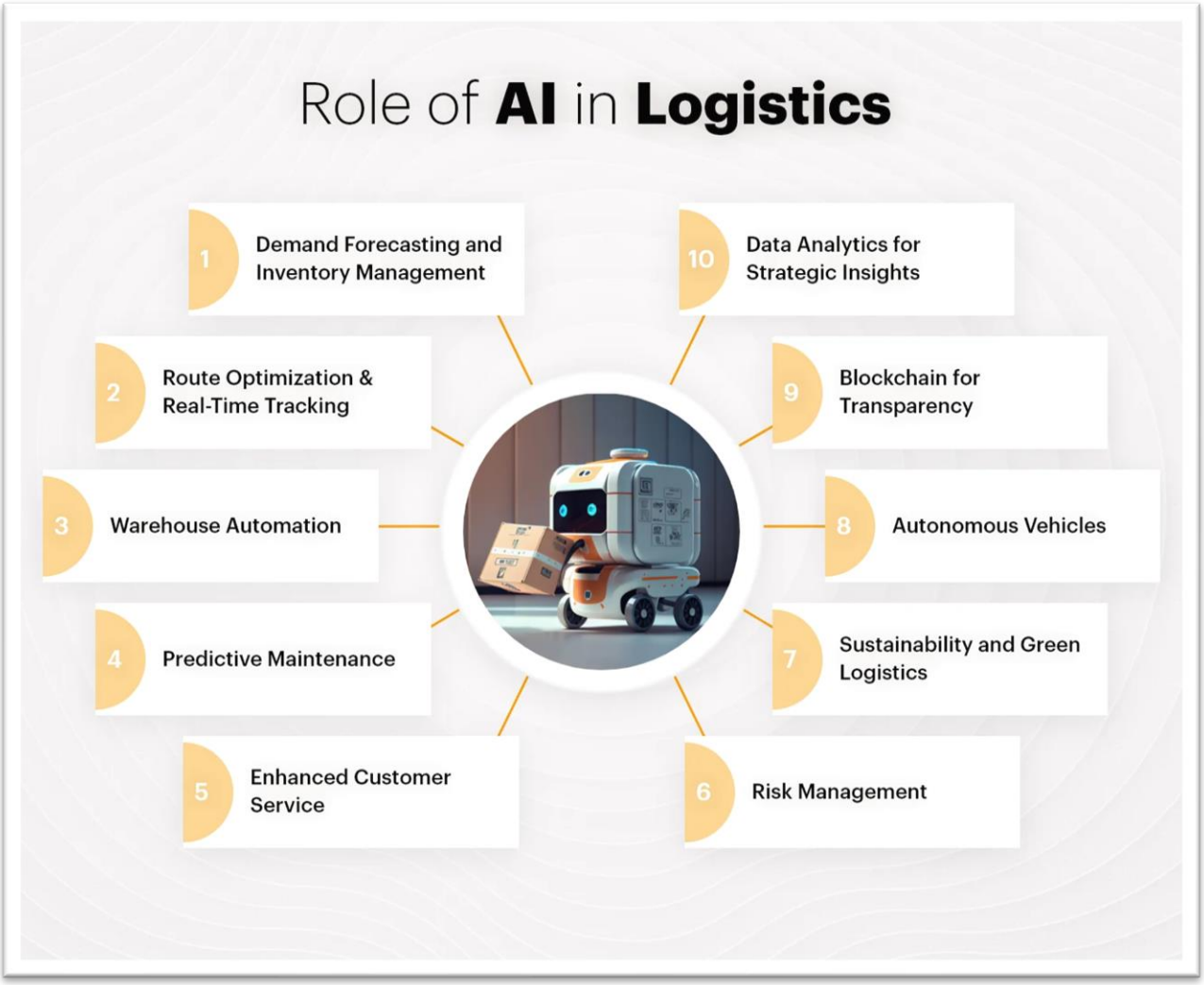
Preventive methods such as isolation, lockdown, safe social distancing, and non-contact deliveries controlled the outbreak of the pandemic effectively (Yang et al., 2021). However, the logistics industry experienced a drop in demand, a lack of transport capacity, changes in service patterns, and disruption of the

logistics network (Liu, Liang, et al., 2020). Continued global trade expansion, however, necessitates improvements in the transportation and logistics infrastructure (Luttermann et al., 2020). A blockchain-based shared mobility architecture and decentralized supply changed management were proposed (Benedict, 2022). (Viu Roig and Alvarez Palau 2020) suggested that in the era of rapid e-commerce growth, the number of direct-to-consumer deliveries and the role of last-mile logistics have improved significantly. This paper focuses on last-mile logistics innovation on consumer goods. It also studies the impact of AI-driven route optimization, drone deliveries, and autonomous vehicles in improving logistics during the pandemic.

Integrating AI-driven route optimization, drone deliveries, and autonomous vehicles in last-mile deliveries.

Last-mile delivery is the end step of business-to-consumer delivery of goods (Yuen et al., 2019). The accelerated growth of the e-commerce industry has motivated logistics companies to develop sustainable and affordable last-mile delivery solutions. This includes automated parcel lovers, low-altitude drones, AI-driven route optimization, delivery robots, etc. Such innovations are able to address such problems as traffic congestion, shortages in the workforce, misdeliveries, etc.

Figure 1: Role of AI in last-mile logistics



a. Autonomous delivery vehicles:

Autonomous delivery vehicles support last-mile delivery during the COVID-19 pandemic. The use of such vehicles protects both the consumers and the delivery agents from virus exposure (Pani et al., 2020). Also, autonomous delivery vehicles offer flexibility and convenience for consumers to select their preferred time of delivery (Chen C. et al., 2021). They also ensure safe and secure delivery, as consumers can easily retrieve their goods after verifying their identity through OTP or QR code scanning.

b. Drones in Last Mile Deliveries:

Drone deliveries enhance accessibility for individuals with limited transportation options (Taveres&, 2019). They are more costeffective than traditional express delivery measures. This position drones to serve a niche market for expediting goods delivery, ushering in a new era of sustainable last-mile logistics. Growing concerns about the environmental impact of transportation, including air pollution, greenhouse gas emissions, and consumption of energy, are driving interest toward drone-based last-mile deliveries (Goodchild &Toy, 2018). Also, drones can play an important role in disaster management by transporting essential supplies rapidly during emergencies.

c. Parcel lockers for last-mile deliveries:

Of all the available last-mile delivery solutions, smart lockers or parcel lockers attained the most attention during the pandemic (Faria, 2022). There are three major benefits of this system for the delivery companies and the consumer. Delivery costs are reduced to enhance overall effectiveness and operational efficiency. Physical contact during parcel delivery is minimized. Package loss is also prevented as shoppers can easily track their packages (Liu et al., 2020; Mitrea et al., 2020).

d. Geographic clustering and zone optimization:

Machine learning algorithms play a significant role in multistop delivery planning for last-mile logistics. These systems will analyze the patterns in the delivery density and will create efficient delivery clusters. AI-driven clustering methods are capable of improving route efficiency by at least 28% compared with the traditional zone-based approaches (Behrend, 2015).

e. AI-driven route optimization for last-mile delivery:

The transformation of last-mile deliveries through AI serves as a backbone of modern delivery optimization systems. Artificial intelligence and machine learning algorithms serve as the primary computational engine in modern last-mile delivery systems(Shrivastav, 2022). AI-driven route optimization will process multiple data streams simultaneously. This includes the historical delivery data, the weather conditions, the real-time traffic information, etc., to generate the optimal delivery route.

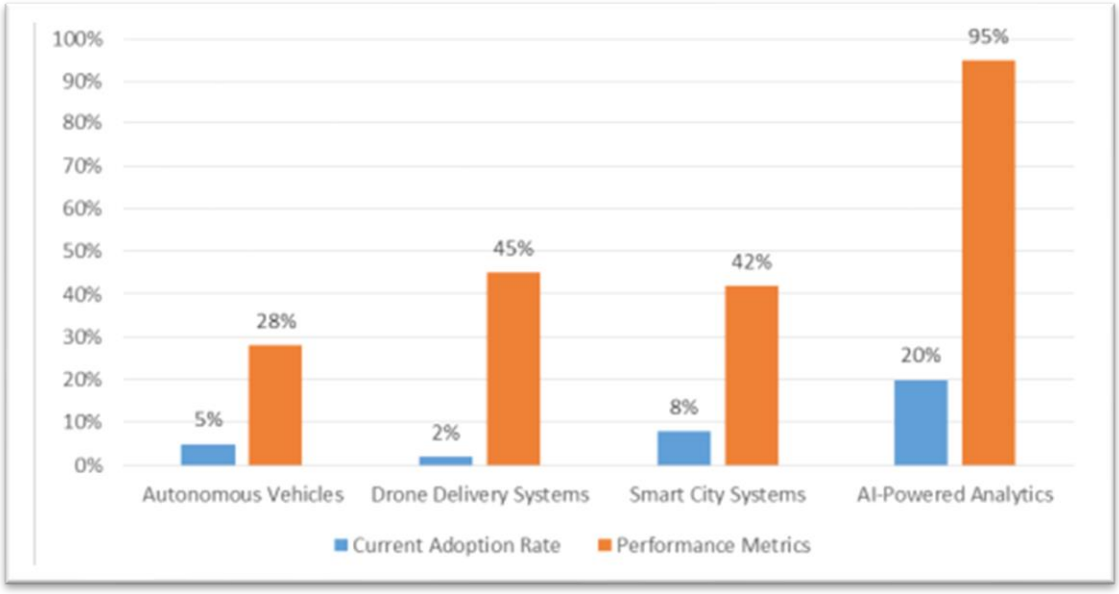
- The Deep Neural Networks have demonstrated effectiveness in route optimization. Implementation studies have shown an improvement potential of up to 40% in the operational costs compared with the traditional routing methods (Pahwa&Jaller, 2022).

- Predictive analytics, powered by advanced regression models and time series analysis, are an important component of AI-driven delivery systems (Sutandi&Evitha 2021). They analyze historical patterns in delivery, seasonal trends, and customer behaviors in order to forecast the demand for delivery with great accuracy.

- Convolutional neural networks can be used in a number oflogistics applications. It includes analysis of package dimensions to verification of delivery. AI-powered visual confirmation systems have reduced disputes in delivery through automated proof of delivery documentation (Pahwa&Jalller, 2022).

- Natural language processing technologies have transformed the way customers communicate in last-mile delivery operations. Modern NLP systems are built on transformer architecture (Sai, 2022). They are capable of processing and responding to customer queries with exceptional accuracy. They also enable real-time updates and communication.

Figure 2: Impact of futuristic technologies on last-mile delivery



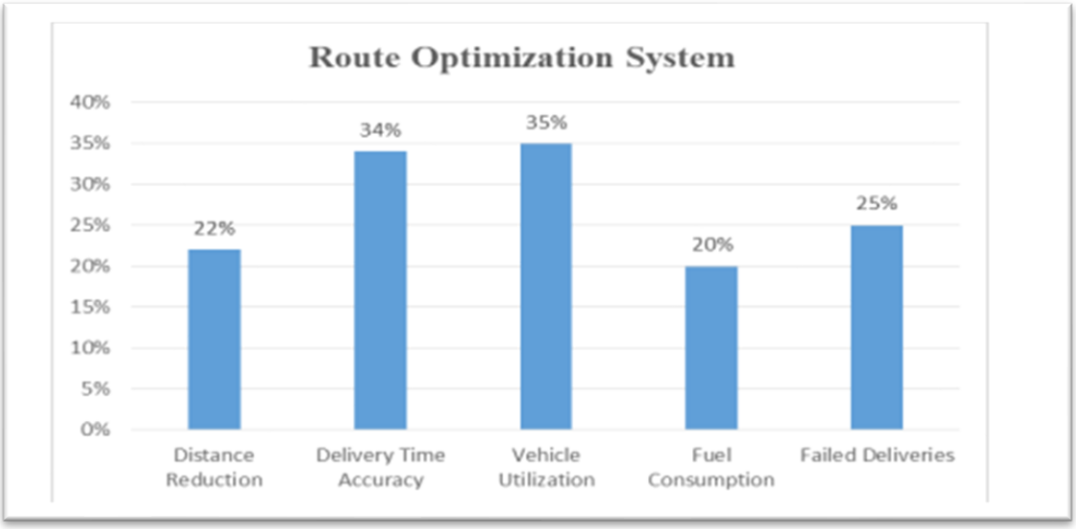
Market growth and data analytics:

The global last-mile delivery market was valued at approximately $40 to 50 billion in the year 2020. This market is projected to grow at a CAGR of 9-10% over the next ten years. Major players like Amazon, Walmart, and UPS accelerated the testing of delivery drones and self-driving vehicles. Companies like Starship Technologies, Nuro, etc, have launched pilot programs for robot deliveries. With AI-driven innovations in the last mile logistics, global e-commerce sales witnessed remarkable growth, reaching $4.28 trillion in the year 2020.

- Implementation case studies have revealed that AI-powered last-mile delivery systems are able to reduce delivery times by 30% and improve delivery accuracy by 98% (Jucha, 2021). These systems also minimize environmental impact by enhancingthe utilization of vehicles.
- Dynamic route optimization has revealed that AI-powered systems can reduce the cost of delivery by 27% (Pahwa, 2022). It will also improve the capacity of vehicle utilization by 31%.
- Predictive analytics in last-mile logistics has led to a 25% reduction in failed delivery attempts. They are also instrumental in improving the rates of customer satisfaction by nearly 40% (Paul, 2021).
- By implementing AI-driven laid optimization along with intelligent routing systems, it is possible to improve route efficiency by up to 28% (Faget, 2021).

- Geographic clustering and zone optimization powered by advanced ML algorithms play a vital role in multi-stop delivery planning. This is known to have improved the efficacy of last-mile delivery by up to 33% (Boesch P.M. et al. 2016).
- AI-optimized routes can reduce the consumption of fuel by 20%, reduce carbon emissions by 25%, and reduce failed deliveries by 33% (Galkin et al., 2019).

Figure 3: Performance of route optimization in last-mile logistics



Recommendations:

Future research studies on this topic should focus on the technological, regulatory, societal, and economic aspects of last-mile logistics. A multi-disciplinary approach that combines AI, IoT, sustainability, and urban planning is crucial for shaping the future of consumer goods logistics.

- Future research shall research the algorithms used in predictive analytics for traffic, cost, and personalized delivery experiences for route optimization.
- The regulatory challenges, cost-benefit analysis, and environmental impacts of large-scale drone delivery should be studied.
- Assess infrastructure readiness, consumer acceptance, and operational efficacy of self-driving last-mile delivery systems.
- Evaluate the role of AI, drones, and autonomous vehicles in lowering carbon emissions and fostering environment-friendly logistics.
- Investigate possible cyber risks in AI-enabled last-mile logistics and the measures that may ensure customer data protection.
- Study effective combinations of human couriers, autonomous vehicles, and drones for efficient last-mile solutions.
- Based on the exploration of certain policies, cost efficiency, and global scalability for last-mile innovations, future research is venturing.

Bottom Line:

Supply chains and last-mile logistics have been disrupted owing to the COVID-19 pandemic. Though several innovative last-mile logistics solutions have been proposed, all of them have certain limitations. They are motivated by alternative last-mile logistics solutions such as autonomous vehicles, route

optimization driven by AI, drone deliveries, etc. Autonomous vehicles are trucks that are dedicated to a specific geographical location and carry the inventory on the basis of the estimated demand requirements. The integration of such technologies will create a comprehensive AI ecosystem that is capable of addressing the challenges of last-mile delivery. The real-time optimization engines will combine data from multiple sources, such as IoT sensor data, GPS, traffic and weather monitoring systems, etc. It creates an integrated approach towards last-mile delivery and remarkably improves efficiency in delivery, especially in the pursuit of the pandemic.

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