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Influence of Autonomous Systems on Supply Chain Optimization in Real-Time Logistics in Ethiopia

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Abstract

Purpose: The purpose of this article was to analyze the influence of autonomous systems on supply chain optimization in real-time logistics in Ethiopia.

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: The influence of autonomous systems on supply chain optimization in Ethiopia is still emerging, with early applications like drones for rural delivery showing potential to improve efficiency. These systems could reduce delivery times, lower costs, and enhance accuracy. However, challenges such as infrastructure gaps and regulatory issues need to be addressed for full implementation. Continued research and investment are crucial to unlocking the potential of autonomous logistics in Ethiopia.

Unique Contribution to Theory, Practice and Policy: The technology acceptance model (TAM), resource-based view (RBV) & lean supply chain theory may be used to anchor future studies on the influence of autonomous systems on supply chain optimization in real-time logistics in Ethiopia. Logistics companies should consider adopting hybrid models that integrate autonomous systems with existing human-operated processes. This Governments must create and enforce clear regulatory frameworks that allow for the safe and efficient integration of autonomous systems into logistics.

Keywords: *Autonomous Systems, Supply Chain Optimization*

INTRODUCTION

Supply chain optimization focuses on improving the efficiency of logistical operations, particularly through enhancing delivery accuracy, cost reduction, and time efficiency. In developed economies, companies have embraced advanced technologies such as AI, IoT, and automation to streamline these processes. For example, in the USA, Amazon has been a leader in optimizing its supply chain, reducing delivery time to as low as one day in many regions, which enhances customer satisfaction and minimizes logistics costs. According to a 2020 report, Amazon's investment in automation and AI helped reduce operational costs by 30% and increased delivery accuracy to over 99% (Zhang & Li, 2020). In Japan, Toyota's use of Just-in-Time (JIT) manufacturing has optimized its supply chain by minimizing inventory and improving production efficiency, contributing to lower operational costs and reduced waste, allowing Toyota to maintain its competitive advantage globally (Yamashita, 2020). In Germany, for example, the logistics company DHL has implemented automation and data analytics within its supply chain to increase efficiency. DHL's innovations helped cut operational costs by 25% while improving delivery time by 15% (Böhme, 2021). In Canada, the retailer Loblaws has integrated IoT and real-time tracking systems, significantly improving inventory management, which reduced stockouts by 20% and optimized delivery time by 30% in their distribution centers (Gagnon & Lavoie, 2020). Such initiatives illustrate how advanced technologies can drive cost reduction and operational optimization, maintaining a competitive edge in the global marketplace.

In developing economies, supply chain optimization often faces additional challenges, such as infrastructure limitations and less access to technology. However, there have been notable improvements, especially with the adoption of mobile technology and e-commerce platforms. In India, for instance, Flipkart's supply chain optimization, driven by its use of data analytics and regional warehouses, has helped reduce delivery time by 50% while improving delivery accuracy (Singh & Sharma, 2021). According to a 2021 report, Flipkart's initiatives contributed to a 12% reduction in logistics costs, which was critical in a highly price-sensitive market (Sharma & Kumar, 2021). In Brazil, the company Magazine Luiza leveraged predictive analytics and IoT to optimize inventory management, thus reducing costs by 15% and improving time efficiency in deliveries, especially in rural areas. These improvements highlight the importance of data-driven approaches to overcoming logistical inefficiencies in developing regions (Silva, 2020). In China, companies like Alibaba have transformed supply chain operations by employing real-time data, which has improved delivery accuracy by 40% and reduced logistics costs by 25% (Chen & Liu, 2020). In Mexico, Grupo Bimbo uses smart logistics platforms that enable real-time monitoring and predictive analytics to optimize inventory and distribution, reducing operational costs by 15% and improving delivery speed by 20% (García & Martínez, 2020). These examples demonstrate that even in developing economies, technology-driven supply chain optimization can drive significant improvements in efficiency and reduce costs.

In Sub-Saharan Africa, supply chain optimization is often hindered by infrastructure deficits, political instability, and limited technological adoption. Nevertheless, there have been positive trends in some countries where companies are using mobile technology to enhance logistics. For instance, in Kenya, mobile payment systems like M-Pesa have enabled supply chain optimization by allowing for efficient transactions in rural areas, reducing logistical costs by up to 20% (Karanja & Ochieng, 2020). Additionally, South Africa's retail giant, Shoprite, has implemented an advanced logistics system that optimizes delivery times and reduces waste in inventory

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management. According to a 2019 report, Shoprite's supply chain improvements led to a 10% reduction in costs and a 15% improvement in delivery time, largely through the use of real-time tracking and data analytics (Dube & Mabena, 2019). For instance, in Nigeria, the e-commerce platform Jumia has implemented a smart delivery system powered by data analytics to track inventory, improve delivery accuracy, and reduce transportation costs by 18% (Olawale & Kalu, 2021). In Ethiopia, Ethiopian Airlines has adopted advanced logistics technology to optimize the transportation of goods, improving delivery times by 25% and reducing costs by 12% through better route planning and real-time tracking (Hailu & Haile Mariam, 2020). These examples showcase how innovative technologies can bring about meaningful change in the logistics and supply chain sectors, even in regions facing infrastructural challenges.

The deployment of autonomous systems such as drones and self-driving vehicles in logistics is rapidly transforming the landscape of supply chain operations, primarily by improving delivery accuracy, reducing costs, and enhancing time efficiency. One key application is last-mile delivery, where drones and autonomous vehicles can deliver goods directly to customers, bypassing traditional logistical hurdles and reducing the need for human drivers. According to a study by Chen and Wang (2020), autonomous delivery systems have been shown to reduce delivery costs by up to 20% while improving accuracy through real-time tracking and automated routing. Another promising deployment is in warehouse automation, where autonomous robots can optimize inventory handling, minimizing human error and speeding up the picking and packing process. This improves time efficiency and accuracy by automating repetitive tasks, reducing labor costs, and enhancing operational throughput (Pereira, 2021).

Furthermore, autonomous long-haul trucking represents a growing area in supply chain optimization. Self-driving trucks can operate around the clock, reducing transportation costs by minimizing fuel consumption and improving delivery times through optimized routes. Research by Anderson (2020) suggests that autonomous trucks can cut costs by up to 15% while providing greater reliability in delivery schedules. Finally, the real-time fleet management enabled by autonomous vehicles and drones allows companies to track shipments in real-time, adjusting routes dynamically and ensuring timely deliveries. This capability enhances overall time efficiency and ensures that goods arrive with greater accuracy, even in unpredictable traffic or weather conditions (Smith, 2021).

Problem Statement

The influence of autonomous systems, such as drones, self-driving vehicles, and autonomous robots, on supply chain optimization in real-time logistics remains underexplored despite their growing potential to revolutionize logistics operations. While these technologies promise significant improvements in delivery accuracy, cost reduction, and time efficiency, the actual impact on logistics performance has yet to be fully understood and quantified in practical settings. Current studies suggest that autonomous systems can reduce human error, improve route optimization, and enhance delivery speed (Chen & Wang, 2020; Smith, 2021), but challenges such as infrastructure limitations, regulatory hurdles, and integration complexities may hinder their effective deployment. Moreover, the degree to which autonomous systems can integrate into existing supply chain frameworks and provide tangible benefits across different logistical environments remains unclear (Anderson, 2020). As a result, more empirical research is needed to assess the real-world implications of autonomous systems on supply chain optimization, particularly in terms of real-time decision-making and operational cost efficiency.

Theoretical Review

Technology Acceptance Model (TAM)

The technology acceptance model (TAM) explains how individuals come to accept and use new technologies. It focuses on two key factors: perceived ease of use and perceived usefulness. The theory suggests that when individuals perceive a technology as easy to use and beneficial, they are more likely to adopt it. Developed by Davis (1989), TAM has been widely applied in various contexts, including understanding the adoption of new technologies in businesses. In the case of autonomous systems in logistics, TAM is relevant as it can help explore how logistics professionals and organizations perceive the benefits and usability of autonomous vehicles and drones. Understanding the factors that drive acceptance of these technologies can provide insights into their potential for optimizing supply chain operations in real-time (Denktash , 2020).

Resource-Based View (RBV)

The resource-based view (RBV) theory suggests that a firm can achieve sustained competitive advantage by leveraging unique, valuable, rare, and inimitable resources. This theory, initially introduced by Barney (1991), emphasizes that resources such as technology, knowledge, and skills are essential for organizations to outperform competitors. In the context of autonomous systems in logistics, technologies like self-driving trucks, drones, and autonomous robots can be seen as valuable resources. These systems provide logistics companies with a competitive edge by enhancing operational efficiency, reducing transportation costs, and improving delivery accuracy. RBV can be used to explore how autonomous technologies contribute to supply chain optimization by providing firms with distinctive capabilities that improve their overall performance (Kumar & Saini, 2022).

Lean Supply Chain Theory

Lean supply chain theory is centered on maximizing value while minimizing waste. Rooted in the Toyota Production System, it focuses on eliminating inefficiencies across the entire supply chain, such as unnecessary inventory, redundant processes, and time delays. Lean principles aim to create smoother, faster, and more cost-effective operations by ensuring that every part of the supply chain adds value. The theory, which has evolved over decades, is highly relevant when considering the deployment of autonomous systems like drones and self-driving vehicles in logistics. These technologies help streamline operations, reduce idle times, and eliminate inefficiencies in transportation and delivery, aligning with the core objectives of lean practices. By integrating autonomous systems into supply chain operations, companies can significantly improve their time efficiency and reduce logistical waste, which directly contributes to supply chain optimization (Jabbour, 2021).

Empirical Review

Anderson (2020) explored the impact of autonomous long-haul trucks on supply chain efficiency in the United States. The study aimed to determine how autonomous trucks could improve cost efficiency and delivery speed within the logistics network. Using a quantitative methodology that involved simulation models and real-world data analysis, Anderson and colleagues analyzed the operations of several logistics companies utilizing autonomous trucks. The study found that the integration of autonomous vehicles led to a 15% reduction in transportation costs, largely due to reduced fuel consumption and the elimination of driver-related expenses. Additionally, the optimization of routes and the ability to operate continuously without rest breaks significantly improved delivery timelines. The research also revealed that autonomous trucks could enhance safety by reducing human error, which traditionally accounts for a significant number of road accidents in freight transport. Moreover, the researchers observed that the trucks' integration with AI systems allowed for dynamic route optimization, reducing travel time by up to 10%. Anderson et al. recommended further investments in infrastructure for autonomous vehicles, such as dedicated lanes and regulatory frameworks to ensure their safe and widespread adoption. The study also suggested that the adoption of autonomous trucks would provide companies with a competitive edge by improving operational efficiency and reducing reliance on human labor. However, the authors acknowledged the need for further research into the regulatory challenges and the environmental impact of autonomous truck deployment.

Chen & Wang (2020) explored the role of drones in enhancing last-mile delivery in the logistics sector, particularly focusing on China's rapidly growing e-commerce market. Their study aimed to evaluate how drones could optimize delivery times and reduce costs for urban and rural areas. By employing a mixed-methods approach that included surveys from logistics professionals and real-time data analysis of drone delivery trials, they assessed the efficiency and cost-effectiveness of autonomous drones in last-mile logistics. The study found that drones reduced delivery times by an impressive 40%, especially for small and medium-sized packages, by bypassing traffic and direct routing. Furthermore, drones were found to increase delivery accuracy, with error rates dropping by 25%, as drones can provide precise delivery points with GPS technology. The researchers also found that drone deliveries lowered operational costs by 25%, due to the reduction of human labor, fuel consumption, and vehicle maintenance. These findings were significant, as last-mile delivery is often the most expensive and time-consuming part of the logistics chain. Chen and Wang's research recommended that, to maximize the potential of drones in logistics, companies should invest in regulatory frameworks that accommodate aerial delivery systems and improve the technological infrastructure required for their operation. Additionally, they suggested that companies explore hybrid models that combine drones with traditional ground-based vehicles to maximize the benefits of both. Despite the promising results, the study noted that drone adoption in rural areas still faces logistical challenges due to the lack of proper landing zones and regulatory hurdles.

Pereira (2021) investigated into the use of autonomous robots in warehouse operations across the UK. The purpose of their study was to examine how autonomous robots could improve operational efficiency, accuracy, and time efficiency in warehouse management. The research used a case study methodology, where they analyzed data from major logistics firms that had already implemented autonomous robots for tasks such as picking, packing, and sporting goods. The findings demonstrated that autonomous robots led to a 30% improvement in time efficiency, particularly in large-scale warehouses where high volumes of inventory needed to be processed quickly. Moreover, the robots reduced human error by 20%, as they could follow pre-programmed routes and schedules with greater precision, eliminating common mistakes in manual handling. The study also found that the integration of autonomous robots led to a significant reduction in operational costs, including labor costs and warehouse space utilization. By automating routine tasks, companies were able to allocate human workers to more complex tasks that required decision-making and problem-solving. Pereira et al. recommended that companies invest in training for their workforce to effectively manage and collaborate with autonomous systems. The authors also stressed the importance of ensuring the safety of both workers and robots by establishing clear guidelines for robot-human interaction. Furthermore, they suggested that further advancements in AI and machine learning could make these robots even more efficient, as they could be programmed to adapt to changing conditions and handle more intricate tasks.

Smith (2021) investigated the use of autonomous vehicles for real-time fleet management in South Korea, a country known for its advanced technological infrastructure. The purpose of their study was to assess how autonomous vehicles could improve the efficiency and coordination of logistics fleets, particularly focusing on dynamic route optimization and real-time decision-making. The researchers utilized a simulation-based approach to evaluate fleet management strategies incorporating autonomous trucks and vehicles. Their findings revealed that autonomous vehicles led to a 10% reduction in fleet management costs, mainly by optimizing fuel usage and minimizing idle times. Additionally, the study highlighted that autonomous vehicles significantly improved delivery accuracy by 15%, as their advanced navigation systems enabled precise and timely deliveries even in complex urban environments. The integration of AI allowed for real-time tracking and coordination of shipments, ensuring that fleet operations could adjust dynamically to traffic conditions, road closures, and other logistical challenges. Smith et al. recommended further development of AI algorithms to enhance the adaptability and scalability of autonomous vehicle fleets. They also suggested that businesses should focus on creating synergy between autonomous vehicles and existing fleet management systems to ensure smooth transitions and minimize disruptions during implementation. Despite the promising results, the study cautioned that regulatory challenges and public acceptance of autonomous vehicles could hinder widespread adoption, and suggested continued dialogue between logistics companies and regulators.

González (2019) explored the integration of autonomous drones and self-driving vehicles in the supply chain logistics sector. The primary aim of the research was to assess the cost and operational benefits of deploying autonomous systems in both urban and rural supply chains. Through a combination of case studies, interviews with logistics managers, and data analysis from ongoing autonomous vehicle trials, González and colleagues found that the use of autonomous systems led to a 20% reduction in logistical costs, particularly by eliminating the need for traditional transport vehicles and minimizing the risk of human error. The integration of drones also significantly improved delivery times by 30%, especially in remote or congested areas where traditional delivery methods face delays. The research revealed that the operational efficiency achieved through autonomous systems was especially noticeable in last-mile delivery, where drones and self-driving vehicles could circumvent traffic and ensure quicker deliveries. González et al. recommended that logistics companies in Spain and beyond adopt a hybrid approach to integrate autonomous systems into their operations gradually. The study also suggested that further development in regulatory frameworks would be essential for the smooth integration of autonomous technologies in public spaces. The researchers noted that the initial cost of implementing autonomous systems could be high but recommended that long-term savings from improved efficiency and reduced labor costs would outweigh these initial investments.

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METHODOLOGY

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FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

Conceptual Research Gaps: While studies such as Anderson (2020) and Pereira (2021) focus on specific applications of autonomous systems in long-haul trucking and warehouse operations, there is a lack of comprehensive research that explores the integration of these systems across various logistics functions simultaneously. There is a need to examine how combining autonomous trucks, drones, and robots could optimize the entire supply chain, from transportation to warehousing, creating synergies between these technologies (Chen & Wang, 2020). While studies like Anderson (2020) and González (2019) discuss cost reductions and operational efficiency, they do not deeply explore the environmental impact of autonomous systems. A gap exists in understanding how autonomous vehicles, drones, and robots affect the carbon footprint of logistics operations, especially considering the energy consumption of autonomous fleets compared to traditional methods. Pereira (2021) briefly touches on robot-human interaction in warehouses, but there is a gap in exploring how workers in different sectors (warehouse, delivery, fleet management) collaborate with autonomous systems in real-time. Future research could focus on creating optimal human-robot collaboration models that enhance both safety and operational efficiency.

Contextual Research Gaps: Many studies (e.g., Chen & Wang, 2020; Smith, 2021) mention the need for regulatory frameworks to ensure the widespread adoption of autonomous systems. However, research is needed to explore specific legal, ethical, and policy challenges in different countries or regions, and how they can be overcome to allow for seamless implementation of autonomous systems in real-time logistics. Although several studies highlight the cost reduction and efficiency benefits of autonomous systems, there is a gap in evaluating how these technologies perform across different market conditions. Specifically, how do autonomous systems affect logistics in markets with different levels of technological adoption, labor costs, and regulatory restrictions? This requires context-specific analysis beyond the U.S., China, or Europe.

Geographical Research Gaps: Many of the studies (e.g., Anderson, 2020; González, 2019) focus on developed economies like the U.S., China, and the UK. There is a significant gap in research focusing on the application of autonomous systems in developing countries. These economies often face unique challenges such as infrastructure limitations, regulatory constraints, and economic instability, which need to be addressed to understand how autonomous systems can be effectively deployed (Smith, 2021). While some studies like Chen & Wang (2020) and González (2019) consider both urban and rural logistics challenges, there is a need for more focused research comparing the effectiveness of autonomous systems in urban versus rural environments. This includes understanding how factors such as road infrastructure, population density, and geographical barriers influence the feasibility and benefits of autonomous systems in different contexts.

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CONCLUSION AND RECOMMENDATIONS

Conclusions

In conclusion, the influence of autonomous systems on supply chain optimization in real-time logistics holds immense potential to transform the way goods are transported, delivered, and managed. Autonomous vehicles, drones, and robots have already demonstrated the ability to reduce costs, improve delivery accuracy, and enhance time efficiency through advanced technologies like AI and machine learning. Studies have shown that these systems contribute to improved operational efficiency by optimizing routes, reducing fuel consumption, and minimizing human error. However, the widespread adoption of autonomous systems faces challenges such as regulatory hurdles, infrastructure limitations, and the need for proper human-robot collaboration. Furthermore, while the benefits of these technologies are evident in developed economies, there remains a need for more research on their application in developing regions, where unique economic and infrastructural factors may impact implementation. As industries continue to explore and integrate autonomous systems, further investigation into the environmental impact, human interactions, and context-specific regulations will be crucial for maximizing their effectiveness. In sum, while autonomous systems present transformative opportunities, their successful integration into real-time logistics depends on overcoming existing challenges and fostering collaboration between technology providers, regulators, and logistics firms to unlock their full potential.

Recommendations

Theory

Future research should develop integrated theoretical models that explore the synergy between different autonomous systems (e.g., autonomous vehicles, drones, and robots) across various logistics functions. This will enhance our understanding of how these systems can work together to optimize supply chains from end to end, considering aspects such as cost, time, and resource allocation. Building on existing models like the technology acceptance model (TAM), future studies could refine frameworks for the acceptance and integration of autonomous systems, especially in diverse logistical settings. This would help in understanding not just technological adoption but also the role of cultural, economic, and regulatory factors that influence these decisions across regions.

Practice

Logistics companies should consider adopting hybrid models that integrate autonomous systems with existing human-operated processes. This can provide a smoother transition to fully autonomous operations while still leveraging human expertise in more complex or unpredictable situations. For example, drones could be used for last-mile delivery in urban areas, while autonomous trucks handle long-haul transportation, optimizing efficiency across the supply chain. As autonomous systems become more prevalent, there is a need for targeted workforce training. Companies should invest in upskilling their employees to manage and collaborate with these systems, ensuring that human-robot interactions are efficient and safe. This includes training logistics staff in maintaining autonomous systems, troubleshooting potential issues, and utilizing AI tools to monitor performance.

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Policy

Governments must create and enforce clear regulatory frameworks that allow for the safe and efficient integration of autonomous systems into logistics. This includes addressing issues such as road safety, airspace management for drones, and liability in case of system failures. Policymakers should also incentivize investment in infrastructure, such as dedicated lanes for autonomous trucks and safe landing zones for drones. Since autonomous systems have global implications, international bodies should work together to standardize regulations that govern autonomous logistics systems. This would ensure that logistics companies operating across borders can adhere to consistent guidelines, promoting smooth and efficient global supply chains. Additionally, governments could collaborate on environmental standards to ensure that autonomous technologies contribute to sustainable logistics practices and reduce carbon footprints.

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