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Optimisation Of Transportation Networks Using Advanced SC Analytics: Implications For Managerial Accounting

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Abstract

Transportation networks are a critical component of modern SCs, enabling the efficient movement of goods across geographically dispersed markets. As global SCs become increasingly complex due to globalization, multi-modal transportation systems, and fluctuating demand patterns, organizations require advanced analytical approaches to improve logistics performance and cost efficiency. This review article examines The function of advanced chain of supplies analytics in optimizing transportation networks and explores its implications for managerial accounting practices. The study synthesizes existing literature on transportation network structures, analytical optimization models, and digital technologies such as artificial intelligence, big data analytics, machine learning, and blockchain. These technologies support data-driven decision-making by improving route optimization, demand forecasting, fleet management, and resource allocation within logistics systems. The review also highlights the importance of managerial accounting tools, including activity-based costing, performance measurement systems, and cost allocation frameworks, in evaluating transportation efficiency and supporting strategic financial planning. In addition, the paper discusses sustainability considerations in transportation networks, emphasizing green logistics strategies such as low-carbon transportation planning, eco-routing models, and environmental cost accounting. Despite the advantages of advanced analytics, organizations face several implementation challenges, including data quality issues, high technological investment costs, integration with legacy systems, and cybersecurity risks. The review concludes that integrating advanced SC analytics with managerial accounting frameworks can significantly enhance transportation network optimization, cost transparency, & SC management's strategic decision-making.

Keywords: Transportation networks, SC analytics, transportation optimization, managerial accounting, logistics sustainability

1. Introduction

Transportation networks make up an essential part of contemporary Supply Chain (SC) and provide transportation of raw materials and intermediate goods and final products across the geographically separated markets. In a more globalized economy, effective transportation systems would allow organizations to retain competitive advantage, as they contribute to the timely delivery of products, reduce operational delays and make use of resources in the most efficient manner. The need to manage SC networks has been exacerbated by the complexity of the modern SC, which has become the global sourcing, multi-modal forms of transport, and changing demand trends. With organizations extending their operations beyond national borders, transportation choices are turning out to be the most important key of the end-to-end SC performance and organizational profitability (Adeniran et al., 2024). The efficiency of transport is crucial in the operation of the logistics systems in the world. Good transportation networks lead to reduction of lead time, decreased distribution costs,

and increased service reliability which lead to better customer satisfaction and competitiveness in the market. There are several key performance indicators (KPIs) that are used to measure logistics efficiency, which include delivery time, cost efficiency, capacity utilization, and service quality. These indicators are used to track the performance of operations and find the opportunities to optimize these performances in the transportation systems (Anand and Grover, 2015). Moreover, movement operations have a major effect on the sustainability of the environment and economic performance, especially as companies endeavor to shift to green logistics. Transportation can be made more sustainable through efficient route optimization and energy-saving logistics processes to improve the economic performance and, at the same time, mitigate the effects on the environment (Agyabeng-Mensah et al., 2020).

The recent years witnessed the creation of advanced SC analytics that has revolutionized the operation of transportation networks. Advanced analytics is the use of technologies including optimization algorithms, machine learning, artificial intelligence (AI), and big data analytics to improve the SC operations in making decisions. The technologies assist organizations to quickly process the large volumes of operational data in real time and identify patterns, predict demand fluctuations, and optimize transportation paths and resource distribution. The adoption of digital technologies in the SC management has spawned the invention of data-driven logistics tools that can enhance efficiency, transparency, and responsiveness throughout the SC networks (Attaran, 2020). Moreover, real-time data analytics has also helped companies to continuously follow the performance of transportation, identify inefficiency, and take corrective measures to enhance responsiveness of the SC and operational efficiency (Alonge et al., 2023). Transportation optimization and logistics management are also the new spheres impacted by artificial intelligence and smart technologies. AI-based systems have the power to process complicated logistics data, to plan routes routinely and to assist in predictive decision making. These technologies enable the SC to be more efficient in terms of inventory management, better transportation schedules, and A proactive strategy for reducing risks. In dynamic business settings, the combination of AI-associated solutions with intelligent inventory management practices increases the stability of The chain of supplies and the functioning of business operations (Alshurideh et al., 2024). Thus, sophisticated analytics has now turned into a paramount facilitator of optimization of the transportation network within contemporary chains of supply.

Managerial accounting wise, transportation decision has major implications to cost management, budgeting and strategic planning. The importance of transportation costs can be considered as a significant part of the total expenditures on logistics, and this issue is a pressing concern of managerial accounting systems. To make informed decisions and utilize resources efficiently, the allocation of costs, performance measurement, as well as financial evaluation of transportation activities should be done correctly. Managerial accounting aids like activity-based costing, performance measurement systems and cost control mechanisms help organizations to determine the degree of effectiveness in transportation and recognize possibilities of minimizing costs. Improved financial planning associated with logistics operations can be obtained by combining transportation analytics and managerial accounting practices, which will provide firms with more precise insights on costs. Although the application of advanced analytics for SC management has increased, there is still a considerable gap in the literature about the implementation of transportation optimization analytics into managerial accounting philosophies. Most of the literature that is available is either the analytical model of transportation optimization or the managerial accounting technique of controlling costs, but little has been done concerning the combination of the two in strategic decision making. This disconnect limits the capacity of organizations to maximize the use of analytical knowledge in the process of financial and operational optimization of transportation networks.

Thus, the key aim of this review paper is to investigate how advanced SC analytics could be involved in optimization of transportation networks and to clarify its consequences on accounting practices of managers. In particular, the review will integrate the existing studies in the area of transportation network optimization models, logistics management based on analytics, and cost management frameworks to determine the main trends, issues, and opportunities of integration. This study aims at filling the gap between the SC analytics and managerial accounting domains and ensuring that the process of data-driven optimization of transportation can be used to make strategic decisions on the financial side. The rest of the paper is presented in the following way. The following section explains the conceptual basis of transportation networks and its use in the SC activities. Later sections discuss the use of advanced SC analytics in optimization of transportation and discuss the impact to managerial accounting systems. It then discusses the considerations on sustainability and implementation issues and ends in the conclusion with some of the key ideas and future research avenues.

2. Conceptual Foundations of Transportation Networks

2.1 Structure of Transportation Networks

2.1.1 Nodes, Links, Hubs, and Distribution Centers

Transportation networks are organized systems that make it possible to move goods through SCs by means of the interconnected physical and logistical elements. Such networks are made up of node networks, links networks, hubs and distribution centers which all together allow efficient logistics operations. Nodes are places of origin, storage, or delivery of goods, including manufacturing plants, warehouses, and retail stores ((Dolgui et al., 2018). The connection between these nodes is known as links which consist of highways, railways, shipping lanes and air corridors. Distribution centers and hubs play at the role of consolidation and redistribution, which optimize the logistics operations and improve coordination and efficiency in distribution processes, which assists organizations to handle the complex distribution system and resiliency in SCs of dynamic environment.

2.1.2 Multi-modal Transportation Systems

Multi-modal transportation systems encompass the combination of various modes of transport such as road, rail, maritime and air logistics to help in the movement of the goods along SC most efficiently. This strategy helps organizations to strike the balance between cost effectiveness, speed of delivery and environmental factors in designing transportation pathways ((de la Torre et al., 2021). As an illustration, long-distance deliveries can be done by rail and maritime transport because they are cost-effective and last-mile deliveries are managed with the help of road transport. Planning and decision-support systems are needed to coordinate various types of transportation. Multi-modal networks are also being appropriately managed using optimization and simulation models to improve on logistics effectiveness in various global SCs which are complex.

2.1.3 Network Flow Concepts

The network flow concepts give a theoretical and analytical base on how goods pass through the transportation networks. These ideas aim at ensuring the streams of goods in the origin to the destination are optimized at minimum costs and meeting the operations constraints in terms of transportation capacity, availability of available routes and delivery requirements. Shortest path algorithms, maximum flow models and minimum-cost flow optimization are mathematical models extensively applied in transportation planning. The use of such models enables the organizations to determine the most effective routing strategies and they also enable the organizations to allocate the logistics resources effectively. The availability of decision-making data backed by big data analytics also promotes the capacity of firms in optimizing the transportation network flows and developing value in the SC operations (Chen et al., 2015).

2.2 Evolution of Transportation Network Management

2.2.1 Traditional Logistics Models

The conventional transportation network management was based on the relatively simple logistics framework and manual planning mechanisms. The initial logistics systems were largely concerned with reduction of the direct transportation expenses by use of elementary routing and time scheduling choices. Nevertheless, such models could be typically poorly fed on limited data and were not provided with real-time insight into transportation operations. With the growth of global trade and the complexity of SCs, the old-fashioned logistics strategy was not applicable in responding to disruptions, changes in demand, and uncertainties in operations. The growing complexity of the global supply networks has also resulted in the necessity of both more sophisticated approaches to planning that can enable to handle dynamically changing logistics situations and enhance the responsiveness of the transportation systems.

2.2.2 Digitally Integrated SCs

The fast development of digital technologies has altered the management of transportation networks considerably as it has allowed developing the digitally integrated SCs. Cloud computing, big data analytics, and enterprise information systems among other technologies promote the smooth flow of information and coordination among SC partners. Digital integration provides organizations with the opportunity to gather and process high amounts of logistics data to enhance decision-making in terms of route planning, demand forecasting, and capacity utilization. Another benefit of these digital platforms is the improvement of visibility and transparency of SCs since it is possible to monitor transportation activities in real-time. Consequently, organizations are better placed to react to disruption and evolving market conditions with the global logistics networks.

2.2.3 Smart Logistics Ecosystems

Smart logistics ecosystems are the latest trend in the field of control over the transportation network, which is marked by the combination of intelligent technologies: artificial intelligence, Internet of Things (IoT), and sophisticated analytics (Chen et al., 2024). These technologies will allow tracking logistics operations in real time, analyze transportation disruptions in advance, and make routing decisions automatically. The use of intelligent transportation systems can also help in enhancing traffic management and carry out less congestion in urban logistic settings. With the use of AI-based analytics and digital infrastructure, companies can develop adaptive transportation networks that have the potential to enhance operational effectiveness and sustainability goals and resiliency of the SC in the long term.

2.3 Key Performance Indicators in Transportation Networks

2.3.1 Transportation Cost

One of the most significant indicators that can be used to assess the efficiency of logistics operations in SCs is transportation cost. Such expenses usually involve fuel expenses, labor expenses, vehicle maintenance expenses, infrastructure usage costs and administrative logistics expenses. The optimal design of the transportation network is designed to reduce these costs and ensure both high operational efficiency and service quality rates. With the help of the sophisticated analytical tools and optimization methods, organizations can grasp the opportunities to decrease the costs due to the optimization of the routes, loads, and better use of the fleets. Using the data-based methods of logistics, the companies will be able to decrease the needless transportation costs and lead to the improved financial outcome of the SC operations.

2.3.2 Delivery Lead Time

The lead time used to deliver goods can be defined as the time in which a good is taken to reach its final destination after leaving the point of origin. It is an essential indicator of responsiveness of the SC and it has a direct impact on customer satisfaction and quality of service. An effective transportation system should also be designed to decrease the lead time of delivery through better route planning, minimization of delays, and increase in the coordination of logistics partners. Traffic management technologies and intelligent transportation systems are significant in solving the problem of congestion and inefficient routes. Such technologies allow organizations to optimize transportation times and enhance delivery predictability over the logistics networks that become more complicated (Cheng et al., 2020).

2.3.3 Service Level and Sustainability Indicators

Measures of service level and sustainability have gained prominence as important measures of transportation network performance. Service level measures are normally used to gauge the reliability of delivery, on time delivery, and the general quality of the logistics services to the customers. Simultaneously, carbon emissions, energy usage, and environmental impact have become an indicator of sustainability which is increasingly being required because of growing regulatory and societal pressure to take up environmentally responsible logistics practices. The concept of sustainable transportation focuses on fuel-efficient cars, efficient route planning and consumption. These practices do not only promote environmental goals, but also promote overall long run operational effectiveness and competitiveness in the contemporary SC systems.

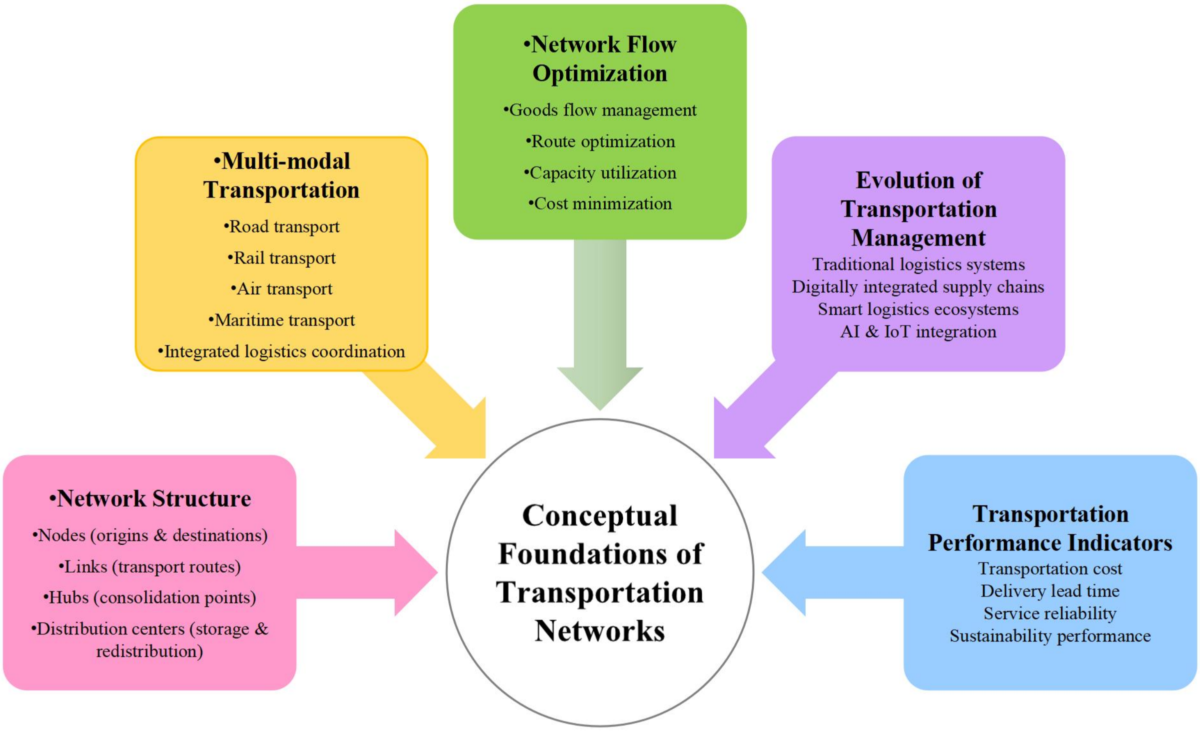

Figure 1. Conceptual Framework of Transportation Networks in SC Management

The important conceptual elements of transportation networks in the context of SCs are presented in figure 1. It emphasizes the elements of network structure that include nodes, links, hubs, and distribution centers, and multi-modal transportation systems. The model also gives the network flow optimization, development of transportation management, and transportation performance indicators that altogether affect the efficacy of logistics and SC performance.

3. Overview of SC Analytics

3.1 Dimensions of SC Analytics

3.1.1 Descriptive Analytics

SC analytics can be described as the systematic application of data, statistical techniques and models of analysis to aid in making decisions in the SC operation. Descriptive analytics is the first layer of SC analytics that involves the analysis of past data to establish the past SC performance. The organizations can establish the patterns in the logistics activities, flows of the inventory, and the performance of the transportation with the help of such methods as data visualization, reporting dashboards, and statistical summaries. Descriptive analytics allow managers to understand the areas of operational inefficiency and performance gaps in SCs. The historical data of logistics by analyzing this data, organizations can be more aware of demand issues, disruption of operations, and general trends in SC performance (Farooq et al., 2021).

3.1.2 Predictive Analytics

Predictive analytics refers to a series of products that goes beyond historical analysis in the sense that it relies on statistical models and machine learning algorithms to predict future outcomes of the SC. These models are used to analyze big data to determine trends, correlations, and patterns that can assist organizations predict any change in demand, disruption in supply, and delays in transport. Predictive analytics also comes in handy to enhance demand prediction, inventory management and SC logistics (Golan et al., 2020). Through predictive models, organizations will be able to take the initiative in making changes to production schedules, transportation plans and inventory to mitigate the operational risks. The recent literature on SC resilience and risk management in uncertain settings is connected to the more significant role of predictive analytics.

3.1.3 Prescriptive Analytics

Prescriptive analytics is the highest level of SC analytics, and it aims at suggesting the best decisions in the light of predictive data and optimization algorithms. This aspect involves complex SC issues that are determined through mathematical modeling, simulation, and decision-support systems to decide on the most desirable action to be taken. Prescriptive analytics have the potential to aid organizations to optimize transportation routes, resource allocation, disruption management of logistics networks (Hahn & Packowski, 2015). Prescriptive analytics allows managers to consider a variety of options by combining predictive forecasts and optimization algorithms and choosing strategies that will result in the highest operational efficiency and profitability. These sophisticated analytical models have become more significant in the latest SC decision making.

3.2 Role of Big Data in SC Optimization

3.2.1 Data Sources in Modern SCs

Big data has become one of the essential factors in the optimization of the SC as it provides organizations with extensive volumes of operating information based on various digital sources. The current logistics systems are producing massive amounts of data with the use of Internet of Things (IoT) sensors, RFID tags, GPS tracking devices, and enterprise resource planning (ERP) systems. These technologies record in-depth information on the shipment flow, stock levels, vehicle status and the activities in the warehouse. The combination of these data sources will help organizations to have a full picture of the SC activity and determine the possibilities of transportation efficiency and inventory optimization. Information-driven knowledge allows companies to improve the decision-making process, as well as enhance the overall flow of SC operations.

3.2.2 Real-Time Logistics Monitoring

Real-time monitoring of the logistics has become an essential facility of a contemporary SC management. Developed analytics solutions enable companies to monitor deliveries, observe the work of vehicles, and assess transportation parameters in real-time. This feature improves the visibility of the SC and allows the organizations to react quickly to the unforeseen disruptions like delays, equipment malfunctions, or changes in demand. Real-time monitoring further enhances the coordination between the SC partners because it offers the appropriate and precise information on the logistics operations in real-time. Under the conditions of intense dynamics in SCs, real-time information analysis becomes critically important in keeping all operations efficient and maintaining the delivery performance quality (Ha et al., 2023).

3.3 Technologies Driving Advanced Analytics

3.3.1 Artificial Intelligence and Machine Learning

Machine learning and artificial intelligence (AI) technologies have become the main elements of more advanced SC analytics. Organizations use these technologies to process large and complex data, recognize the unseen patterns, and make commitments and decisions automatically with the use of logistics systems. Machine learning will help find a better demand forecasting, manage transportation routes, and identify anomalies in the SCs. AI-based analytics can also be used to predictively maintain transportation assets and plan roads. With AI incorporated into SC management systems, organizations will be able to become more efficient in their operations, decrease costs, and increase the overall responsiveness of transportation and logistics networks.

3.3.2 Blockchain in Logistics Transparency

The blockchain technology has become a significant innovation to enhance transparency and trust in the operations of the SC. Blockchain environments form secure and decentralized digital registries that store transactions and logistics occurrences throughout SC networks. This technology enables the stakeholders to check the information on shipment, trace the origin of the products, and maintain integrity of the data during the logistics process. Blockchain can be used to eliminate information asymmetry and enhance coordination among the SC partners in transportation networks. Traceability and accountability of global logistics systems also improve through the application of blockchain, which leads to a better level of transparency as well as the reliability of operations in complex SCs (Gibassier & Schaltegger, 2015).

3.3.3 Cloud-Based Analytics Platforms

Cloud-based analytics systems have greatly increased the scale of SC analytics through the avenue of scalable computing systems and state-of-the-art data-processing software. These systems enable companies to store and process big amounts of logistics data with little to no on-premise IT infrastructure. Cloud computing aids in collaborative analytics through the sharing of data and insights between the SC partners across the borders of the organization. Also, cloud-based systems contribute to implementation of more sophisticated analytical models, such as machine learning algorithms and optimization tools (Table 1). The use of cloud-based analytics has enhanced the speed, flexibility, and access to SC data analysis, which organizations have been able to make better logistics decisions.

Table 1. Summary of SC Analytics Concepts

Section	Summary	Reference
Descriptive Analytics	Analyzes historical SC data to evaluate performance.	Farooq et al., 2021
Predictive Analytics	Forecasts demand, disruptions, and logistics outcomes.	Golan et al., 2020
Prescriptive Analytics	Recommends optimal decisions using optimization models.	Hahn & Packowski, 2015

Big Data Sources	IoT, RFID, GPS, and ERP generate logistics data.	Ha et al., 2023
Blockchain Transparency	Enhances traceability and secure data sharing.	Gibassier & Schaltegger, 2015

4. Analytical Models for Transportation Network Optimization

4.1 Classical Optimization Models

4.1.1 Linear Programming Models

Linear programming models are commonly employed in the optimization of the transportation network to efficiently distribute the resources and to reduce the costs of operation. These models are mathematical equations and constraints, which model the transportation flows, shipment quantities, and capacity constraints. Through these equations, organizations will be able to estimate the best routing and allocation strategies. Linear programming is a framework that offers systematic decision-support systems that enhance resource use and efficiency in large logistics systems (Jabbarzadeh et al., 2018).

4.1.2 Network Flow Models

Network flow models characterize the transportation systems as networks of nodes and links through which the goods move through the SC networks. These models aim at the maximization of product flow taking into account the constraints of capacity limitations and the demand of transportation. Some of the techniques, such as the shortest path and minimum-cost flow algorithms assist in determining effective routing decisions. Network flow optimization optimizes coordination of the logistics operations and the effectiveness of the intricate transport systems.

4.1.3 Transportation and Assignment Models

Classical methods of shipment and resource allocation across logistics networks involve transportation and assignment models. Transportation models establish the most economical manner of delivering goods among various suppliers to various destinations whilst assignment models assign particular resources like vehicles or routes to tasks. These analytical models facilitate effective decision making since they balance supply, demand and constraints of operation in the transportation systems.

4.2 Heuristic and Metaheuristic Approaches

4.2.1 Genetic Algorithms

Genetic algorithms are metaheuristic algorithms that are based on the evolutionary mechanisms of natural selection and genetic mutation. They are the algorithms that produce several solutions, which are potential solutions and then improved through refinement to achieve an approximate optimality of the transportation strategies. Genetic algorithms are especially applied to the solution of complex routing problems in logistics networks that can no longer be solved using traditional optimization models that can be computationally challenging. They have the flexibility that enables them to resolve multi-objective logistics problems based on uncertain operational conditions (Homayouni et al., 2023).

4.2.2 Ant Colony Optimization

The Ant colony optimization method is based on the foraging characteristic of ant, which hunts food by means of following the pheromone tracks. Artificial ants are used in the optimization process of a transportation network to mimic the exploration of routes with updated pheromone cues to find the most efficient routes. With time, the algorithm tends to narrow down to the best or close to the best paths. The method has been found useful in addressing the problems of vehicle routing and scheduling logistics in complicated distribution networks.

4.2.3 Simulated Annealing

Simulated annealing is a stochastic algorithmic optimization method which imitates the annealing process in metallurgy. The method finds the best solutions by examining alternatives of routing solutions and decreasing the likelihood of the less optimal solutions being accepted. This will enable the algorithm to come out of local optima and search more solution spaces. Simulated annealing especially applies to solving large scale transportation network problems with many constraints and high probability of uncertain operation.

4.2.4 Particle Swarm Optimization

Particle swarm optimization is an algorithm which is population-based and is based on the common movement of birds or fish. In this approach, it is the candidate solutions that pass through the search space and change their positions accordingly depending on personal experiences and the performance of their neighbouring solutions. The problem of transportation planning, vehicle routing and logistics scheduling, have been solved using particle swarm optimization. The approach is useful in addressing dynamic logistic problems in which fast decision-making is needed.

4.3 AI and Machine Learning Applications

4.3.1 Demand Forecasting Models

There is a significant role applied in artificial intelligence and machine learning models in enhancing demand forecasting in SCs. These models will examine the past sales record, market trends and operational variables to forecast the future demand trends. Proper forecasting allows the organizations to optimise transportation planning, inventory and resources allocation. AI-based forecasting models increase the responsiveness of the SC and minimize operational inefficiencies by enhancing the visibility of the demand (Hasan et al., 2024).

4.3.2 Route Optimization Using Reinforcement Learning

Reinforcement learning is a complex machine learning method which allows transport systems to gain knowledge of the best routing strategies in an environment of constant interaction with the operational environment. The algorithm takes into consideration the various routing choices on the basis of feedback in either rewards or penalties. The system also over time determines routes that cut on the duration of traveling, costs of operations and effects of congestions. Reinforcement learning has graduated as useful in controlling the dynamics of the logistics environment where the conditions evolve very quickly (Jackson et al., 2024).

4.3.3 Intelligent Fleet Management Systems

Smart fleet management systems are applied based on advanced analytics, real-time tracking, and decision-support tools that are based on AI to streamline the work of vehicles. Such systems monitor the position of the vehicles, the driver behaviour, fuel usage and also the maintenance needs in order to enhance the operations of the fleet. With the inclusion of machine learning algorithms, organizations will be able to optimize route planning and save on fuel costs, as well as generally increase efficiency in their logistics. Smart fleet systems are thus very important in the contemporary transportation network optimization.

4.4 Digital Twin and Simulation Models

4.4.1 Simulation-Based SC Optimization

Simulation-based models allow companies to develop virtual models of transportation networks and experiment with the various logistics strategies under controlled conditions. These models enable the decision-makers to understand the impact of the change in routing, capacity allocation or demand patterns on the transportation performance. Computer simulation is popular to test the working conditions and enhance the resilience of the SC. Simulation models can be used to facilitate strategic planning in the complicated logistics networks due to the ability of simulation to facilitate experimentation without risking the actual world.

4.4.2 Scenario Analysis and Risk Modelling

The analytical tools that are significant in the evaluation of the possible disruption in the transportation networks are scenario analysis and risk modeling. By using these approaches, organizations can study the impacts of uncertainties, including disruptions in supply, delays in transportation, or the fluctuation in demand. Through examination of other scenarios, managers can be able to create contingency strategies and enhance network resilience. Risk tracking and decision-making in the state of contemporary logistics are also enhanced by the latest technologies like blockchain and artificial intelligence (Hong and Xiao, 2024).

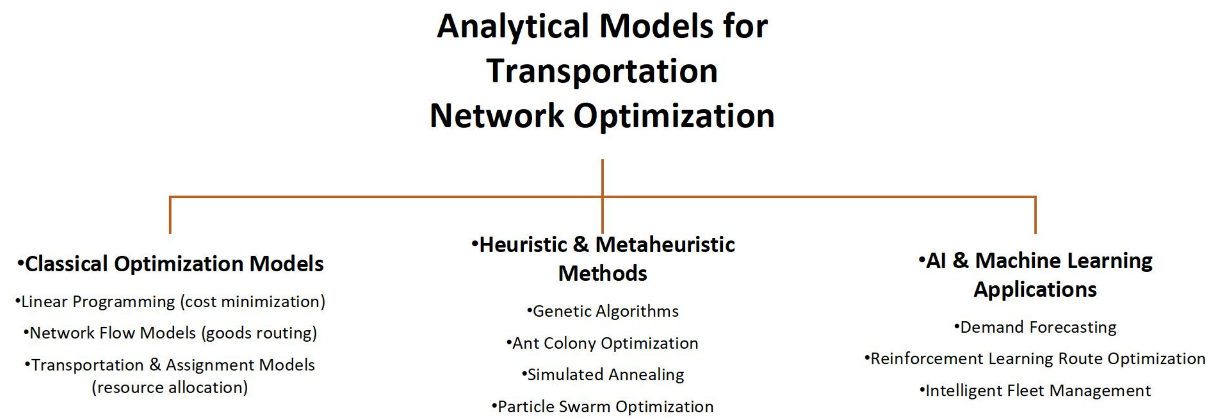

Figure 2. Analytical Models for Transportation Network Optimization

Figure 2 illustrates major analysis methods that are applied to the optimization of transportation network. Classical optimization models are concerned with cost and resource allocation. The heuristic and metaheuristic are efficient solutions to complex routing problems. Machine learning and artificial intelligence can be used to improve the efficiency of the logistics process and transportation decision-making by improving forecasting, route management, and fleet management.

5. Transportation Cost Structures and Managerial Accounting

5.1 Cost Components in Transportation Systems

5.1.1 Fixed Costs

Fixed costs are the costs that are fixed as long as the amount of transportation activities is present. These expenses incorporate transport infrastructure investments, purchasing of vehicles, warehouse centers, and technology that will be employed in the coordination of logistics (Mohsen, 2023). Fixed costs are a determining factor in the planning of a transportation network since they have an effect on the long term capitalization and operations in the network. Management of these costs needs proper financial planning and integration with the sophisticated SC technologies that enhance transparency of the costs and performance.

5.1.2 Variable Transportation Costs

Variable transportation costs vary according to the degree of activity of the logistics and the quantity of goods transported. These expenses are usually fuel consumption costs, toll fees, vehicle use, and shipment handling costs. These costs grow in line with transportation demand, and hence it is a major factor in the decisions of logistics. Data-driven analytics has become an effective tool to track and manage variable costs in organizations to plan their routes more efficiently and allocate transportation resources across SCs networks more efficiently (Lee and Mangalararaj, 2022).

5.1.3 Fuel and Maintenance Costs

Fuel and maintenance expenses are a major cost in the operation of the transportation systems. The consumption of fuel is also related to the route distance, traffic, and efficiency of the vehicle, whereas maintenance expenses are associated with regular servicing, repairs, and replacement of the equipment (Mehmood et al., 2017). These costs should be effectively monitored to enhance fleet efficiency and operational disruptions. Relying on the latest developments in data analytics and monitoring technologies enables logistics managers to monitor the performance of their vehicles, maximize the fuel consumption, and apply a certain number of predictive maintenance measures to improve the efficiency of transportation.

5.1.4 Labor Costs

The other significant element of transportation spending is labor costs which include wages, benefits and training of drivers, logistic coordinators and halls personnel. Effective workforce management is critical in ensuring that there is efficiency in the operations of the transportation networks. Companies need to strike a balance between the level of labor productivity and the quality of service delivery so as to achieve timely delivery and good logistics coordination. The use of advanced digital technologies and automation tools has further aided workforce planning and enhanced the efficiency of the operation in the transportation management.

5.2 Managerial Accounting Tools for Transportation Decision-Making

5.2.1 Activity-Based Costing (ABC)

Activity-Based Costing (ABC) is a managerial accounting system where the expenditures are distributed to the specific logistic activities through their resource usage. ABC in the transportation systems assists organizations to determine the actual cost of activities that include route planning, vehicle operations, shipment handling, and order processing. Tracing the costs to specific logistics functions allows the managers to get a better idea of the cost drivers and operational inefficiencies. This strategy allows making better decisions and enables organizations to optimize transportation and allocate resources (Nielsen, 2022).

5.2.2 Target Costing

Target costing is a cost management strategy that is centered towards attaining predetermined cost in the stages of planning of a product or service. Target costing in transportation management assists the organization to develop cost-effective logistics systems that yield service quality and operational efficiency. This strategy fosters cooperation between the members of the SC in order to eliminate unnecessary costs and enhance the performance of the logistics. Through cost planning as part of the SC design, companies are able to be competitive in terms of pricing and at the same time provide efficient transportation activities.

5.2.3 Standard Costing in Logistics

Standard costing is the process of setting fixed cost standards of transportation activity like shipping, consumption of fuel and use of vehicles. These standards enable organizations to determine the actual costs against estimated costs of logistics, so that managers can recognize inefficiencies and deviations in performance. Performance evaluation and budgetary control in transport networks use standard costing. With constant monitoring of cost changes, logistics managers will be able to take corrective measures which will enhance operational efficiency in the systems and cost discipline in transportation systems.

5.3 Cost Allocation in Multi-modal Transportation Networks

5.3.1 Cost Tracing Methodologies

Cost tracing techniques are critical to the proper distribution of transportation expenses in the multi-faceted logistics systems. These methodologies will include the identification of cost drivers, imposition of costs to certain transportation activities, routes or SC partners. Cost tracing is especially critical in multi-modal transportation systems since the goods are transported by a variety of transportation modes and distribution levels. The use of advanced analytics tools and digital technologies allows organizations to follow logistics operations step-by-step and enhance the cost transparency and more precise financial decision-making in the SC management (Kashem et al., 2023).

5.3.2 Inter-organizational Cost Management

Inter-organizational cost management prioritizes the management of cost control activities of more than one organization that is engaged in SC operations. In the transportation networks, collaboration between the suppliers, logistics provider and distributors are important in managing the shared transportation costs (Table 2). There is a digital technology that is applied to enhance transparency and information sharing among SC partners, e.g., blockchain and high-quality analytics platforms. The technologies assist organizations in aligning the cost management strategies, minimizing the inefficiencies, and raising the overall performance of the SC.

Table 2. Transportation Cost Structures and Managerial Accounting Summary

Aspect	Summary	Reference
Fixed costs	Infrastructure and vehicles.	Mohsen, 2023
Variable costs	Costs linked to transport activity.	Lee & Mangalaraj, 2022
Fuel & maintenance	Vehicle fuel and servicing.	Mehmood et al., 2017
Activity-based costing	Activity-based cost allocation.	Nielsen, 2022
Cost tracing	Cost allocation across routes/partners.	Kashem et al., 2023

6. Integration of SC Analytics with Managerial Accounting

6.1 Data-Driven Cost Management

6.1.1 Real-Time Cost Monitoring

The real-time cost monitoring has become one of the fundamental parts of the modern SC management as it allows organizations to monitor the expenditures on transportation as the logistics activities proceed. State-of-the-art analytics interfaces combine workload data of the transportation system which enable the managers to monitor cost changes dependant on such aspects as fuel consumption, route choice and delivery times. Constant observation of these financial indicators helps the organizations in identifying the inefficiencies and initiating corrective measures promptly. Financial transparency and enhancing managerial accounting use in logistics operations are enhanced through real-time monitoring (Olajide et al., 2020).

6.1.2 Analytics-Enabled Cost Forecasting

The predictive models and enhanced data analytics are analytics-enabled cost forecasting, which approximates upcoming logistics costs. These models are used to model the historical cost data, operational variables as well as the external market conditions in order to predict the transportation and distribution costs more precisely. Better budgeting and financial planning is also enabled through predictive analytics tools, as they are able to detect possible cost changes in the SC operation. The combination of AI and predictive models will greatly improve the precision of cost prediction and better decision-making by managers in the logistics systems (Nweje & Taiwo, 2025).

6.2 Performance Measurement Systems

6.2.1 Balanced Scorecard for Logistics Operations

The balanced scorecard framework is such that is common in the managerial accounting to assess the performance of the organization both financially and operationally. Balanced scorecard is a system that uses metrics about cost-efficiency, service quality, reliability of operations, and innovation in logistics operations. When logistics performance indicators are connected to financial results, the managers will be able to have a thorough overview of the effectiveness of the transportation network. Analytical platforms usage also increases the possibility to track these indicators and compare the performance of logistics with the overall organizational goals (Okolo et al., 2023).

6.2.2 Logistics Performance Dashboards

Logistics performance dashboards present graphical illustrations of important operational and monetary data pertaining to the transportation networks. Such dashboards incorporate real-time logistics information, making the managers track the performance of the deliveries, the costs of transportation, and the efficiency of operations all in one place. Dashboards enable faster and more effective decision making by simplifying complex data using user friendly visual formats. Dashboarding driven by analytics also aids in determining the trends of operation and areas of performance and hence the organizations with the help of analytics are able to keep on improving the logistics processes and ensure the performance of the SC is improved.

6.3 Strategic Decision Support

6.3.1 Route Selection Decisions

The SC analytics is also critical to aid in making consistent strategic choices on routes to be used in transport network. The sophisticated analytics instruments assess various routing options based on the parameters of transportation costs, delivery time, traffic conditions and operational risks. Through the analysis of these variables, organizations will be in a position to choose those routes that are efficient without compromising on service reliability. The information-based routing will provide more efficient logistics performance and minimized operations uncertainty, which will add value to the more efficient managerial accounting and transportation planning process.

6.3.2 Warehouse Location Planning

The warehouse location planning is a strategic logistic decision and it has a huge impact on the cost of transportation and efficiency of the SC. The analytical models assist the organizations to identify the best locations of warehouses basing on measures like transportation distances, demand distribution, and the availability of infrastructure. The combination of SC analytics allows managers to model the various location scenarios and determine the financial implication of such location scenarios. This data-oriented method enhances the cost allocation and aids in the long-term logistics planning in the multifaceted transportation networks (Okolo et al., 2021).

6.3.3 Transportation Outsourcing Decisions

The choice of transportation outsourcing is based on researching the potential to retain or outsource logistics operations to third-party logistics operations. The SC analytics aids in making these decisions through the analysis of SC operational expenses, availability of reliability in service, and the risks that may arise in case of outsourcing arrangements. Evaluations based on the data enable organizations to comparisons between the internal performance of logistics and external service providers. Nevertheless, the outsourcing decisions should also take into account possible cybersecurity risks and vulnerabilities of the transportation networks, the need to develop an effective solution to manage the risk and ensure the resilience of the SC.

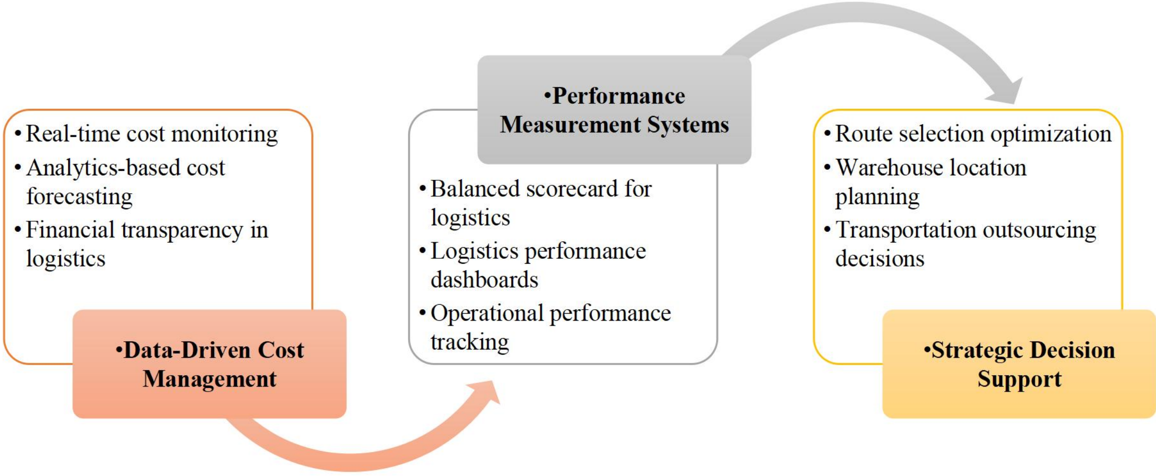

Figure 3. Integration of SC Analytics with Managerial Accounting

Figure 3 illustrates how managerial accounting is supported using SC analytics in logistics. Smart transportation cost management allows tracking and predicting transportation cost in real-time. The performance measurement systems are used to monitor the efficiency of operation using scorecards and dashboards. The insights can be used to make strategic decisions on route optimization, planning warehouse location, and outsourcing transportation to enhance performance of the SC.

7. Sustainability and Green Transportation Analytics

7.1 Environmental Impact of Transportation Networks

7.1.1 Carbon Emissions in Logistics Operations

The transport systems also play a significant role in environmental pollution by carbon emission as a result of logistic activities. The transport of freights, such as road, air, and marine transportation, generates significant greenhouse gases as a result of the use of fossil fuels. These emissions are environmental hazards and are part of the climate change concerns (Queiroz & Telles, 2018). Leading organizations are starting to adopt monitoring systems that are based on analytics to measure and control the amount of carbon emitted in transportation systems. The analytics of big data can help a firm to analyze its logistics and find ways of minimizing environmental effects and at the same time keeping its SC efficient.

7.1.2 Energy Consumption

Another major environmental problem that applies to transportation networks is energy usage. The logistic process consumes a lot of energy in the running of vehicles, working in warehouses and also in transit. Poor transportation paths and poor technologies of vehicles may add up the energy consumption and operation expenses. The sophisticated predictive analytics tools can enable the organizations to examine the pattern of the energy consumption and establish the way to enhance the energy efficiency in the logistics operations. Trying to minimize the use of fuel by optimizing transportation routes and fleets, firms can minimise the amount of energy needed and increase the sustainability of works of SCs (Onukwulu et al., 2023).

7.2 Green Logistics Optimization Models

7.2.1 Low-Carbon Transportation Planning

This is a low-carbon transportation planning that aims at designing logistics systems that do not have any or very little environmental impact and yet still efficient with regard to operations. Organizations are replacing their optimization models with those that consider the carbon emission limit in their transportation routes and logistics operations planning (Oncioiu et al., 2019). In selecting the best distribution strategies, the models put into consideration such factors as fuel consumption, vehicle efficiency, and transportation distance. Incorporating environmental concerns into the logistics planning process enables companies to enhance the level of sustainability performance, as well as competitive SC operations, and to decrease the level of environmental footprints.

7.2.2 Eco-Routing Models

Eco-routing models are developed to find transportation paths that ensure the reduction of fuel usage and environmental effects. Eco-routing models, unlike the standard routing techniques that consider only the speed or cost factor as a parameter, are environmentally aware and take into consideration, the emission of gases, fuel efficiency as well as the traffic conditions. The latest data analytics tools and online logistics can help companies consider alternative routes and choose those ones with less environmental implications. The application of eco-routing strategies can enable organizations to decrease the emission of greenhouse gas and yet, achieve an efficient logistics operation within the transportation networks.

7.3 Sustainability Reporting and Managerial Accounting

7.3.1 Environmental Cost Accounting

The environmental cost accounting gives attention to the identification and quantification of the environmental cost of the logistic operations and transportation operations. This accounting plan aids organizations to trace the costs associated with environmental control, energy usage and adherence to environmental regulations. By incorporating the environmental cost accounting within the managerial accounting systems, the companies can be able to have a better feel of the financial commitment of the sustainability projects. With efficient cost allocation techniques, organizations have the ability to spread the environmental expenses throughout the SCs and to make more informed decision-making with respect to sustainability (Panfilova et al., 2020).

7.3.2 Carbon Accounting in SCs

Carbon accounting is the process through which the emission by the greenhouse gases is measured and reported in the SC operations. Carbon accounting systems are used in the transportation networks to enable organizations to measure the amount of emissions produced in logistics activities and their efforts towards sustainability. By utilizing superior data analytics, the firms will have the ability to gather precise data on emissions and enhance the transparency in the environmental reporting (Table 3). The combination of carbon accounting and managerial accounting practices helps to make decisions that are more sustainable and persuade organizations to use logistics that are environmentally responsible.

Table 3. Sustainability in Transportation Networks

Aspect	Summary	Reference
Carbon emissions	Transport-related greenhouse gases.	Queiroz & Telles, 2018
Energy use	High energy demand in logistics.	Onukwulu et al., 2023
Low-carbon planning	Emission-reduction logistics design.	Oncioiu et al., 2019
Environmental accounting	Tracks environmental costs.	Panfilova et al., 2020

8. Industry Applications and Case Studies

8.1 Retail and E-commerce Logistics

8.1.1 Last-Mile Delivery Optimization

Last-mile delivery is one of the most challenging and expensive operations of retail and e-commerce logistics. It entails the delivery of products to distribution centers to the end consumers which may be within highly populated urban centers. Firms are turning to the use of digital technologies like IoT devices and data analytics to monitor shipments and streamline the delivery process. These technologies allow to plan routes better, coordinate the delivery vehicles, and better serve the customers, which increases the efficiency of the logistics of the e-commerce SCs (Sallam et al., 2023).

8.1.2 Real-Time Route Planning

The use of real-time route planning has become a necessity in the contemporary retail logistics as there are rising customer demands in speedy delivery. The most recent analytics and digital SCs can help logistics managers to view live traffic statuses, delivery plans and transportation limitations (Tiwari et al., 2024). This service will enable organizations to optimally modify the delivery routes as well as enhance efficiency in the operations. The increasing level of SC digitalization has considerably contributed to the improvement of the capacity of the companies to quickly react to the logistics issues and provide stable performance in delivery.

8.2 Manufacturing SCs

8.2.1 Integrated Production–Distribution Models

IPD models are essential in manufacturing SCs coordination in that they link production aspects with transportation and distribution. These models are used by manufacturers to match the production outputs with the logistics capacity so that products can be delivered to the distributors and customers as promptly as possible. Through a combination of transportation planning and manufacturing operations, the organizations are able to save costs associated with holding inventory as well as enhance efficiency of the SC. These models are also facilitated by the use of digital SC management systems that facilitate improved coordination in the production facility and the distribution channel.

8.3 Global Transportation Networks

8.3.1 Cross-Border Logistics Optimization

The optimization of cross-border logistics is aimed at enhancing the efficiency of the transportation networks, which work beyond the international borders. Global SCs need a good coordination of transportation pathways, custom systems, and regulations (Tariq, 2025). High-tech analytics and sustainable logistics practices help companies to streamline international transportation flows, reducing environmental effects to the minimum. The efficiency and sustainability of long-haul freight traffic in the global transport systems have also been increased with the development of low-carbon transportation corridors and new logistics technologies.

8.3.2 Trade and Transportation Policies

Trade and transportation policies are significant to the performance and sustainability of global logistic networks. The workings of the transportation systems in various areas are affected by government laws, environmental policies and international trade agreements. Green logistics and sustainable transportation are the trends currently being advocated by policymakers to minimize environmental effects. To be competitive and ensure compliance in global SC operations, organizations need to correspond their logistics strategies with regulatory requirements and sustainability targets (Trivellas et al., 2020).

9. Challenges in Implementing Advanced Transportation Analytics

9.1 Data Quality and Availability Issues

Availability and quality of data represent one of the biggest issues linked to the implementation of advanced transportation analytics. The transportation networks produce volumes of different operational data, but unstable data format, information gaps, and erroneous records might decrease the efficiency of analytical models (Wang et al., 2016). The low quality of data may result in wrong predictions and the low efficiency of logistics. Assurance of sound data gathering and integration between the SC systems is thus a requirement to successful implementation of analytics.

9.2 High Implementation Costs

Implementation of new transportation analytics is often associated with a high financial cost of using digital infrastructure, analytical tools, and skilled workers. To facilitate the logistics operations that rely on analytics, organizations need to invest in platforms, software, and technological upgrades that facilitate data management systems. These costs may amount to significant adoption obstacles, especially in the case of many firms, especially those that are small and medium-sized. The cost of implementation can be a barrier to the adoption of advanced analytics because of the costs involved, even though it has the potential to improve transportation efficiency and SC performance in the long-term (Türkay et al., 2016).

9.3 Integration with Legacy Systems

Most organizations have a logistics system that is based on an old infrastructure of information technology that may not readily be compatible with new analytics systems. To combine modern transportation analytics with the current systems, it may be both technically complicated and time-consuming. Old systems are not usually flexible enough to process real-time data and support complex models. Consequently, system upgrades and integration plans need a keen consideration by organizations to prevent any disruption or delays in the adoption of analytics tools in the current SC operations.

9.4 Organizational Resistance to Analytics Adoption

Organizational resistance to technological change is another problem that could arise during the implementation of transportation analytics. The adoption of analytics-based decision-making can be resisted by employees and managers because of the fear of job loss, new technologies, or alterations in the traditional ways of working. To end such resistance, there should be effective change management plans, training courses and support by leadership. Promoting an organizational culture that is based on data can assist companies to implement advanced analytics in transportation and logistics decisions successfully.

9.5 Cybersecurity Concerns

The growing use of online platforms and information-exchange systems within transport networks has brought about high cybersecurity issues. Sophisticated analytics systems can be based on integrated technologies and cloud-based systems, which can be compromised through cyberattacks and data losses. These risks may undermine the logistics activities and sensitive SC information. Companies should thus adopt effective cybersecurity systems and information protection measures to ensure protection of transportation analytics systems and operational resilience.

10. Future Research Directions

10.1 AI-Driven Autonomous Logistics Systems

The further advancements of transportation analytics are associated with the creation of AI-based autonomous logistics. It is a type of automation that is based on artificial intelligence, robotics, and advanced analytics to automate transportation processes including vehicle routing, warehouse management, and freight management. The efficiency, lower operational costs, and better decision-making under the conditions of dynamic SCs can be significantly improved (Zhang et al., 2023). Further studies are needed to solve the technological, regulatory, and operational issues related to the deployment of autonomous transportation systems on a large scale within a logistic network.

10.2 Integration of Blockchain and SC Analytics

The combination of blockchain technology and SC analytics is a potential field of study to enhance transparency and trust on the logistics networks. Blockchain offers decentralized and secure data storage that improves logistics transaction traceability and transportation activities. With the help of advanced analytics, blockchain systems would be able to help verify data better, coordinate partners of the SC, and monitor the logistics more effectively. Future researchers need to examine the potential of using blockchain-based analytics systems to enhance data safety and efficiency in transportation networks (Xu and Bo, 2024).

10.3 Sustainable Transportation Optimization Models

The concept of sustainability has emerged to be a burning issue in contemporary transport systems as more concerns relate to the environment and environmental regulations become a challenge. The next round of studies needs to be on integration of superior optimization model which considers both the environmental goals and the economic performance measures. These models are capable of assisting organizations to minimize carbon emissions, fuel consumption, and enhance energy efficiency in the operations of logistics. Researchers can also help in creating a more sustainable and resilient SC system by incorporating sustainability aspects in the transportation planning.

10.4 Real-Time Decision Support Systems

In the future, real-time decision support systems will be very important in transportation analytics. These systems offer immediate insights to logistics decisions using big data analytics and artificial intelligence combined with cloud computing. Real-time analytics allows managers to react immediately to any interruption like traffic jams, demand, and SC delays. Future studies can be conducted to investigate how smart decision-support systems could be designed to handle big data and provide practical solutions to transport network optimization.

10.5 Integration of Managerial Accounting with Predictive Analytics

The second research area to consider is the integration of the management accounting practices with predictive analytics tools. Predictive models have the potential to offer meaningful insights into the future costs and risks of logistics as well as requirements of resource allocation. Through the integration of predictive analytics into managerial accounting systems, organizations will be able to enhance financial planning and the level of strategic decision-making in transportation networks. The researchers are supposed to continue their work and examine how information-based accounting systems can facilitate better cost estimates and performance analysis within the framework of contemporary SC settings.

11. Conclusion

In the context of a modern SC, transportation networks are very important in terms of its performance and efficiency especially in an environment that is becoming more globalized and more digitally connected. This review has discussed the role of sophisticated SC analytics in optimization of transportation networks and the implications of the same on managerial accounting practices. The comparison has shown that analytical models, such as classical optimization methods, heuristics and artificial intelligence-based models are very important in improving transportation planning, routing efficiency, and resource utilization. Such technologies allow organizations to control the complicated logistic systems better and enhance the reliability of the services and costs of operations. Activity based costing tools, performance measurement systems and cost allocation methodology are some of the managerial accounting tools that help make informed financial decisions in mobility management. Even though there are great advantages to the use of healthcare analytics in transport, there are a number of challenges, such as poor quality of data, expensive implementation, legacy integration, organizational change, and data security. These issues will be critical in organizations aiming to leverage transportation systems based on analytics to the maximum. In future studies, the researchers are advised to put their interest in new technologies including autonomous logistic systems, blockchain-driven analytics capabilities, and real-time decision support systems to improve further optimization of the transportation network and strategic decision-making by the manager.

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