CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

A literature review plays a critical role in any research study as a basis of knowledge on what is considered to be literature existing in the field, the gaps and lastly the research questions. In this chapter, we explore existing work and focus on delivery route optimization in e-commerce logistics. The need for efficient and cost-effective delivery system has become a tough issue that businesses face as e commerce continues to grow. This problem can be addressed with understanding the existing theory and practice of optimization techniques, such as linear programming and its use in transportation and logistics. The objective of this chapter is to fill the gaps in current studies and systematically analyze relevant literature in order to establish theory for our study. The structure for this chapter is built into several sections. In the first section of the study, the conceptual framework is provided, the key concepts and theories that frame the study are identified. The work on the following sections focuses on existing research about delivery route optimization, challenges within e-commerce logistics, and the application of linear programming models. Finally, the chapter also identifies research gaps and suggests directions in which novel insights will be brought to the field. At the end of this review, the chapter will have shed light of the academic and practical underpinnings of this research, and highlight the need for more research on how linear programming methods can be harnessed to optimized delivery routes in e-commerce.

2.2 E-Commerce

Ecommerce meaning, electronic commerce is when you buy or sell something online. Where traditional retail has failed, e-commerce has succeeded: Convenience, variety and accessibility have become easily accessible to consumers (Osaragi et al., 2023a). Customers can place a product order anywhere in the world, have it delivered to their doorsteps within hours to days and all with just a few clicks. The growing phenomenon of customers switching from inanimate to animating their shopping behavior and the corresponding need for improved supply chain network efficiency has enabled online marketplaces, specialized retailers, and direct to consumer brands to leverage on efficient delivery systems in order to meet expectations and continue to remain competitive (Kim et al., 2024a). Digital platforms, payment gateways, warehousing and logistics (Mallari et al., 2023a) are some of the interconnected components to the e-commerce ecosystem. Some of these are very important, chief among which are logistics and delivery for fulfilling customer orders. In contrast to regular retail, in e-commerce customers visit a business's website, but nothing comes to them. The delivery operations have become more complex and important. Efficient logistics ensures that delivering customer orders at the right time and in the right condition reduces customer satisfaction, as inefficiency results in delays, damaged goods, and higher costs that will damage the business's reputation (van der Gaast et al., 2019a).

The nature of online transactions lends itself well to delivery in e commerce. The products customer's purchase doesn't arrive in the customers' hands immediately, customers do not have immediate access to what they have purchased; instead, they depend on a delivery system to fill the gap between what customers buy online and when customers buy and receive the products offline (Oršič et al., 2022a). For e-commerce companies, delivery has become the 'moment of truth' — the promise of a fast turnaround and low price is either kept or broken. As a result, delivery performance is a crucial component of building trust, loyalty and repeat business (Alrasheed et al., 2024a). Based on the concept of last-mile delivery, the relationship between e-commerce and delivery is even more developed. Last mile is the last leg to which the product is delivered, almost to the end user. The stage is usually the most expensive and logistically challenging part of the delivery chain (Elvas et al., 2023a). Last mile delivery is important because such factors as urban congestion, scattered delivery locations, and time sensitive customer demands make the e-commerce logistics a key focus area of the innovation and optimization (Khalili-Fard et al., 2024a).

New delivery models, as with e-commerce, have also been adopted to deal with last mile delivery challenges. Among such drivers are same day delivery, crowd source delivery, and use of technology driven tools such as drones and autonomous vehicle (Haripriya & Ganesan, 2022a). Same day delivery is a nice luxury of instant gratification, but you need a highly efficient logistics network to do it. Gig workers, however, are used by crowd-sourced delivery platforms such as Uber Eats and Instacart to keep delivery options flexible, particularly grocery and essential deliveries. As emerging technologies such as drones offer faster and cheaper solutions for rural and hard to reach areas (Chen et al., 2024a). Integration of real time tracking and communication is another critical aspect of e commerce delivery. Today's delivery systems are souped up with technologies enabling customers to track their orders in real time, giving them an insight into exactly what is happening with their order along the journey (Amini & Haughton, 2023a). It makes online purchases less anxiety inducing and gives customers the confidence of knowing when to expect it. Real Time data is of huge benefit to businesses for planning and optimization of routes, and also minimizes fuel consumption and maximizes delivery efficiency (Hamid et al., 2023a).

E-commerce and delivery have become more and more about what happens after sustainability has been considered. Higher volumes of waste packaging because of increased online shopping, and higher emissions of carbon from delivery vehicles (Sanchez et al., 2024a). To tackle these problems, many e-commerce companies are embracing the concept of eco-friendly measures like using recyclable packaging, switching to electric vehicle fleets and maximizing deliveries so that their fuel consumption is kept to a minimum. In addition to cutting down environmental impact, environmentally conscious consumers (Lee et al., 2023a). find practice in sustainable delivery practices satisfying. But the growth of e-commerce was accelerated by the COVID-19 pandemic and renewed delivery systems around the world. But lockdowns and social distancing encouraged unprecedented online shopping, driving an increase in the demand for delivery services (Gu et al., 2023a). So, e-commerce companies were suddenly expected to scale their logistics operations and add safety measures, such as contactless deliveries and stay at home protocols. Crisis (citation) has underscored the importance of delivery systems to guarantee continuity of commerce and deliver to the consumer's needs.

The consequences of e-commerce delivery are huge economically. Competitive pricing and growth decisions are possible with reduced operational costs achieved through efficient delivery systems (Osaragi et al., 2023a). However, poorly designed delivery operations can waste away your profit margin, especially those small and medium sized enterprises (SMEs) whose operations are at the brink of breaking even. Delivery costs are extremely costly for e-commerce companies and are a portion of their total logistical budget. Controlling such costs through optimizing delivery routes, and utilizing technology, will increase profitability for businesses (Oršič et al., 2022a). Moreover, the relationship of e-commerce with delivery is dynamic, while a new relationship between the two is being developed. Advancement in and integration of the New Technologies (such as artificial intelligence, machine learning, and Internet of Things [IoT]) has changed delivery systems by providing Smart and more Automations (Alrasheed et al., 2024a). Fors example, predictive analytics can predict demand and optimize inventory placement so that there is less distance and time involved in deliveries. Real time Information is provided by IoT devices that are deployed inside the vehicles and inside the packages, which can be used to predict the delivery accuracy and efficiency (Elvas et al., 2023a) .These innovations are remaking the future of e-commerce logistics, faster, more reliable, and more sustainable.

2.3 **Delivery Route Optimization**

Delivery Route Optimization has been rich in literature that propels the need to deploy effective routing mechanics to reduce costs; minimize travel time; and improve service quality in logistics. This research has been focused on how to solve challenges in route planning, vehicle utilization and sustainability while incorporating advanced technologies such as artificial intelligence and IoT. Optimization of the delivery route has been solved by the emergence of the linear programming and mixed integer linear programming models as fundamental tools. The applications these models have for handling vehicle routing problems (VRPs) of minimizing operational costs and route selection have proven to be very effective. However, deterministic inputs often limit their adaptability to changing environments, e.g., urban traffic or changeable demand patterns (Haripriya & Ganesan, 2022a). These models are further advanced in extending them to include stochastic variables in order to address uncertainties to better fit into real world scenarios.

Many metaheuristic algorithms such as, Ant Colony Optimization Algorithm and Genetic algorithms have a great impact while solving more complex route optimization issues in delivery services. The strength of these methods lies in the ability to search large solution spaces, which fits the VRP well considering the numerous constraints possible, such as time windows and carrying capacity of a vehicle. However, metaheuristics present robust solution offering aggressiveness in solving problems at the cost of computational times hence unsuitable for real-time decision-making situations particularly in high density urban logistics networks (Sanchez et al., 2024a). Another key characteristic known as dynamic and adaptive routing models has emerged as key in meeting the demand observed in on-demand delivery solutions. Such models also take information from IoT devices when routing the delivery information in the real time fashion depending on traffic conditions, weather conditions and priority of the delivery. This innovation is best illustrated by dynamic truck-drone routing models, which incorporate drones for last-mile delivery leading to reduced delivery time and operating expense. However, some restrictions like the limited payload of the drones and the regulatory restraints that are still in place, slow down the usage of drones further (source). A blend of conventional vehicle and the advanced technologies appears to be an effective strategy to improving routes. There is clear evidence and proof that integrating trucks, tricycles, and drones in supply chain reduces costs and is sustainable, especially in the last-mile delivery. These multi-fleet systems facilitate free and dynamic routing in a way that solves problems with access to zones in large cities. However, the major challenge with managing heterogeneous fleets is still the coordination of the different vehicles (Amini & Haughton, 2023a).

Delivery route optimization is a topic that has received heightened concern over the years in particular when it comes to the integration of sustainability principles into the systems. Calculating realistic and operational electric and hybrid vehicles' emission factor, the green vehicle routing models enlighten logistics decision making with an idea to decrease carbon emissions. Extended this approach through Closed-Loop Supply Chain manages the reverse logistics for recycling of the resources. These strategies conform to various global sustainability initiatives; however, their practical application implies significant investments in infrastructure and the careful calculation of the costs of production in regard to their influence on the environment (Osaragi et al., 2023a). Delivery route optimization has been enhanced through the IoT and cyber-physical systems since the technology brings real-time data for decision making. These technologies increase awareness of logistics processes and facilitate real-time alteration of routes, as well as rationalization of resource usage. Remote dispatching and tracking using IoT is taken to the next level by cloud-based logistics systems that harness complex computational algorithms to further improve optimization of logistics across large networks. Nevertheless, these systems are usually hampered by high implementation costs as well as the necessity of a stable digital environment (Mallari et al., 2023a). The delivery route optimization was the first to receive a touch of the blockchain and, more recently, of artificial intelligence. Blockchain brings accountability and visibility in logistics while AI improves prescriptive analysis in the long-run planning for routes and approximate demand. These technologies have proved their readiness to enhance delivery efficiency together with customers' satisfaction. However, these studied start-ups face limitations in terms of accessibility because of the high initial costs, and the technicality of the equipment (Hamid et al., 2023a).

Innovative approaches to delivery route optimization by sustainability focused hybrid models have been introduced. Electric vehicles, drones, and tricycles are integrated with these models into logistics networks, reducing environmental impact while preserving the network operation efficiency. For the multi-fleet delivery problem model, the use of the complementary strengths of the different vehicle types also shows impressive improvement in last mile logistics efficiency. But there are problems with coordination of the fleet and infrastructure requirements (Gu et al., 2023b). Optimizing on-demand logistics systems with variable demand patterns requires continuous route adjustments, and hence dynamic algorithms have been crucial in optimizing these systems. Such algorithms are effective in the high delivery density domain, where timely and cheap deliveries were a priority. Yet they perform poorly in suburban and rural areas, where delivery volumes are lower and travel distance longer, resulting in higher operational costs (Chen et al., 2024b).

Vehicle routing problems on large scales are complicated by their computational complexity and scalability demand. To handle these challenges, heuristic methods, especially large neighborhood search methods, have been developed for efficient route optimization for thousands of delivery points. However, despite such good performance under controlled conditions, these methods are not suitable to real time variables, like traffic and demand fluctuations (Kim et al., 2024b).

The integration of real time data in with advanced algorithms gives cloud-based logistics systems the ability to optimize delivery routes across wide swaths of a network. They help better resource allocation, route planning and price determination, which cuts delivery times and associated costs. Despite that, they are limited in applicability in regions with inadequate technological development (Lee et al., 2023b). Regardless of which kind of research examines the delivery route optimization, operational efficiency, cost, and environmental sustainability, all research emphasizes the trade-offs. While Linear Programming serves as a strong foundation, convergence of latest technologies such as IoT, AI, and Blockchain, provide options to address current constraints. The literature suggests the need for the use of hybrid approaches which are a combination of traditional and emerging logistics methods to provide a more complete and sustainable logistics solution (Oršič et al., 2022b). Table 2.1 summarized the current research on delivery optimization.

Table 2.1: Summary of Related Literature

Title and Year	Methodology	Strengths	Weaknesses
Multi-Fleet Collaboration Model (2024)	Mixed Integer Linear Programming	Enhanced last-mile efficiency through multi-vehicle	Infrastructure and coordination complexities

		collaboration	
Dynamic Truck-Drone Routing (2023)	Dynamic Routing Algorithm	Reduced costs and improved flexibility	Limited by drone payload and battery life
Polling-Based Milk-Run System (2019)	Linear Programming	Optimized warehouse and delivery operations	Scalability challenges
Cloud-Based Logistics System (2023)	IoT and Ant Colony Optimization	Real-time dynamic routing	High initial setup costs
Green Vehicle Routing (2024)	Closed-Loop Supply Chain	Reduced emissions and integrated recycling	Operational complexities
Disruptive Technologies in Last-Mile Delivery (2023)	AI, Blockchain, IoT	Enhanced transparency and efficiency	High technical expertise required
Large-Scale VRP with Hard Time Windows (2022)	Heuristic and Robust Optimization	Effective for large datasets	Real-time adaptability limitations
On-Demand Logistics Systems (2023)	Dynamic Algorithms	Managed variable demand efficiently	Urban scalability challenges
Cyber-Physical Logistics System (2023)	IoT and Cloud Computing	Improved order allocation and cost savings	Dependency on cloud infrastructure
Hybrid Delivery Models (2024)	Mixed Integer Programming	Reduced carbon footprint	Significant infrastructure investment

2.4 Linear Programming

Linear Programming is a commonly used mathematical technique, which solves the problems consisting of linear relationships of the decision variables. Because today's problem is almost always to do with logistics, it is very useful in this case, where you want to minimize costs, optimize delivery routes, or otherwise increase efficiency. Thus, logistics planners would choose their optimal solutions to an objective function constrained within a set of given linear constraints. Such logistical models are known as LP models. LP has been heavily used in solving vehicle routing problems (VRPs) in delivery route optimization. Delivery vehicle routes in these problems must look for the cheapest way to deliver goods subject to vehicle capacities, delivery time windows and customer demands. Unlike LP, its deterministic nature guarantees solutions with a high degree of accuracy in well-defined conditions, making it the perfect choice for static routing those cases whose input parameters remain constant.

In predicted cases (for example, firm demand, known travel times), the deterministic nature of LP gives a huge advantage. It's a way to optimize to an exact point, which means we'll get the best possible outcome that works within the constraints. For instance, we demonstrated successful adoption of LP technique in optimizing warehouse operations and delivery schedules in polling-based milk run system for reduced travel distance and operational costs. Nevertheless, the rigidity of LP in dealing with uncertainties often restricts its use in dynamic and complicated logistics system. LP does not have a direct ability to model nonlinear relationship. Finally, many real-world logistics scenarios involve nonlinear factors, e.g., variable fuel consumption, traffic congestion and changing customer demand. To cope with these challenges, researchers have combined linear program with stochastic elements, or hybridized linear program with other optimization techniques. With these enhancements LP is able to incorporate these uncertainties and real-world complexities more effectively.

The limitation of using standard LP has been overcome with hybrid approaches that combines LP with metaheuristic algorithms such as genetic algorithms and ant colony optimization. These hybrid models combine the precision of LP to solve deterministic parts of the problem and metaheuristic methods to explore potentially larger scales. They have been particularly effective for the solution of large scale VRPs with thousands of delivery points. As with multi-fleet logistics systems, there are many different vehicle types involved: Trucks, drones, and, even, tricycles, for example, for last mile delivery. Fleet allocation and route planning is done by using LP models to optimize cost efficiency and on time delivery. Coordination of heterogeneous fleets introduces more complexities and, in many cases, supplementary algorithms are needed to confront these issues sufficiently.

Also, LP has been integrated with the IoT enabled system and its applicability has been expanded in the dynamic logistical set up. LP models can be fed with real time data from IoT devices such as traffic conditions, vehicle's locations and statuses of the delivery in order to adjust routes dynamically. Through the combination, the logistics providers have been able to satisfactorily respond to the change in conditions, thus maintaining the higher efficiency and service quality. LP has become a central focus area in logistics, and sustainability has become a key focus area, of which green vehicle routing is essential. Lastly, such models have taken environmental constraints, such as emissions as well as energy consumption into consideration to design eco-friendly delivery routes. LP provides logistics companies the ability to optimize their operations whilst balancing economic and ecological goals, aligning with the global sustainability goals. Unfortunately implementing these models often depends on huge investments in green technologies and infrastructure.

On demand logistics needs are addressed by dynamic routing models with LP. These models integrate real time data and adaptive constraints so that even in fluctuating demand scenarios, these models provide optimal routing decisions. For example, dynamic truck drone routing systems employ LP to optimize resource allocation so as to respond to changing operational conditions. Computational challenges in large scale LP applications result due to exponential growth of variables and constraints. With the purpose of improving the scalability of LP models, researchers developed the advanced computational techniques like parallel processing, decomposition methods. Because of these enhancements, LP can address large scale logistics networks comprising multiple depots and delivery points. LP's application to closed loop supply chains, where the goal is to maximize the return and recycling of products in reverse logistics settings. These models both optimize use of resources and reduce waste towards a circular economy. That said, the forward and reverse logistics are not easy to manage simultaneously.

The modeling advantage of LP is in the fact that it can handle multi objective optimization problems. This capability gives flexibility to manage cost, delivery time and resources simultaneously in logistics. Since this set of Pareto optimal solutions are provided by multi objective LP models, decision makers can pick up the optimum trade off using their priorities. Considering the integration of LP with blockchain technology, new dimensions have been brought into logistics optimization. Blockchain provides both transparency and traceability throughout the supply chain, while LP models find a way to allocate and route resources which optimize. Such a combination increases reliability and efficiency of logistics operations, in particular when several actors are involved.

However, although its strengths, LP often depends on high quality input data for effective implementation. Absent accurate or incomplete data, suboptimal solutions can result from them. By offering real-time high-fidelity data for an LP model, IoT and big data analytics are essential to address this challenge. Evolution of LP also has been influenced by the advancement of machine learning. Through incorporating the predictive analytics, LP model can predict supply pattern and optimize logistics operation beforehand. Together this tailors LP for more dynamically changing environments, which better aligns with contemporary logistics issues. Commencing with internal internship programs, LP has been key to optimizing warehouse operations, especially in product allocation and order picking. LP modeling the movement of goods in warehouses can help mitigate time spent handling goods and in doing so help improve overall efficiency. The use of LP to address different aspects of supply chain is illustrated by these applications.

The repeatability is ensured by the deterministic nature of LP, and the reliability is also essential to logistics planning and decision making. It does, however, offer a limitation in highly volatile environments. For this, researchers are studying such adaptive LP models that make use of feedback mechanisms that react to changing conditions dynamically. There has been the use of LP models to solve for the resource and route allocation in logistics networks with several depots. Through these models we guarantee balanced utilization of the depots and vehicles, lowering total costs and improving service levels. Managing inter depot dependencies, however, introduces additional complexities which require advanced modelling techniques. However, integration of LP with emerging technologies including autonomous vehicles and drones is the future of LP in logistics ambits. The resulting technologies produce large amounts of data, which can be readily exploited by LP models to bring about real-time optimization. These advancements allow us to leverage them and, in so doing, to continue to use LP to transform the way logistics is done. As a result, LP continues to be a fundamental tool in delivery route optimization, providing precision, scalability and flexibility. Scaling, data requirements and integration complexities are hurdles, but ongoing research and technological progress is solving them. LP is likely to remain a key piece of the functioning of modern logistics optimization by making use of hybrid approaches and leveraging real time data and emerging technologies.

2.5 Application of Linear Programming

It has been widely used to solve problems in the field of logistics and delivery optimization with solutions that are precise as for almost any operational problem. A deterministic nature results in providing reliable results which is why a problem like route planning, resource allocation, cost minimization problems in delivery systems are addressed using this. Based on case studies and real-world applications, this discussion explores various applications of LP in logistics. Vehicle routing problems (VRPs) are problems that contain the objective of determining the least costly routes for a fleet of vehicles to deliver goods, and LP models are the key to solving them. These models are constrained by vehicle capacity, delivery time window, and customer demand, with maximal utilization of the resource (Amini & Haughton, 2023b). In one such instance, LP was successfully used to determine the routes for a multi hub VRP, to minimize the operations costs and travel times (Gu et al., 2023b).

LP has been applied to minimize order fulfillment cost in e-commerce logistics. For example, the polling-based milk run system which has LP used for product allocation and delivery schedule optimization. However, underlying this application is reduced travel distance and improved warehouse efficiency with scalability to large networks remaining elusive. Dynamic routing systems also use LP to adapt to real time conditions. LP models dynamically adjust routes with changing conditions by incorporating traffic and delivery status IoT enabled data. In particular, this application is relevant to the field of urban logistics because of the additional challenges of traffic congestion and unpredictable demand (Chen et al., 2024b).

As an important application, LP is also discussed in the green vehicle routing. The goal of these models is to minimize environmental impact of logistics operations in both fuel consumption and emissions. By including constraints associated with vehicle emissions and energy use, LP allows logistics providers to create eco-friendly delivery routes in line with sustainability concerns (Haripriya & Ganesan, 2022b). Many studies of last mile delivery optimization have employed LP models to allocate resources efficiently, delivering items on time and at the lowest cost possible. LP is used for coordinating operations of multi-fleet logistics systems with various vehicle types, e.g., trucks, drones, and bicycles. The balancing out of each class’s strengths remains the focus of this application which acknowledges cost and delivery efficiency (van der Gaast et al., 2019b). Closed loop supply chains have been optimized using LP on both forward and reverse logistics. The supply chain includes these models for recycling process and reuse processes, which would combine to create efficient resource utilization. For instance, LP was employed to determine how to collect and transport used products for recycling in a circular economy (Sanchez et al., 2024b).

In the warehousing field, LP models have been applied on space, inventory, and order picking. These applications decrease handling time and increase general effectiveness, especially in the large volume e-Commerce profiling centres. Through simulation of flow of stock within the warehouse, LP facilitates efficient, effective, and optimum use of the available space and other physical resources (Mallari et al., 2023b). LP has also be integrated with predictive analytics to forecast the tendency of demand to precede on and take necessary measure on routing plan set in advance. In addition, it makes the models easy to predict the logistics demand in the future and optimize the logistics operations. This application is especially valuable in industries where demand is seasonal, i.e. it varies considerably (Gu et al., 2023b). In the context LP integrated with the blockchain has improved the visibility and accountability of logistics processes. Blockchain brings data integrity for supply chain data exchange and LP is to make the right decisions on how resources are allocated and where they need to go. This combination has been used in such areas as the pharmaceutical industry where traceability is essential (refer).

In healthcare logistics, LP models have been used to optimize the distribution of medical supplies and vaccines. These applications ensure equitable distribution while minimizing transportation costs and delivery times. During the COVID-19 pandemic, LP was instrumental in designing distribution networks for vaccine delivery under stringent time constraints (Osaragi et al., 2023b).

They have applied LP to disaster logistics for the purpose of supplying relief supplies. By modeling the availability of resources and transportation networks, resources for essential goods to be delivered to affected areas are demonstrated to be available on time. In terms of urgent delivery patterns and limited resources (Amini & Haughton, 2023b), this application is critical. For example, LP is used in agricultural logistics to make the optimum arrangements for the transportation of perishable goods. But these models will consider shelf life and how the products should be stored so they get to their destinations in optimal condition. By minimizing waste and better pricing for farmers and distributors (Elvas et al., 2023b), this application does just that. Energy logistics has also been addressed by LP which optimizes the distribution of fuel and energy resources. LP builds supply and demand models across multiple locations, optimizing allocation of energy resources (Lee et al., 2023b) with reductions in transportation costs and corresponding environmental impact.

LP models have been applied to solving the scheduling problems and inventory replenishment in retail logistics. LP integrates data of sales patterns and inventory levels to ensure products get delivered to the retail outlets in a timely and cost-efficient manner (Oršič et al., 2022b). LP is used in international shipping and freight logistics for the purpose of maximizing unit carrying cost considering the labor hours associated with container loading and routing. In large scale global supply chains(Hamid et al., 2023b), these models provide efficient utilization of shipping space with minimal transportation costs. LP has been applied to optimize the integration of different transportation modes (i.e., road, rail, and sea) in multi-modal transportation systems. The models provide a means for capping modes associated with seamless transitions between modes to reduce overall transportation time and cost. Public transportation systems are optimized with the application of LP in urban logistics. LP solves efficient use of resources and minimizes commuters' waiting times by modeling passenger demands and transportation capacities (Khalili-Fard et al., 2024b).

By example, in the automotive industry, LP has been employed to solve the problem of supplying the spare parts to dealerships and service centers. Through these models, parts will be made available in a timely fashion and will help minimize downtime while improving customer satisfaction. In the last case, LP has been applied to telecommunications logistics problem of the optimization of the installation and maintenance of network infrastructure. In large scale network deployments (Mallari et al., 2023b), these models guarantee efficient resource allocation and low operational costs. In Table 2.2 we summarized the application of LP in various fields.

Table 2.2 Summary of Application of Linear Programming

Area of Application	**Purpose**
Vehicle Routing Problems	Optimize routes, minimize costs, and improve resource utilization
E-commerce Logistics	Streamline order fulfillment and warehouse operations
Dynamic Routing Systems	Adjust routes in real-time based on traffic and demand changes
Green Vehicle Routing	Reduce fuel consumption and emissions
Last-Mile Delivery	Allocate resources efficiently for timely deliveries

Closed-Loop Supply Chains	Optimize forward and reverse logistics for recycling and reuse
Warehousing	Optimize space allocation, inventory, and order picking
Predictive Analytics	Forecast demand and proactively optimize delivery routes
Blockchain Integration	Enhance transparency and traceability in supply chains
Healthcare Logistics	Distribute medical supplies and vaccines efficiently
Disaster Logistics	Deliver relief supplies to affected areas
Agricultural Logistics	Transport perishable goods while minimizing waste
Energy Logistics	Distribute fuel and energy resources efficiently
Retail Logistics	Optimize delivery schedules and inventory replenishment
International Shipping	Optimize container loading and global routing
Multi-modal Transportation	Integrate multiple transportation modes seamlessly
Urban Logistics	Optimize public transportation systems
Automotive Logistics	Distribute spare parts to service centers and dealerships
Telecommunications	Optimize installation and maintenance of network infrastructure

2.6 E-Commerce and Delivery Route Challenges

Having been transformed into a global retail arena, e-commerce is now offering consumers greater convenience. But as with every transformation, this came with its own set of logistical challenges — most notably in delivery route optimization. Alongside the growth of online shopping, the need for fast, accurate and economical delivery has been skyrocketing, leading to intensifying pressure on logistics providers to discover new ways to optimize their operations. Last mile logistics is one of the most complex parts of e-commerce delivery. This last mile delivery is the last leg of the delivery process where goods are being transported from a local hub to the customer's doorstep. This stage is expensive and time consuming and may represent up to 53 percent of total delivery costs (Elvas et al., 2023b). With urban congestion, scattered delivery points and customer specific time windows at the distributed edge of complex logistics networks, route optimization is a key challenge facing e commerce businesses. Delivery route planning becomes further complicated by dynamic demand fluctuations. Unlike retail, e-commerce has very variable demand patterns, which can be highly variable with promotional events, holidays, and sales campaign. And these fluctuations require adaptive routing systems, that respond to changes in the order volumes and delivery locations (help fill citation). If left untreated, it can result in delays, higher costs and angry customers.

From same day to next day delivery service, it has made things more complicated. Thus, logistics providers must optimize routes minimizing travel time to achieve desired pickups and deliveries within a specified period. This balance can only be reached with strict time constraints with the help of sophisticated algorithms, like linear programming and heuristic approaches (Haripriya & Ganesan, 2022b). One of the most urgent challenges in e-commerce logistics is environmental sustainability. More deliveries mean more carbon emissions and more resource consumption. To address these issues, logistics providers must integrate green vehicle routing strategies including the use of electric vehicles, consumption of fuel, which may be reduced by consolidation of deliveries. Nevertheless, these strategies are quite challenging to implement as they involve large investments in infrastructure and technology (Amini & Haughton, 2023b). Compounding this problem is the fact that logistics operations are expected to meet the rising trend of customer expectations for real time tracking and transparency. Today's consumers need visibility into the status of their delivery, creating the demand for IoT enabled tracking systems. While these systems help improve customer satisfaction and logistics operational efficiency, they also prompt data security and privacy concerns logistics providers must deal with (Mallari et al., 2023b).

Traffic congestion, and lack of parking spaces in urban environments, makes this a unique challenge faced by these environments. Because these factors, advanced optimization techniques, such as dynamic routing algorithms using real time traffic data, are necessary. In addition, urban logistics barriers are also going to be bound by innovative delivery methods (e.g., drones, autonomous vehicles), although they are still hindered by regulatory hurdles (Khalili-Fard et al., 2024b). Where infrastructure is less developed and delivery densities are lower, other challenges exist. The cost long travel distances and the limited number of delivery points increases unnecessarily and diminishes efficiency. To resolve these challenges logistics providers often adapt hub and spoke models or use collaborative networks with local partners to determine optimizing delivery routes (Hamid et al., 2023b). With the rise in mobile channels retailing and multi-channel retailing, the delivery operations is becoming more complex. Advanced IT infrastructure and some kind of seamless data integration (Alrasheed et al., 2024b) is needed to coordinate orders across these channels and integrate them into a unified delivery system. ECommerce has another critical challenge of managing returns, or as it is referred in logistics, reverse logistics. In categories like apparel and electronics, high return rates add route allocation complexity. Dealing with reverse logistics from pickups, you must optimize the routes and integrate it into your forward logistics, in a way that will minimize your costs or improve your efficiency.

The need for recurring delivery has arrived with the rapid adoption of subscription-based e-commerce models, such as meal kits and curated boxes. Fixed delivery schedules are a requirement of these models; yet, ad-hoc orders must be incorporated to ensure route efficiency. The balance described is dependent upon predictive analytics and demand forecasting tools (van der Gaast et al., 2019b). Cross border logistics has become a focus as global e commerce expansion occurs. The art of managing international deliveries consists of overcoming cumbersome regulatory requirements, customs procedures and diverse transportation networks. Robust planning and coordination are needed to minimise delays and costs (Gu et al., 2023b) when optimizing delivery routes across borders. Ecommerce logistics optimization is largely data driven, and that is becoming a cornerstone. Analytics of big data allow logistics providers to find patterns, forecast demand and optimize routes. While sound, data collection and management systems are required, however, this creates a reliance on high quality data that is not achievable for all. Poor routing decision and inefficiencies can be caused by inaccurate or incomplete data. Artificial intelligence (AI) and machine learning integration in logistics operations has changed the way delivery route optimization is made. The most important thing is these technologies support predictive routing, dynamic adjustment and anomaly detection, improving operational efficiency greatly. However, small logistics providers face challenges to adoption due to high implementation costs and demand for technical expertise in implementing AI driven systems (Haripriya & Ganesan, 2022b).

For the past years, delivery logistics played a critical role and have come to the forefront in ensuring supply chain continued. The surge in online orders saw lock down and social distancing measures stress existing logistics systems. To scale, companies had to quickly adapt by optimizing routes and enhancing the capability to handle increased volumes, and by implementing contactless deliveries. Logistics providers have shown to have collaborated in resolving the challenges of e-commerce delivery. Route efficiency and cost can be improved through shared delivery networks, in which a variety of companies join to pool resources and infrastructure. Nevertheless, these models rely on trust, data sharing, and coordinate mechanisms that can be robust (Kim et al., 2024b). Other dimension of route optimization are the customer preferences for flexible delivery options like time slot delivery and other pickup locations. But there are operational constraints they must balance against these preferences so the logistics provider can deliver with a reasonable price as well as in a timely manner. This challenge requires dynamic scheduling and customer centric algorithms. Route optimization is made more complex when seasons of increased orders are considered. In peak times, logistics providers must maintain a level of efficiency through scale. These fluctuations are managed by means of temporary hubs, flexible workforce models and advanced routing algorithms(Alrasheed et al., 2024b).

E-commerce logistics are opening doors for drones and autonomous vehicles to revolutionize delivery operations. Traditionally, these technologies may remove barriers such as traffic congestion and shortages of parking. Though, this adoption must first overcome battery life, payload capacity, and regulatory compliance challenges (Gu et al., 2023b). E commerce delivery still poses a central challenge in cost management. Continuous optimization of routes, resources, and delivery methods, in a competitive pricing environment, is necessary to maintain adequate balance between operational efficiency and pressure from competitive pricing. LP and metaheuristic algorithms offer logistics providers the advanced technologies needed to attain this balance and achieve profitability in a competitive market (Khalili-Fard et al., 2024b). Logistics providers, technology developers and policymakers must work together to come up with innovative solutions to deeply intertwined e-commerce and delivery route challenges. To achieve this, we must address these challenges in effective ways so that the e-commerce ecosystem will continue to grow and be sustainable.

2.7. Literature Discussion and Findings

Delivery route optimization has long relied on Linear Programming (LP) to furnish deterministic and precise solutions. Although the traditional LP approaches have their limitations, such as increasing complexity of the logistics system, evolving customer demands and technological advancements, the traditional LP approaches have been used. Gaps in addressing these need to be addressed to increase the applicability and efficiency of LP in modern logistics. Static data and deterministic models are one of LP's major limitations. Traditional LP takes fixed input parameters including demand, travel distance and costs. However, certain assumptions made in the model are usually unrealistic in dynamic logistic environments, where variables such as traffic, weather and customers preferences are always changing. Improvement to the real time adaptability is a critical challenge; the ability to integrate dynamic data sources into LP models (Lee et al., 2023b). LP is scalable perhaps only for small scale problems. LP is superior to other approaches in small and moderate sized logistics networks, but systematically challenged by increases in the number of variables and constraints. This scalability limitation prevents its use in situations which involve large networks, such as global supply chains or urban logistics with thousands of delivery locations. To make LP scalable advanced computational techniques, such as parallel processing and decomposition methods are desirable(Amini & Haughton, 2023b).

A major limitation of LP lies in its inability to model nonlinear relationships directly. In many real-world logistics problems, however, factors are inherently nonlinear and include aspects like fuel consumption, vehicle wear and near, and variables behaviour with customers. These relationships are traditionally oversimplified in traditional LP, resulting in suboptimal solutions. To fill this gap, hybrid models integrating LP with other types of non-linear programming, or machine learning, are needed (van der Gaast et al., 2019b). With limited ability to handle uncertainties, LP models are regularly criticized. Operations of a logistics system are inherently complex owing to uncertainty, of which factors include fluctuating demand, unexpected delays and availability of resources. Promise for improving LP through phenomenological incorporation of probabilistic elements and uncertainty modelling is offered by stochastic programming and robust optimization (Hamid et al., 2023b). LP faces the opportunity as well as the challenge of integration with new technologies. Real time data and predictive capabilities of current IoT, AI and big data analytics play a valuable role to improve LP model. Unfortunately, advanced algorithms and infrastructure needs to be developed in many logistics systems for the integration of these technologies, but most have yet to evolve. It is necessary to develop frameworks that smoothly incorporate these technologies into LP models (Elvas et al., 2023b).

Moreover, environmental sustainability can also be improved for LP. Green vehicle routing models show the use of LP in minimizing emissions, but these models rarely consider the overall lifecycle of logistics operations. LP models need to be expanded to cover all comprehensive sustainability metrics, which include energy cost and waste management, to match with the global environmental goals (Kim et al., 2024b). There is yet another critical area for improving LP: incorporating multi objective optimization. Typically, logistics problems have conflicting objectives, for example minimizing costs while maximizing customer satisfaction, or minimizing delivery times. A single objective function, however, is its limitation in providing balance solutions as in traditional LP is the case. For example, Mult objective LP models can fill this gap by generating Pareto-optimal solutions allowing decisions makers to make trade-offs between different no estimable goals. We also identify the need for more user-friendly interfaces and decision support tools. Often perceived as complex and technical, LP models are often difficult to implement without special knowledge. LP is becoming more accessible to logistics managers and decision makers by simplifying the modelling process with user friendly software combined with visualization tools (Sanchez et al., 2024b).

Stakeholders' collaboration is essential to move LP applications forward. To deliver to people's demand, the logistics ecosystem, which is made up of the retailers, the logistics providers and the policymakers, is very dynamic and complex. Stakeholder diversity means LP models must address these heterogeneous stakeholders' needs and constraints through a collaboration framework between the need and constraint holders, based on shared data and objectives. Such embeddings will make LP framework more applicable in the multi stakeholder environments (Hamid et al., 2023b).

Another challenge in LP applications involves high dependency on high quality data. Bad or missing data leads to bad or missing solutions and inverness. Reliability of LP will be increased by ensuring data accuracy and consistency by means of robust data collection and pre-processing techniques (Oršič et al., 2022b). A need is growing to incorporate real-time decision-making tools into LP models. In modern logistics, even brief encounters with a dynamic environment, such as the urban delivery network, necessitate very quick route and schedule adjustments, which, in turn, demand a highly flexible transport service. Adding real time data processing and algorithmic adjustments to LP will substantially improve LP’s responsiveness and efficiency (Lee et al., 2023b). New applications of LP are emerging from advances in autonomous vehicles and drones. They produce enormous amounts of real time data that can be used to optimize delivery routes. Integrating autonomous systems into LP models, however, requires specialized algorithms which incorporate constraints specific to, for example, battery life, payload capacities, and regulatory restrictions (Khalili-Fard et al., 2024b).

The second area for improvement is interoperability with other optimization techniques. Genetic algorithms and ant colony optimization algorithms such as metaheuristics have been used in complex and large-scale problem approach. To overcome many of LP’s current limitations, hybrid models can be developed that combine the precision of LP and the exploratory properties of metaheuristics(Haripriya & Ganesan, 2022b). There has been relatively little focused on ethical considerations within logistics optimization. While LP models typically focus on cost and efficiency, this has the potential to lead to overlooking important ethical issues related to fair labour practices and equitable resource allocation. Ethical dimensions are incorporated inside LP models by which these instances become more suitable for the contemporary social corporate responsibility goals (Sanchez et al., 2024b). Since widespread adoption of LP application would require educating and training of logistics professionals, this is important. However, not all organizations possess the required expertise to carry out and exploit LP models effectively. The gap in knowledge that we can fill by providing accessible training programs and resources can enable broader and more efficient use of LP in logistics(Chen et al., 2024b).

A review is presented that shows although Linear Programming is the backbone of delivery route optimization, its effectiveness is limited due to infeasibility assumptions, scalability, and model of uncertainty limitations. Their lack of ability to overcome these gaps prevents its addressing the complexity of modern logistics in dynamic and large scale environments.

Towards enhancing LP's applicability, it is necessary to integrate real time data, multi objective optimization, and hybrid modelling approach. The LP industry needs to collaborate with yet emerging technologies such as IoT, AI, and autonomous systems in order to better serve the real world. Finally, LP models that address sustainability and ethical considerations strike a chord in both the catering industry and many of our society's current expectations.

The current limitations of LP should be overcome by future research on developing user-friendly tools, hybrid models as well as advanced computational techniques. Filling these gaps will continue to keep LP an essential component in logistics, and it will remain a vehicle for lifting the efficiency, sustainability and innovation in delivery optimization.

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