International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

Check for updates

Lean in logistics through autonomous last-mile delivery

Olakunle Abimbola Kumuyi *

Department of System Engineering, College of Technology, Architecture and Applied Engineering, Bowling Green, Ohio, United State.

International Journal of Science and Research Archive, 2025, 14(02), 753-763

Publication history: Received on 29 December 2024; revised on 04 February 2025; accepted on 07 February 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.14.2.0404

Abstract

Efficient last-mile delivery is essential in modern commerce, yet it poses challenges in timeliness, cost-effectiveness, and customer satisfaction. Between 41% and 53% of supply chain expenses, particularly in the United States, are attributed to this final leg. Autonomous technology, with its complex algorithms and driverless vehicles, is capable of revolutionizes last-mile delivery by optimizing routing and scheduling, reducing labor costs, and ensuring the fastest delivery routes. Real-time inventory management can further integrate lean principles into last-mile delivery, and therefore enhancing operational efficiency. This project explores the synergy between autonomous technology and lean concepts, aiming to eliminate non-value-added tasks, maximize resource utilization, and enhance overall efficiency, in terms of travel time reduction, with focuses specifically on develop countries with supporting technologies to support autonomous vehicles and robot technologies infrastructures in place. The research focused on leveraging available traffic data from autonomous technology can enable continuous improvement, enhancing productivity and customer satisfaction. Additionally, incorporating autonomous technology can enhance the reliability and safety of last-mile delivery operations through cost reduction, time reduction, and route flexibility. This research primarily examines the impact of traffic lights on traditional delivery vans, using New York City streets as a case study. A comprehensive model has been developed to quantify the cost implications of traffic light delays, providing a structured method to evaluate these inefficiencies. The model offers a practical approach that can be applied globally users simply need to input relevant parameters, and the system will compute the time, cost, and overall impact of such delays. Additionally, the study highlights the advantages of autonomous delivery systems, particularly drones, over conventional delivery methods. By utilizing this model, businesses and policymakers can make data-driven decisions to optimize last-mile logistics and enhance delivery efficiency. Recommendations include utilizing autonomous technology to meet environmental preservation requirements and offering eco-friendly delivery options. The convergence of lean principles and autonomous technologies offers transformative opportunities, enabling businesses to fulfill consumer demands, reduce costs, operate sustainably, and enhance efficiency.

Keywords: Lean Logistics; Last-Mile Delivery; Autonomous Delivery Vehicles (ADVs); Traffic Light Delays; Route Optimization; Cost Reduction; Environmental Sustainability; Supply Chain Efficiency; Machine Learning in Logistics; Customer Satisfaction

1. Introduction

The pursuit of efficiency, cost-effectiveness, and customer happiness is still crucial in the dynamic world of logistics. This quest is never more evident than in the field of last-mile delivery, where there are several obstacles and chances for advancement on the last segment of the supply chain journey. Last-mile logistics could be revolutionized by integrating autonomous technology with lean principles, as organizations endeavor to manage the complexity of modern commerce [1]. Fundamentally, since lean methodology promotes ongoing process improvement efforts and the removal of non-value-added tasks, organizations can achieve the above objective through lean by finding inefficiencies,

* Corresponding author: Kumuyi Olakunle

improving workflows, and ultimately creating more value for their clients and themselves within the lowest possible cost range by implementing lean principles into their logistics operations [2].

Since last-mile deliveries make up a sizable amount of total shipping expenses, the logistics sector has long struggled to optimize this process due to the benefits that will arise in terms of cost and customer satisfaction. Due to the growth of e-commerce, stiffer competition, and higher customer awareness levels, the growing need for quicker and more effective delivery and low-cost services is needed more than ever before. Therefore, businesses are looking for creative ways to simplify this vital link in the supply chain, especially the last mile, due to it carrying the highest cost percentage in the logistics category. Presenting autonomous last-mile delivery, a state-of-the-art innovation that has the potential to completely transform the way products are delivered from warehouses to consumers' doorsteps [3].

Self-driving last-mile delivery is a natural extension of lean logistics, an organized methodology that focuses on constant waste reduction and resource optimization all the way through the supply chain [3]. Logistics firms can improve customer satisfaction by reducing overhead expenses, streamlining operations, and increasing delivery speed and reliability by utilizing ADVs.

With the use of cutting-edge robotics, artificial intelligence, and sophisticated navigation systems, autonomous delivery vehicles (ADVs) have the potential to significantly lower operating costs, increase delivery efficiency, lower last-mile labor costs, material handling costs, and promote sustainability due to the environmentally friendly nature of those autonomous vehicles. ADVs may work around the clock, reducing delays and optimizing asset usage because they do not require human drivers [4] [2]. Moreover, they significantly lower carbon emissions and traffic congestion thanks to their electric propulsion systems and improved routing capabilities.

This thesis explores the groundwork for examining the revolutionary possibilities of autonomous last-mile delivery within the framework of lean logistics, emphasizing how it may boost productivity, save expenses, and promote sustainability in the dynamic field of supply chain management and logistics [5]. Focusing on the relationship between autonomous last-mile delivery and lean approaches to find opportunities for efficiency in logistics operations. Businesses' approach to last-mile delivery can greatly change because of the incorporation of lean concepts, which prioritize process simplification, waste reduction, and resource optimization.

The metrics of improvements that will be suggested in this thesis will be based on cost optimization that can be achieved through the incorporation of lean into last-mile delivery using autonomous vehicles. The logistics sector has a revolutionary opportunity because of the fusion of autonomous technology with lean approaches [6] [7]. Through the utilization of lean principles in operating automation robotics equipment, companies can significantly lower expenses, improve client experiences, and increase operational efficiency, with focuses specifically on develop countries with supporting technologies to support autonomous vehicles and robot technologies infrastructures in place [8].

The objective of the research will be to

- Evaluate the existing last-mile delivery processes to identify common operational challenges, bottlenecks, and inefficiencies across different industries and geographic locations.
- Create all-encompassing optimization plans based on lean concepts to increase performance, using robots and autonomous technologies to reduce last-mile delivery costs.
- Assess the feasibility of implementing the proposed optimization strategies within various countries, regional and continental level considering factors such as regulatory requirements, infrastructure readiness, and technological maturity.

This study's scope includes a thorough investigation of how autonomous technologies and lean principles are integrated in the context of last-mile delivery logistics, with a particular emphasis on developed nations with well-established infrastructures that support robot and autonomous vehicle technologies. The following important areas are the focus of this study:

- **Geographic Scope:** Focused specifically on United States (Developed country) with infrastructures to support autonomous means of last-mile delivery operations.
- **In Scope Innovations:** Focus on key innovations highlighted in content including autonomous ground vehicles, delivery drones, predictive analytics, and machine learning.
- **Supply Chain Focus:** Emphasize the last-mile delivery using Amazon data as the bases for evaluation.
    - Strategic analysis of emerging innovations like drones, autonomous vehicles to highlight opportunities.

- Evaluate Amazon current last-mile delivery processes to identify challenges, bottlenecks, efficiency gaps.
- Evaluate potential cost and time reduction that can be accomplish by eliminating traffic light delay using drones for last mile delivery.
- Develop recommendations for performance improvements aligned to environmental sustainability best practices.

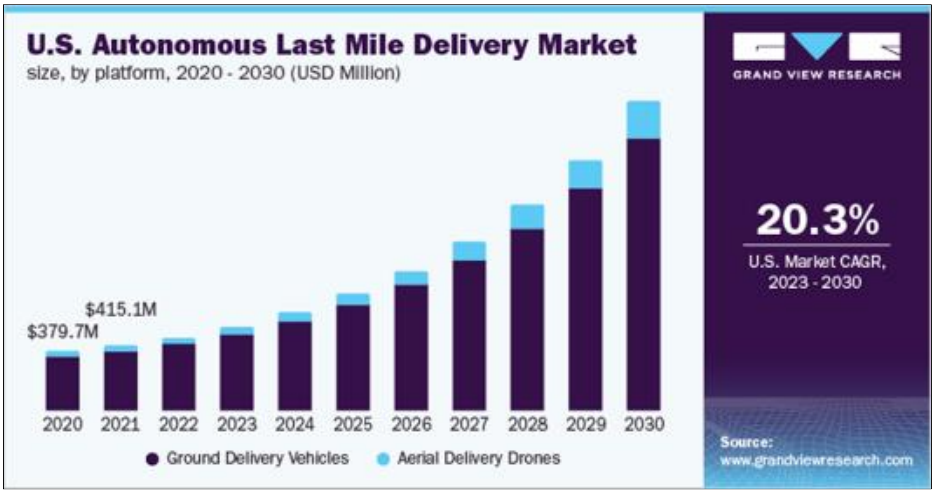
2. Literature Review

The last mile of the supply chain is where goods are delivered from distribution centers to their final locations, which are frequently customers' doorsteps. According to estimates 41% to 53% in the US, it makes up a considerable amount of all logistical costs [9]. Customer happiness, environmental sustainability, and operating costs can all be negatively impacted by inefficiencies in this market. Logistics companies now need to maximize last-mile delivery as e-commerce keeps growing at a significant rate.

Originating in the Toyota Production System, lean concepts have found a natural home in supply chain and logistics as well as on the production floor [5]. The need to streamline processes, eliminate waste, and increase efficiency at every level of the supply chain has spurred this evolution. Fundamentally, lean logistics is a dedication to getting rid of waste—whether it comes from excess inventory, defective products, needless transportation, overproduction, or underutilized personnel. Companies are moving toward smaller, more agile supply chains by adopting approaches like Total Quality Management (TQM) and Just-In-Time (JIT) production [2]. Lean logistics offers numerous and extensive advantages [5]. It not only opens the door to lower expenses and increased output, but it also acts as a spur to raise consumer satisfaction to unprecedented levels. Organizations are positioned to provide value in its purest form by eliminating needless lead times and strengthening service levels, which will truly resonate with the changing expectations of today's astute consumers.

2.1. Growing Market

According to a recent Research and Markets report, the global autonomous last-mile delivery market, estimated to be worth $1.1 billion in 2023 [10] is expected to rise at a stunning compound yearly growth rate of 20.9% from 2024 to 2027, reaching $5.6 billion. This rapidly expanding market is divided into long- and short-term segments, hardware, software, and services solutions, as well as verticals like as healthcare, retail, food and beverage, and logistics, Because of its higher rate of automation adoption in last-mile delivery operations, the North American region is expected to lead the autonomous last-mile delivery industry and that was a bases with which this study is limited to united states of American. Leading companies like Amazon, Walmart, JD.com, and Alibaba which are mostly USA companies except for Alibaba are driving the adoption of drone delivery services by making technological investments to enable package delivery over great distances without the need for human intervention [11]. The most successful use of drones to date has been the delivery of prescription drugs and medical supplies.



source: www.grandviewresearch.com

Figure 1 U.S. Autonomous Last Mile Delivery Market

However, government laws and limited infrastructure make it difficult for driverless last-mile delivery to become widely adopted especially in developing nations, delays or incorrect deliveries may result from inadequate infrastructure and poor internet connectivity. Thus, for the near future, while developing countries might find it difficult to adopt the technology, develop nations will key more into the opportunity, especially land-based robots will be mainly used in urban and college locations at an increasing trajectory [7]. With autonomous last-mile delivery by air drones still limited to less crowded and less air traffic areas, introduction of lean principles will have the capacity to boost the air drone delivery and therefore increasing the likelihood that autonomous delivery systems would succeed more, which would accelerate the profit and the rate of industry expansion ascribe to the logistics industries, particularly in areas of last mile delivery [11].

If lean principles in integrated into last mile delivery the cost benefits will be enormous especially if these present challenges and constraints are overcome or reduced; land delivery robots are thought to be able to drastically cut carbon emissions and save delivery costs by as much as 30–45% [10]. This is especially important because last-mile delivery is the least efficient portion of the shipping system and accounts for about 50% of the overall cost of shipping [1].

Before the e-commerce boom caused a surge in single-package deliveries, items were shipped in bulk, which allowed for shared expenses across all packages [12]. Because there are fewer items to split the delivery expenses among, the last-mile single package delivery now accounts for the majority of delivery costs [13]. Small package deliveries around the world are increasing, which will drive up costs and ultimately affect consumers and the shipping sector.

Even while autonomous delivery's full potential is still unknown, it provides a fascinating illustration of a future supply chain that is leaner and greener and gives a peek of the revolutionary possibilities that lie ahead.

2.2. Last-mile delivery

The last stage of the supply chain is called "last-mile delivery," which involves moving products from fulfillment or distribution hubs to final locations, usually customers' doorsteps. One cannot overestimate its importance in the logistics and transport industry, particularly in the context of e-commerce and online retail [14]. Last-mile delivery is important for a number of reasons. The surge in parcel delivery has been primarily caused by the exponential growth of e-commerce and the growing dependence of consumers on online platforms for a wider range of purchases. Furthermore, new problems brought about by changes in customer behavior and urbanization patterns include traffic jams, parking restrictions, and strict delivery timetables that call for creative solutions in order to guarantee effective and timely delivery. Convenience is a major motivator, as changing customer expectations highlight the need for quick, reliable, and flexible delivery services. In addition to being essential for preserving competitiveness, meeting these expectations also promotes customer loyalty and a favorable image of the business [14]. Effective last-mile delivery has a significant impact on overall business performance and customer satisfaction by influencing opinions about dependability and service quality. It also plays a crucial role in improving the effectiveness of the supply chain because of its significant financial and scheduling consequences. Additionally, because of its negative effects on the environment, eco-friendly measures including route optimization and the use of alternative vehicles are required in order to reduce carbon emissions and advance sustainability. Last-mile delivery, which tackles issues brought on by e-commerce, urbanization, and changing customer preferences, is a crucial part of contemporary logistics. Its optimization is necessary to promote environmental stewardship, increase supply chain effectiveness, and propel corporate growth [15]. Thus, it is essential to keep looking into new ideas and technology in order to improve last-mile delivery procedures.

2.2.1. Lean concepts in logistics and supply chain

Lean principles originated from the Toyota Production System (TPS), developed by the Toyota Motor Corporation in post-World War II Japan to address resource limitations while improving quality, productivity, and waste reduction. Scholars like Womack and Jones (2003) identified five core principles pull, value, flow, value stream, and perfection that form the foundation of lean thinking. Over time, lean concepts have been widely adopted in supply chain and logistics, enhancing efficiency, responsiveness, and cost-effectiveness [16]. By implementing lean strategies, companies can minimize lead times, inventory levels, and transportation costs while improving customer service. In last-mile delivery, where cost reduction is a priority, companies leverage lean methods like route optimization and resource allocation to minimize expenses related to fuel, labor, and storage [17]. A prime example is Zara, which has effectively applied lean logistics to streamline operations and boost sales. Since the mid-1990s, lean principles have continuously emphasized waste reduction and operational efficiency, significantly impacting last-mile logistics by cutting lead times, enhancing delivery schedules, and improving productivity. Optimized last-mile logistics also enhance customer satisfaction by ensuring faster, more reliable, and cost-efficient deliveries, which is crucial in the modern e-commerce landscape [18] [2]. Lean methods further reduce errors, delays, and damages while enhancing shipment visibility, fostering transparency and customer trust. By eliminating inefficiencies and focusing on continuous improvement, lean transportation strategies play a pivotal role in shaping modern logistics and supply chain operations.

Source: https://www.mdpi.com/2071-1050/13/7/3714

Figure 2 Lean Thinking

2.3. Challenges and considerations

While implementing lean concepts into last-mile delivery operations has produced significant advantages in the past, there are also significant obstacles to overcome that have been faced also in the past, for instance.

There are major challenges with data visibility and accuracy, for instance route optimization was hampered by Amazon's struggles with erroneous data on package volumes and delivery times [19] [6]. Even though they made an investment in better data tracking and collection tools to address this and make well-informed decisions for last-mile delivery using drone [15] [16]. Advancement have been hampered by American government resistance through regulation some that demands that drones weighing more than certain pound must be expressly registered with the government and in some cases flight zone for drone are limited to certain areas due to security and military concerns [11].

When rolling out last-mile grocery delivery, Walmart had to deal with the issue of optimized routes occasionally conflicting with customer expectations, arising from conflicting arrival time [19]. They find achieving balance difficult since autonomous equipment still lacks ability to communicate their location speed, delay reason and some other crucial information in real time to customer, achieving balance by providing adaptable delivery choices has been difficult due to limitation in technology, unwilling of customers to adopt certain forms of technologies due to fear of data protections [17]. The limitation faced due to fear of data protection fear grows exponentially bigger when international companies are those in position trying to make last mile delivery [19] [11].

It is difficult to integrate technology with outdated systems [1]. When integrating new lean technologies with the current IT infrastructure, it usually takes significant financial outlays for technological advancements and smooth integration to overcome this [10]. It's crucial to work together with supply chain partners. DHL understood that to successfully apply lean principles, extensive collaboration with retailers, manufacturers, and local contractors was initiated but encountered difficulties particularly during the COVID-19 pandemic, a continuity along this path must be promoted [7].

Some of the above illustrations highlight the complexity of the issues involved in applying lean concepts to last-mile delivery in the past. It will take careful planning, stakeholder involvement, and a dedication to ongoing improvement to overcome these challenges.

3. Materials and Methods

The time conventional delivery vehicles spend waiting at traffic lights is worth analyzing, considering fuel costs and the wages of drivers who idle during these pauses. I'll be assessing the potential savings by using autonomous vehicles, like drones, for delivery. They aren't affected by traffic lights and don't require drivers.

Total cost lost by a conventional car due to traffic light during a particular delivery,

$$= \mathbf{N}(T_{delay} \times (\mathbf{F}_{idle} + \mathbf{L}_{cost}))$$

Where,

- **N** = *Total mile cover per delivery*

3.1. Time spent in traffic light delay,

$$T_{delay} = N_{lights} \times t_{wait}$$

- T_{delay} *= represent the total time spent in traffic light delays during a delivery route*
- N_{lights} *= represent the average number of traffic light within a mile*
- t_{wait} *= Average time spent waiting due to traffic light at each traffic light*

3.2. Average fuel usage per minute for a car in idle state

$$F_{idle} = V_{idle} \times C_{fuel} \times \alpha$$

- **F**idle = Average cost of fuel usage during delivery vehicle idle mode per seconds
- **V**idle = Average volume of fuel usage during delivery vehicle idle mode
- **C**fuel = cost of fuel per unit volume
- **α** = factors representing delivery vehicle fuel usage efficiency (α ranges between 1.0 -1.2)

3.3. Average Delivery driver wages per seconds

$$L_{cost} = L_{phr} / (3600)$$

- Lphr = labor cost per hour
- Lcost = Average driver wage cost per seconds

Table 1 Information Sources and Itemization

Information source	**Item**	**Number data**	**Average number**
(NYC Department of Transportation, 2022) [20]	Numbers of traffic light within New York city	13,543	--------
(Office of the New York State, 2022, p. 6) [21]	Total road length in miles	96,418 /(0.85)	113,433
(NYC Department of Transportation, 2022) [22]	Range of time spent waiting in traffic light in New York City	45 - 120	(45 + 120) / 2 = 82.5
(Office of Energy Efficiency & Renewable Energy. 2024) [23].	Average gallon of fuel usage during car idle mode per hour	0.84	0.84/(3600) = 0.000233333 Gallon per seconds
U.S. Department of Energy. (January 2024) [24]	Cost of Diesel (since the truck uses Diesel)	$3.94/gallon	------
It assumes the delivery vehicle in this case performance optimally (Less than 5 years of usage)	α	1	--------

ZipRecruiter. (2024, April 13) [25]	Location delivery truck driver average per hour wages	$24/hour	-------
(Number of traffic light) / (total road length in miles)	Traffic light per mile	13,543/ 113,433	0.1194

3.4. Using the above detail

$$N\ (Tdelay\ X\ (Fidle + Lcost))$$

3.5. Calculating the delay time per mile

$$Tdelay = N_{lights} \times t_{wait}$$

$$N_{lights =}\ 0.1194 \text{ per mile}$$

$$t_{wait =} = 82.5 \text{ seconds}$$

$$Tdelay\ = 0.1194\ X\ 82.8 = 9.87 \text{ seconds/ per mile}$$

3.6. Average fuel usage per minute for a car in idle state

$$Fidle = V_{idle} \times C_{fuel} \times \alpha$$

$$V_{idle} = 0.000233333 \text{ gallon per seconds}$$

$$C_{fuel =}\ 3.94\$/\text{gallon}$$

$$\alpha = 1$$

$$= 0.000233333\ X\ 3.94$$

$$= \$\ 0.0009194 \text{ per seconds}$$

3.7. Average Delivery driver wages per seconds

$$Lcost = Lphr\ /\ (3600)$$

$$Lphr = \$24/\text{hour}$$

$$Lcost = 24/3600$$

$$= \$\ 0.0006667 \text{ per seconds}$$

Cost lost per mile by a conventional car due to traffic light during a particular delivery.

$$= (Tdelay\ X\ (\mathbf{F}idle + \mathbf{L}cost))$$

$$9.87 \text{ x } (0.0009194+ 0.0006667)$$

$$9.87 \text{ x } 0.0015861$$

$$= \$0.01566 \text{ per mile}$$

$$= 0.01566 \text{ x } 100$$

$$= 1.565 \text{ cent per mile.}$$

3.8. Analysis Assumptions

For the analysis to be valid, certain assumptions must be carefully considered. These are highlighted below and are necessary for the estimates to hold true.

- Traffic lights are evenly distributed per mile in the case under analysis.
- Autonomous vehicles, particularly drones, encounter no delays due to traffic lights.
- Variations in car usage efficiency can be factored in using the variable α.
- The α value ranges from 1, indicating 100% efficiency, to 1.2 for cars with the least efficiency.

4. Result Analysis

The result show that using autonomous vehicles, like drones, for last-mile deliveries can result in possible cost savings and increased delivery efficiency. This benefit adds up to major time and financial savings, especially in crowded cities with plenty of traffic, like New York City, where traffic signals are common and can create major delays.

Based on the data, traditional delivery vans lose an average of 1.565 cents per mile as a result of traffic light delays. Even though this number might not seem like much at first, businesses in the last-mile delivery industry can save a lot of money when taking into account lengthier delivery routes and repeated deliveries.

For example, using autonomous cars might result in cost savings of about 10.955 cents (1.565 cents × 7 miles) each delivery, based on an average delivery route of 7 miles inside New York City. This works out to a savings of over 11 cents for each 7-mile delivery. While this may not sound like much at first, the savings adds up over the course of a big fleet and multiple daily deliveries.

The report also emphasizes how autonomous vehicle deliveries may result in time savings. A traditional delivery vehicle would experience a wait of roughly 9 minutes (82 seconds × 0.1194 lights per mile × 7 miles) over a 7-mile delivery route, based on the estimated average delay of 82 seconds per traffic light and an average of 0.1194 traffic lights per mile.

Autonomous vehicles have the potential to greatly improve customer satisfaction and delivery efficiency by removing delays caused by traffic lights and ensuring timely deliveries. This benefit is especially important for businesses with high delivery volumes and slim profit margins, as even tiny time reductions can have a big influence on overall operational effectiveness and customer satisfaction.

Table 2 Traffic light Per Mile and Cost Relation

Number of Traffic Lights (Per mile)	**Total cost Lost (cents per mile)**	**Fuel cost (Cent per mile)**	**labor cost (Cent per mile)**
0.1194	1.565	0.87	0.695
0.5	7.83	4.35	3.48
1.0	15.66	8.7	6.96
1.5	23.49	13.05	10.44
2.0	31.32	17.4	13.92

The outcome analysis highlights how implementing autonomous vehicle technology for last-mile deliveries can improve customer satisfaction and delivery times while also saving money. To assess a system's overall viability and cost-effectiveness for certain delivery businesses, the implementation safe cost and reflects leans concepts.

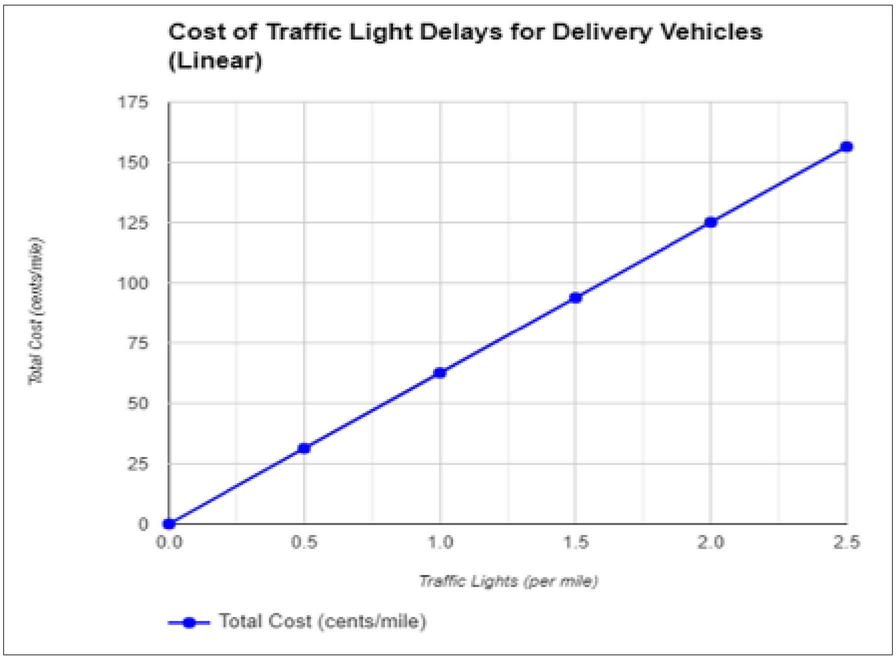


Figure 3 Cost- Delay Graph

5. Discussion

As seen the adoption of autonomous vehicles and drones for last-mile delivery offers numerous advantages, including reduced costs, increased efficiency, environmental sustainability, enhanced customer satisfaction, and scalability. These benefits stem from the elimination of human drivers, optimized routing, and long-term significant cost and time optimization. However, challenges such as regulatory constraints, infrastructure readiness, public acceptance, integration with existing systems, initial investment costs, and cybersecurity risks hinder widespread implementation. Overcoming these limitations requires collaborative efforts between governments, companies, and stakeholders, including the development of clear regulatory frameworks, infrastructure investments, addressing public concerns, and fostering innovation. Incorporating lean principles as shown to further increase the efficiency and sustainability of autonomous last-mile delivery systems by focusing on continuous improvement of time and cost waste reduction.

Despite current challenges, ongoing technological advancements, regulatory reforms, infrastructure development, and the adoption of lean principles hold the potential to fully realize the benefits of autonomous last-mile delivery, leading to a more efficient, sustainable, and customer-centric delivery ecosystem.

6. Conclusion

According to the study, last-mile delivery is greatly improved by combining autonomous technology with lean logistics concepts, which optimize expenses, cut down on delays, and boost productivity. A more sustainable and customer-focused approach to logistics is provided by autonomous cars and drones, which remove non-value-added duties like traffic light waits. The results underline the possibility of higher productivity and environmental advantages, as well as quantifiable cost reductions per mile. This study opens the door for data-driven decisions in last-mile logistics by offering insightful information to companies and legislators. In the conclusion, the study advances economical, environmentally friendly, and successful urban delivery alternatives.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Routific, "Last Mile Delivery Costs," 9 April 2024. [Online]. Available: https://www.routific.com/blog/last-mile-delivery-costs. [Accessed 14 August 2024].

[2] P. Dennis, Lean Production Simplified, Foreword by John Shook., 2015.

[3] Springer International Publishing, Next Generation Supply Chains: A Roadmap, Germany: Springer International Publishing., 2020.

[4] S. R. M. W. R. W. M. &. N. A.-G. Leminen, Autonomous vehicle solutions and their digital servitization business, 2015.

[5] American Institutes for Research, Urban Institute, & Mayo Clinic, "Improving Care Delivery Through Lean," American Institutes for Research, Urban Institute, United state of American, 2024.

[6] H. Q. G. X. N. H. &. P. H. Hongjian Hu, "Column generation based hybrid optimization method for last-mile delivery service with autonomous vehicles," Semanticscholar, vol. In Adv. Eng. Informatics, no. https://www.semanticscholar.org/paper/532a1c5edae608ca9a9b88e79a662adea40528d3, 2024.

[7] Y. D. S. D. Y. S. &. M. L. Yuzhan Wu, "Autonomous Last-Mile Delivery Based on the Cooperation of Multiple Heterogeneous Unmanned Ground Vehicles.," In Mathematical Problems in Engineering., no. https://www.semanticscholar.org/paper/48669f741ee357ef83aa59a9698a8f58cfb0ae91, 2021.

[8] L. Huang, "Evaluate Sustainability of Using Autonomous Vehicles for the Last-mile Delivery Industry.," In BOHR International Journal of Future Robotics and Artificial Intelligence, no. https://www.semanticscholar.org/paper/72fc879f519eff6a15b111b017dd6bdc23a3472d, 2021.

[9] D. P. a. D. K. A. a. D. S. Poojitha, "The Future of Logistics: Trends, Impacts, and Recommendations," Semantic Scholar , 2023.

[10] Starship Technologies. (n.d.). Company, • Starship Technologies. (n.d.). Company, 11 April 2024. [Online]. Available: https://www.starship.xyz/company. [Accessed 19 November 2024].

[11] M. Johnston, "The World's Top 10 Retailers (WMT,," Investopedia, 14 December 2023. [Online]. [Accessed 11 Janaury 2025].

[12] R. Muralidharan, "The Impact of E-Commerce on Parcel Shipping Operators in," https://www.nyc.gov/html/dot/html/infrastructure/signals.shtml, New york city, 2022.

[13] O. L. &. A. Saraceni., " Efficiency in the Last Mile of Autonomous Ground Vehicles with Lockers," From Conventional to Renewable Energy Transport. In Sustainability, Vols. https://www.mdpi.com/2071-1050/15/23/16219, 2023.

[14] C. Lemardelé, "Life-cycle analysis of last-mile parcel delivery using autonomous," Transportation Research Part D: Transport and Environment,, vol. 103842. , no. DOI: 10.1016/j.trd.2023.103842. Available at: https://www.sciencedirect.com/science/article/pii/S1361920923002390, 2023.

[15] C. Lemardelé, "Life-cycle analysis of last-mile parcel delivery using autonomous," in Transportation Research Part D: Transport and Environment, Transport and Environment, 103842. DOI: 10.1016/j.trd.2023.103842, 2023, p. 71.

[16] F. Bouhannana., "INTEGRATING LEAN, GREEN AND AGILE CONCEPTS IN SUPPLY CHAIN MANAGEMENT," SUPPLY CHAIN MANAGEMENT , 2021.

[17] S. &. M. P. Chopra, "Strategy, Planning, and," Supply Chain Management, 2019.

[18] P. S. &. R. Bourafa, "A review of the automated guided vehicle systems: dispatching systems and navigation concept," Automobile transport., p. https://www.semanticscholar.org/paper/25a786cb6c250ac21c86b102522b5fc59811b9f7, 2023.

[19] PYMNTS, "Amazon Recruiting Local Businesses for Last-Mile Delivery.," (2023, March 28.

[20] (NYC Department of Transportation, "Numbers of traffic light within New York city," NYC Department of Transportation, 2022, https://www.nyc.gov/html/dot/html/infrastructure/signals.shtml, 2023.

[21] Office of the New York State, "Total road length in," Office of the New York State, http://www.osc.ny.gov/files/localgovernment/publications/pdf/locally-owned-roads-by-the-numbers.pdf, 2022.

[22] U. D. o. Energy., "Cost of Diesel (since the truck uses Diesel)," U.S. Department of Energy. , https://afdc.energy.gov/fuels/prices.html, (January 2024).

[23] ZipRecruiter., "Location delivery," ZipRecruiter, United State of American truck driver average per hour wages, (2024, April 13).

[24] N. D. o. Transportation, "Range of time spent waiting in traffic light in New York City," NYC Department of Transportation, https://www.nyc.gov/html/dot/html/infrastructure/sig, 2022.

[25] (Office of Energy Efficiency & Renewable Energy. 2024)., "Average gallon of fuel usage during car idle mode per hour," Office of Energy Efficiency & Renewable Energy, https://www.energy.gov/eere/vehicles/fact-861-february-23-2015-idle-fuel-consumption-selected-gasoline-and-diesel-vehicles, 2024.