**Cargo Hitchhiking: A Public Transport-Integrated Model for Sustainable Urban Freight Logistics**

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# Abstract

Urgent population growth coupled with the exceptional rise of e-commerce operations has made urban freight logistics management more complex especially for last-mile delivery services. Urban metropolitan areas experience excessive traffic issues due to dedicated road transport which create environmental damage while reducing operational effectiveness. The proposed research integrates freight delivery operations into public transportation systems through which activity is called cargo hitchhiking or urban freight logistics.

The research evaluates the practicality and operational effectiveness together with environmental advantages of freight delivery systems through a worldwide examination of Amsterdam, London, Tokyo, Munich and Singapore. This research analyzes historical as well as contemporary implementation practices of public transport freight delivery while discussing operational aspects and evaluation of advantages and limitations for adoption. The examined research shows how these systems lead to emission reduction alongside cost reduction and better urban mobility together with effective last-mile delivery service.

The research utilizes simulation methods to create a model for freight distribution in urban retail operations through metro-bus network integration which considers delivery costs along with emission outputs operational capacity and scheduling constraints as key variables. The evaluation system includes CO₂ emission reductions alongside metrics for cost efficiency and delivery success rates as well as public transport utilization improvement evaluation.

The research shows that cargo hitchhiking leads to reductions of 20–40% in delivery expenses while offering up to 50% decreases in emissions together with major reductions in city traffic congestion. Significant hurdles persist in the implementation of advanced delivery systems because of limited infrastructure availability together with scheduling complications and regulatory requirements and public acceptance problems. AI scheduling together with smart compartments and IoT tracking along with supportive policy structures make the effective implementation possible according to study.

The research develops an organized model of transit-integrated freight systems to offer practical solutions which advance the development of sustainable and scalable urban delivery operations in urban logistics literature. The research identifies potential study directions which include single-firm real-world trials and research about AI optimization methods and user approval processes for developing urban logistics strategies.

*Keywords*: Urban Freight Logistics, Last-Mile Delivery, Public Transport Integration, Cargo Hitchhiking, Sustainable Urban Transport, Transit-Integrated Freight, Smart Urban Logistics, Simulation Modeling

# Chapter 1: Introduction

## 1.1 Need for Sustainable Freight Solutions

The urban logistics sector keeps expanding due to growing human population along with surge in e-commerce activities and requirements for optimized supply chain operations. The conventional freight transportation systems of cities encounter multiple persistent difficulties while cities continue their expansion because of limited sustainability and inefficiency. The sector encounters multiple operational obstacles composed of traffic congestion and environmental consequences and inefficient delivery to the final destination and strict regulatory requirements. Researchers and policymakers now seek creative responses to urban freight systems through public transit integration because this approach enhances product delivery efficiency together with diminished environmental and financial impacts (Heitz & Berthon, 2025).

### 1.1.1 Traffic Congestion and Infrastructure Strain

Urban logistics faces an acute challenge because of traffic congestion which stands as one of its key problems. The growth of online shopping resulted in substantial last-mile delivery volume growth which produced excessive delivery vehicles that now occupy urban centers. Research demonstrates that freight vehicles substantially increase urban traffic volumes which then generates transportation delays together with reduced system efficiency (Papa, Hribar, Petelin, & Vukasinovic, 2025). The worsened traffic congestion leads to longer delivery schedules and more fuel usage by vehicles along with increased business expenses.

The transportation of freight leads to both substantial greenhouse gas emission pollution and atmospheric contamination. The studies indicate that urban freight generates as much as 25% of CO₂ emissions in metropolitan areas (Alotaibi, Almasoudi, & Alqurashi, 2025). Logistics providers need to discover environmentally sustainable delivery options since governments enforce stronger environmental regulations. Public transport networks that move toward electric and hybrid fleets provide an effective solution to decrease emissions since these systems substitute individual delivery carriers with shared transportation infrastructure.

### 1.1.2 Inefficiencies in Last-Mile Delivery

The supply chain stage known as the “last-mile” constitutes the most difficult and costly part of the entire operational process. Data shows that the costs related to last-mile logistics make up half of the entire delivery expenses because of delivery failures and restricted parking spaces and splitting distribution networks (Chen, et al., 2025). Public transportation systems work to reinforce last-mile logistics when operators use existing transportation facilities and rendezvous points to connect stores with end-consumers.

### 1.1.3 Regulatory and Policy Challenges

Several cities have imposed limitations on vehicles and established zones for low emissions as well as charging systems for congestion management. The effectiveness of sustainability policies generates new operational obstacles for companies using conventional freight transportation methods. The combination of freight services with public transit networks provides a regulatory-compatible solution which maintains logistical efficiency (Hamedani, Aslam, & Hamedani, 2025).

## 1.2 Public Transport as an Increasing Viable Solution

Urban development along with rising e-commerce needs create an urgent task to guarantee efficient sustainable freight distribution in urban areas. Public transport integration with urban logistics represents an attractive solution for last-mile delivery because it carries the potential to reduce traffic congestion while cutting down emissions along with delivery expenses. The current network of urban public transportation includes buses, trams and metro networks that represent untapped infrastructure if used for delivering goods (Papa, Hribar, Petelin, & Vukasinovic, 2025).

Most urban centers operate well-developed public transport networks equipped with scheduled routes and regular schedules and exclusive transportation paths. The use of current transit system excess capacity allows cities to transport small to medium delivery packages thus eliminating the need for more road-based delivery vehicles (Alotaibi, Almasoudi, & Alqurashi, 2025). Passenger transit hours outside peak periods must optimally function as freight transport routes to maintain passenger convenience.

### 1.2.1 Potential Modes of Public Transport for Logistics

Urban logistics integration uses several different public transport systems as investigated solutions for urban distribution. Buses provide space in their cargo areas which transportation organizations can transform for parcel delivery applications mainly in last-mile operations. The cities of Europe serve as demonstration sites for cargo trams which provide dedicated track service for commercial district goods delivery. The transportation system of the metro operates at night to move packages through its underground rail network which eases daytime traffic congestion (Queiroz, Abe, Mendes dos Reis, & Renon, 2025). Different urban spaces have implemented freight-on-transit methods as part of their city logistics optimization efforts.

“Transport for London” through its subsidiary TfL tested underground metro deliveries as a method to transport packages during non-busy travel periods. The cargo tram program in Amsterdam became operational to efficiently deliver retail items along with reducing retail transportation traffic. Japan through Tokyo has investigated metro-based logistics systems to provide e-commerce package delivery to urban centers (Chen, et al., 2025).

### 1.2.2 Challenges in Implementing Transit-Based Logistics

The implementation of freight service within public transport systems encounters multiple obstacles because of these obstacles, current transit infrastructure must be adjusted to support freight transport because it primarily serves transportation for passengers. Running logistics operations in sync with existing transit schedules proves difficult especially when it demands advanced technology for resolution. The transport policies require updates to enable dual operations between passengers and cargo transportation (Jiang, Lavanya, & Nam).

## 1.3 How Is Public Transport Being Used for Transport Of Goods and Materials

Public transport integration into freight logistics appears as an efficient sustainable remedy that addresses city problems including congestion and environmental degradation in last-mile logistics operations. Cities that relocate freight operations through their existing transportation infrastructure reduce air pollution and decrease traffic overcrowding and improve operational economies. Studies confirm transit-integrated logistics systems support both ecological developments in cities and maximize their public infrastructure benefits

### 1.3.1 Environmental Sustainability

The shift toward electric components in public transport systems provides greater energy efficiency than conventional freight vehicles do especially when city administrations choose hybrid and electric transit vehicles. The movement of urban freight onto public transportation systems reduces emission levels of carbon and air pollutants to a significant extent. The implementation of freight transport systems with electric bus operations would reduce urban logistic emissions by twenty and thirty percent (Wang, Dong, Zhang, & Wang, 2024). Cities enhance their sustainability efforts through the substitution of fossil-fuel transportation with emission-reducing public transit options for deliveries.

### 1.3.2 Traffic Congestion Reduction

The high number of delivery vehicles currently creates major road congestion in urban areas. Trains and vans that deliver freight, waste road space which leads to traffic delays and reduced operational efficiency for urban transportation. Public transit networks which integrate freight activities result in a 20-25% decline of delivery vehicle requirements and this leads to improved traffic conditions. Cities that employ empty transit capacity spaces can release transportation bottlenecks without building new infrastructure.

### 1.3.3 Cost-Effectiveness and Economic Efficiency

Applicators that use public transport as their distribution method enable businesses to cut their freight costs yet add money to transit agencies. Using public transportation networks for final delivery routes could reduce overall company expenses which stem from decreased fuel expenses and maintenance costs together with staffing costs (Horcher & Tirachini, 2021). Public transit agencies build financial stability by collecting freight transportation fees which help support their public transport funding and reduce reliance on subsidies.

### 1.3.4 Last-Mile Delivery Optimization

The supply chain's final delivery phase represents its most challenging component because it leads to prolonged delivery times and numerous delivery failures together with suboptimal delivery routes. Micro-distribution centers positioned at public transport hubs have an optimal placement between residential areas and commercial zones. Public transport systems enabled for urban logistics operations increase last-mile efficiency through multimodal transportation methods (Correia, Vagos, Marques, & Teixeira, 2022).

### 1.3.5 Social and Urban Benefits

The integration of freight solutions with public transportation systems creates positive impacts on urban environment, while improving accessibility for residents. Fewer heavy delivery vehicles create streets that promote pedestrian safety and provide better use of public areas. The location of logistics hubs beside public transport stations enables quicker service delivery to local businesses along with e-commerce providers.

## 1.4 Challenges and Barriers to Implementation

To achieve sustainable implementation of public transport solutions in urban freight logistics operators must resolve various implementation barriers. Successful implementation of public transport for urban freight demands overcoming various barriers which span from insufficient infrastructure to government regulations and daily operations in combination with transport-related public concerns. The path to resolving these problems demands goal-oriented strategies and new technological solutions combined with political reforms (Daramola, 2021).

### 1.4.1 Infrastructure and Capacity Constraints

Public transportation networks mainly work for carrying passengers because they adopt designs that do not prioritize freight distribution. Commercial buses alongside metro trains and trams need special modifications to support freight transportation because they lack designated cargo storage areas that affect passenger safety and travel convenience. The absence of proper storage facilities at existing transit stations creates challenges for efficient freight movement assistance (Alahakoon, Cerneckiene, Jansons, & Tekshan, 2025).

The main problem relates to the maximum weight that can be transported. Disparities exist between freight truck and public transit vehicle design since transport vehicles need to accommodate only lightweight passengers. Transporting heavy freight can damage public transit vehicles to the point of requiring more frequent and costlier maintenance and operational slowdowns (Anderson, 2013).

### 1.4.2 Operational and Scheduling Conflicts

Recommendations include establishing set times for combining delivery services with passenger routing to develop an effective transportation strategy. Fixed scheduling in urban transit demands makes it hard to implement flexible freight delivery services because such changes could disrupt existing passenger transit operations. Freight activity at transit stations requires strategic planning because mistakes can create interruptions to service especially when trains or buses are heavily used (Zohrehvandi & Ghazanfari, 2013).

A successful integration of urban freight with public transport requires advanced logistics coordination along with real-time tracking systems to prevent conflicts between passenger and freight operations. Additionally route optimization should be implemented. Transit-integrated freight will produce operational inefficiencies along with longer transit delays because it lacks smart logistics infrastructure.

### 1.4.3 Regulatory and Policy Challenges

Traditional urban regulations regarding public transportation agencies prohibit systems that integrate freight services with passenger transportation systems. The current regulatory frameworks ban public transport vehicles from carrying out commercial freight transport which requires both policy updates and pilot trials to prove integrated operations (Chen, et al., 2025).

Public transport operators along with transit agencies require establishing security and safety practices to oversee the cargo management process inside their vehicles. Maintaining efficient service delivery and regulatory compliance implementation creates a challenging situation for institutions responsible for both aspects.

### 1.4.4 Public Perception and Acceptance

Passengers constitute the main user base for public transport networks which raises concerns among them about freight integration. A low number of available seats coupled with possible service interruptions and security concerns would produce resistance from transit passengers and their governing bodies. Public acceptance stands as a vital determinant that decides the fate of transit-integrated freight programs (Donne, Alfandari, Archetti, & Ljubic, 2023). Cities must run public awareness campaigns before implementing public transport-based freight solutions to present advantages and resolve passenger concerns. Public backing for freight transport will largely depend on avoiding any limitations it creates for passenger freedom of movement and accessibility comfort.

## 1.5 Cargo Hitchhiking: A Novel Public Transport-Based Freight Model

E-commerce development alongside evolving consumer needs has stimulated rising urban delivery needs so congestion and environmental problems have become more prominent. Cargo hitchhiking represents an innovative delivery method which combines parcel delivery service with public transportation networks to boost efficiency while managing urban transport issues. The current operational capabilities of buses trams and metro allow cargo hitchhiking to minimize delivery van usage thereby decreasing operational costs and environmental impact during last-mile logistics (Jaap, 2015).

### 1.5.1 Concept and Mechanism of Cargo Hitchhiking

The phenomenon of cargo hitchhiking enables real-time distribution of transport vehicle space which is allocated for parcel shipment. Real-time logistics coordination enables this model to perform uninterrupted package loading and routing and unloading that avoids disturbing passenger transit activities. Key components include:

1. The integration of digital platforms together with AI-driven logistics systems performs ongoing optimization of transportable cargo capacity inside rail and bus vehicles (Coors, Pietruschka, & Zeitler, 2022).
2. Small parcel storage area installation exists in several transit systems since they modified their vehicles with dedicated secured cargo spaces (Coors, Pietruschka, & Zeitler, 2022).
3. The cargo hitchhiking system integrates with conventional transportation networks to connect main transportation stops with urban distribution points (Coors, Pietruschka, & Zeitler, 2022).

### 1.5.2 Benefits of Cargo Hitchhiking for Urban Freight

#### 1.5.2.1 Sustainability and Environmental Benefits

The main benefit of cargo hitchhiking emerges as its positive effect on city-wide sustainable transportation systems. The current last-mile shipping industry heavily uses diesel engine vehicles which significantly produce harmful gases. Integrating freight delivery into established public transportation networks leads cities to reduce their CO₂ pollution by significant amounts. The German research demonstrated how long-distance bus transit enabled cargo hitchhiking to decrease emissions by 25% by diminishing the requirement of dedicated delivery vehicles (Woensel & Derse, 2024).

#### 1.5.2.2 Cost Efficiency and Economic Viability

The hitchhiking system for cargo delivery both benefits logistical companies through reduced costs and helps transport operators earn more profits. Businesses cut their delivery costs associated with fuel and labor expenditures at the same time transport agencies create new revenue streams because they optimize vehicle space for freight. The Dutch study by Van Duin discovered that moving parcels through city routes by bus decreased the expenses of final-mile distribution by 40% (Duin, Wiegmans, Tavaszy, Hendriks, & He, 2019).

#### 1.5.2.3 Traffic Congestion Reduction

Heavy vehicle traffic in cities increases to the point of becoming a significant problem because of growing delivery vehicle count. Cities achieve significant road traffic decreases and create additional vehicle parking areas when they redirect freight transportation through public transit systems. The implementation of cargo hitchhiking as an urban co-modality model leads to decreased delivery-related traffic levels through research which shows a maximum reduction of 30% (Derse & Van Woensel, 2024).

## 1.6 Case Studies of Cargo Hitchhiking in Urban Areas

Localized projects of cargo hitchhiking have appeared across multiple cities to test their operational potential. The UK organization Transport for London (TfL) examined metro trains to transport overnight parcels with the intent of decreasing daily traffic during rush hour.

The urban delivery efficiency of Netherlands' city Amsterdam improved because they introduced cargo tram service on transit corridors. The parcel delivery pilot programs in Tokyo use metro-based operations during off-peak hours for small shipments which enhances e-commerce fulfillment purposes (Romano Alho, et al., 2021).

## 1.7 Challenges and Implementation Barriers

### 1.7.1 Infrastructure Limitations

Transit systems beginning as passenger transportation networks continue to serve only human travelers rather than carrying freight shipments. Making vehicles ready for transport purposes needs conversion work including addition of special cargo hold areas and protective freight compartments (Gatta, Marcucci, & Serafini, 2019).

### 1.7.2 Operational and Scheduling Conflicts

The established schedule of passenger transit never matches the delivery needs of freight services. Advanced scheduling tools and logistics management solutions enable the harmonization of cargo hitchhiking operations without performance disruptions (Woensel & Derse, 2024).

### 1.7.3 Regulatory and Policy Constraints

A significant number of urban transit regulations today prevent the establishment of transportation systems that mix passenger travel with freight transportation. Public transport networks need regulatory readjustments to allow cargo integration (Lienkamp & Rambha 2024).

### 1.7.4 The Future of Cargo Hitchhiking and Scalability

The future success of cargo hitchhiking will be determined by combined advancements of new technology with the backing of relevant policies. Routinary movements like AI-based delivery route planning along with automated package drop points improve operational effectiveness in transportation systems. Transit agencies along with logistics companies together with local governments must form partnerships to make cargo hitchhiking become a regular urban logistics fulfillment solution.

## 1.8 Global Case Studies and Best Practices

Public transport integration within urban freight logistics has become a worldwide trend due to city needs for sustainable delivery systems which function efficiently. Multiple testing stages and active implementations prove that public transport networks create effective solutions for goods transportation including both last-mile delivery and point-to-point delivery needs. Multiple real-world projects disclose practical knowledge about successful methods alongside evaluation of difficulties and expansion capabilities.

1. Amsterdam, Netherlands: Cargo Trams for Urban Freight

Amsterdam serves as a leader in transit-integrated freight by establishing cargo trams to spread goods nationwide. The initiative makes use of already operating tram systems to conduct parcel deliveries which eventually reduces the need for road-based delivery vehicles. Through its implementation the system cut down 30% of freight CO₂ emissions while simultaneously reducing road congestion levels significantly (Alahakoon et al., 2025) (Alahakoon, Cerneckiene, Jansons, & Tekshan, 2025). The coordination of logistics becomes essential to resolve scheduling issues that occur between passenger and cargo services. The municipality applied its best practice approach by designating off-peak time slots for goods transport.

1. London, UK: Underground Freight Logistics

The London Underground system tested overnight parcel delivery operations by Transport for London (TfL). Small parcel delivery occurs through a program which transforms unoccupied metro carriage space and thus reduces street congestion during regular operating hours. It has been demonstrated by research that central London could reduce its central road freight movements by 20% which created less peak-hour traffic congestion (Khan, 2019). The deployment of parcels on passenger metros requires addressing security risks and handling safety standards. The best practice includes automated parcel tracking systems that work alongside designated areas with secure handling measures.

1. Tokyo, Japan: Metro-Based E-Commerce Deliveries

The dense population of Tokyo prompted the city to develop innovative logistics solutions through e-commerce deliveries managed by its metro system. The association between railway operators and logistics companies in Japan enables the public transit system to serve as a delivery network for parcels. The implementation resulted in a 25% improvement for last-mile delivery efficiency which mainly benefited e-commerce and food delivery operations (Doi & Murakami, 2021). The implementation faces obstacles from passengers who do not want shared cargo spaces as well as requirements to modify metro stations. The best practice involves establishing metro stations intended for freight transport alongside real-time parcel tracking systems.

1. Burdwan, India: Bus-Based Cargo Hitchhiking

Public buses in Burdwan India serve as delivery vehicles between stores to lower reliance on air-polluting delivery vans. Reducing fuel expenses by 35% combined with enhanced retail accessibility represents the key impacts of this initiative (Roychowdhury & Chattopadhyaya, 2021). The system faces restrictions because the necessary digital infrastructure for logistics tracking remains unavailable. Integration of mobile-based inventory management for efficient tracking of deliveries is being considered as the best viable solution for this issue.

1. Stockholm, Sweden: Multimodal Freight Integration

The city of Stockholm implements multimodal urban freight through buses, trams, boats and other transport modes for sustainable logistics operations. The research revealed that urban freight transportation declined by 22% which lowered air pollution and traffic congestion (Eliasson, Hulykrantz, Nerhagen, & Rosqvist, 2009). Transportation operations face difficulties due to the need for multi-mode coordination to achieve efficient logistics management. An AI-enabled freight management system functions as the best practice for undertaking route optimization.

1. Berlin, Germany: Smart Mobility and Freight Sharing

The city of Berlin has established freight-sharing models that allow public transport vehicles to use their unused space for parcel delivery dynamically. Through this system delivery efficiency rose by 25% which decreased last-mile delivery expenses by 25% (Shuaibu, Mahmoud, & Sheltami, A Review of Last-Mile Delivery Optimization: Strategies, Technologies, Drone Integration, and Future Trends , 2025). Difficulties arise because of regulations that prohibit multiple activities in transit systems. Development of policy frameworks which support freight-sharing platforms represents the best practice model.

1. Johannesburg, South Africa: Intermodal Urban Logistics Framework

Johannesburg created an intermodal logistics framework to connect freight movement between public buses and minibus taxis and rail transportation. The implementation produces two main results which include enhanced connections between metropolitan zones and affordable transportation options for goods (Mbatha, 2024). The implementation faces challenges because certain parts lack adequate public transit networks. Transport operators receive financial support from the government when taking part in freight logistics operations.

Various cities utilize the mentioned group of shared strategies. Utilizing unpopular time slots and periods for transportation shipments helps minimize disturbances to passenger services. Security and efficiency can be improved through digital tracking system implementations. The dedicated set-up of transportation areas should be built inside public transit vehicles for cargo handling. Public organizations should create policies together with incentives to promote freight-sharing agreements. The examined case studies prove that integrating public transport systems with urban freight operations succeeds while showing various operational benefits. Sustainable urban deliveries show a promising future because these initiatives have demonstrated successful outcomes even though challenges remain regarding infrastructure adaptation and policy reforms.

## 1.9 Emerging Trends in Public Transport-Integrated Freight

### 1.9.1 Smart Mobility and Digitalization

Smart mobility solutions based on “Internet of Things” (IoT) enabled tracking alongside artificial intelligence (AI) for route optimization together with blockchain for secure logistics present great possibilities to transform freight-on-transit models. AI forecasting tools help manage freight space distribution on public transport systems which leads to better transport efficiency (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023).

The implementation of IoT sensors allows companies to track their cargo conditions when they transport temperature-sensitive materials. Through blockchain-based logistics platforms customers gain better security combined with transparency throughout their transit-integrated deliveries.

### 1.9.2 Electrification and Sustainable Fleet Expansion

Modern public transportation agencies throughout the world implement electric buses along with hydrogen-powered transport systems and electric trams and metro units. The deployment of low-emitting vehicles in urban freight operations results in significant reductions of carbon emission output from last-mile logistics. The integration of freight transportation with electric public transit networks offers potential CO₂ emission reductions amounting to 40% (Russo & Rindone, 2021). New routes specifically designed to support freight transportation within transit systems will advance sustainability goals.

### 1.9.3 Autonomous and On-Demand Public Freight Transport

Urban mobility experiences a transformation because of autonomous vehicles (AVs) and “Mobility-as-a-Service” (MaaS) developments. Self-driving public transport vehicles should be able to perform cargo transportation during off-peak hours through automated programming which results in unattended logistics optimization. The conceptual implementation of autonomous bus operations exists in Singapore and Sweden for delivering passenger and freight transportation (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024). The exploration of modern transportation concepts focuses on adapting public transport systems to add freight delivery services through micro-transit models. Research gaps concerning transit-integrated freight operation require immediate investigation.

1. Infrastructure and Spatial Planning Constraints

Through their original design urban transit systems did not plan to function for freight delivery. Research is needed to assess:

1. Development of combined large-load-passenger transportation systems that maintain both secure operations and operational excellence (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024).
2. Multi-use transit hubs need development to establish freight loading facilities which enable uninterrupted operations alongside passenger movements (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024).
3. Research must evaluate methods of achieving optimal cargo space use while passengers' demand changes (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024).
4. Policy and Regulatory Challenges

The current emphasis in transportation policy on passenger mobility creates empty spaces when it comes to governing mixed-use transit systems. The assessment of safety guidelines concerning passenger vehicle freight co-loading demands additional research projects. The examination of cities with innovative urban freight policies through case studies provides useful strategies for adjusting regulations. Administrative bodies need to establish public-private agreements which will provide performance benefits to encourage logistics companies to use transit-based freight services.

1. Public Perception and Stakeholder Engagement

Strong integration of transit freight transportation requires agreeable reception from transit control agencies combined with support from delivery businesses as well as public transit users. An analysis of public transport cargo sharing receptiveness requires both survey methods and behavioral research studies. Frameworks for stakeholder engagement must be built through a process which aims to unite the objectives between states, governments, and transport agencies with business interests.

1. Economic Viability and Business Models

Current research reveals minimal analysis regarding the financial viability of freight-on-transit business practices. Operational costs create what type of relationship between dedicated freight transport methods and logistics managed through public transport systems can be made. Transit authorities possess the capability to establish new income streams by developing partnerships for cargo delivery. Research needs to clarify whether dynamic pricing systems can use freight costs that adapt based on transit demand levels.

## 1.10 Future Directions for Research and Implementation

Public transport systems show great potential as part of sustainable urban freight logistics operations but require further development research. The growth of cities toward innovative last-mile delivery optimization and emission reduction through congestion relief has led to increased interest in public transit network utilization for freight transportation. Research on this topic faces important gaps that concern implementing operations alongside infrastructure modifications as well as integrating technologies and creating regulatory guidelines. The research concentrates on forthcoming developments in transit-integrated urban freight and identifies essential investigation fields (Meng, Liu, Zhong, & Jiang, 2022).

1. Pilot Projects and Real-World Testing

Cities need to execute wide-scale pilot studies as a method to verify the potential success of transit-integrated freight delivery systems. Research on different city regions enables a measurement of their capability to adapt and scale related strategies. The successful innovation of mixed-use transit depends on collaborations between universities and transport agencies and logistics business entities.

1. AI-Powered Logistics Optimization

AI-driven logistics software integrated into public transportation systems allows for real-time freight asset redistribution according to passenger movements and road condition changes and delivery priority requirements. Real-time cargo allocation optimization occurs due to AI-based machine learning algorithms which accurately forecast demand. The use of digital twin models allows urban freight systems to simulate future operational complications as well as their corresponding solutions.

1. Green Logistics and Circular Economy Models

Sustainable outcomes result from public transport freight systems when they adopt circular economy principles. A city can implement reverse logistics systems through transit-integrated freight operations that also handle waste collection and recycling duties. The study of zero-emission urban freight models needs to investigate the integration methods between transit-based freight and ride-sharing along with micro-mobility systems.

## 1.11 Research Gap

Significant research has examined public transport integration in urban freight logistics but certain crucial gaps continue to exist.

1. Lack of Real-World Implementation and Business-Specific Models

Research studies mostly construct theoretical models of city logistics without providing adequate operational analysis at the retail level (Meng, Liu, Zhong, & Jiang, 2022). Available research fails to examine how retail operations at major organizations can directly interweave public transportation for store connections and delivery promotions.

1. Limited Simulation-Based Approaches for Freight on Transit Models

Academic research introduces freight-on-transit models whereas the validation research for their efficiency in retail practice remains absent (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023). Simulation-based analysis needs to assess the delivery systems of high-traffic facilities by evaluating performance elements including transportation periods and savings together with product shipment sequences.

1. Lack of Empirical Data from Retailers and Logistics Providers

The research field shows no integration of primary delivery acceptance data acquired from store operators and supply chain managers together with customer feedback (Russo & Rindone, 2021). A systematic survey approach aimed at stakeholders from retail management and logistics as well as consumer groups would help bridge this research gap. The survey questions should focus on implementing and accepting new delivery models.

1. Operational and Cost Feasibility for Specific Retail Chains

The current research in transit-integrated freight systems does not measure economic benefits for large-scale retailers (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024). A study that integrates simulation modeling analysis of retail store operations alongside survey results about business operations would deliver targeted business insights.

## 1.12 Research Objectives

The Study will design and implement a simulation model that evaluates how transit-based logistics would work with retail distribution networks. A simulation model would be designed and implemented to assess the practicality of integrating buses, metro and other ride-sharing companies in the supply chain of retail stores for both store-to-store movement and last-mile delivery.

The study will also assess the way that delivery timetables and transportation system limits and urban traffic patterns influence operational logistics performance. A comparison will be made between simulation results of traditional retail delivery systems with a transit-integrated freight model.

The study will also analyze whether using public transport logistics systems holds feasible operational costs for various retail operations An assessment will also be conducted regarding the fuel efficiency together with maintenance costs and workforce expenses and warehouse-space optimization because of freight-public transport integration.

An examination will be conducted regarding expected operational difficulties which include scheduling problems in addition to security requirements for shipments and system capacity constraints. Not only this, but the assessment will also be carried out regarding how well large retail chains can scale up their freight operations using transit-integrated freight systems.

It is also necessary to analyze whether employees and public transport stakeholders are willing to incorporate freight delivery through public transport networks.

The study will also focus on the following aspects:

1. Assess the perceptions regarding public transport-integrated freight by conducting surveys among retail managers, logistics service providers and consumer participants.
2. The major obstacles to adoption which embrace regulatory issues together with infrastructure problems and service-related concerns.
3. How customers want their final delivery steps via public transportation networks to be executed.
4. Assessment of both environmental effects and traffic consequences linked to public transport integration in freight logistics systems.

## 1.13 Scope of The Study

The research explores how feasible and efficient it would be for urban freight operations to adopt the cargo hitchhiking method and enhance sustainability aspects within public transportation systems. The main analysis examines the potential uses of current public transit systems that consist of trains and buses and trams for efficient delivery services in busy metropolitan areas.

A study provides analysis which combines case research worldwide with modeling simulations as well as careful literary assessment for assessing benefits versus constraints in freight systems connected to transit. The research evaluates four essential factors regarding delivery operations which comprise emission reduction, cost efficiency, congestion management, delivery reliability and public transport network optimization. The research examines both technical barriers and operational obstacles that hinder cargo hitchhiking implementation when using models in urban environments.

The research also uses simulation methods to analyze operational parameters that consist of delivery timelines as well as emission results alongside vehicle loading capacity and expenditure effects. This research analyzes dual metrics determining public transit integration of freight services alongside environmental and economic effects while employing CO₂ emission reduction metrics along with delivery time enhancement metrics along with cost-efficient fuel usage metrics and public transport usage enhancement metrics.

International testing demonstrates systematic feasibility but the research directly applies to twenty-first century cities undergoing congestion growth together with environmental problems and growing e-commerce requirements. The research evaluates small to medium parcel delivery integration while disregarding both large freight shipments and the delivery of hazardous materials. Along with this the research examines delivery distances restricted to public transportation areas for intra-city locations.

Lastly, the research establishes operational plans together with simulation systems and evaluation methods which support practical advice for public authorities and urban designers as well as logistics companies and transport organizations to optimize their sustainable urban freight delivery operations.

## 1.14 Conclusion

Public transport integration into urban freight operations holds potential as a beneficial solution to solve the escalating problems of last-mile delivery services, traffic jams and environmental issues. Urban logistics based on delivery vans and other transportation networks presents numerous problems because rising urban populations create additional e-commerce needs while making these standard operations more inefficient and environmentally damaging and costly. The implementation of public transit for goods distribution represents both an efficient use of current infrastructure and a reduction of pollution together with improved traffic conditions.

The research will develop a simulation model for large-scale retail chains to evaluate its feasibility and operational efficiency and cost management implications in transit-based freight transportation. The research will adopt simulation modeling using Python programming language and stakeholder survey techniques to establish empirical evidence about retail delivery capabilities of buses and metro along with other ride-hailing services. The research outcomes will show if freight integration within public transportation networks leads to better supply chain operations and cheaper delivery expenses and promotes environmentally sustainable urban transportation systems.

This research will also investigate essential barriers related to infrastructure limitations as well as regulatory impediments and public doubts regarding freight shipping transit activities. The study will analyze stakeholder feedback from retail management to logistics firms and consumers to establish why public transport integrated freight adoption occurs and provide recommended policies which lead to successful implementation. Drawing conclusions from this analysis will assist public officials together with retailers and logistic service providers to develop sustainable efficient urban freight solutions. Research into future applications should use real-life pilot studies to test the model and examine how smart technology like AI-controlled logistics and automated freight movement could optimize results.

# Chapter 2: Literature Review

The pivotal function of urban freight logistics relies on efficient goods distribution within cities while all these operations confront growing dependence from urban expansion along with congestion and pollution issues. The current reliance on delivery vans and trucks for freight transport results in heightened traffic congestion and worse air pollution and these lead to lower delivery efficiency in last-mile operations (Meng, Liu, Zhong, & Jiang, 2022). The research community together with policy developers investigate different urban delivery systems which unite public transit networks to enhance delivery operations and improve environmental outcomes (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023).

Public transport systems integrated with freight operations represent a developing concept which redirects freight vehicles while carrying goods along with regular transit passengers through buses and metro systems and trams. The freight-on-transit system shows promise because it utilizes transit system undercapacity while lowering the need for dedicated delivery vehicles according to (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024). Research shows that when freight logistics uses public transport networks it brings lower operational expenses as well as better delivery speeds alongside urban traffic congestion reduction (Solecka, 2020).

## 2.1 Rationale for Integrating Public Transport into Freight Logistics

Resolving to integrate public transport into urban freight logistics derives from sustainability aims as well as economic efficiency requirements and urban mobility needs the following:

1. Environmental Sustainability

The main issue in urban logistics occurs when freight transport activities generate large carbon pollution rates. Research has demonstrated that metropolitan area urban freight generates between 20 and 30 percent of road-based CO₂ emissions (Meng, Liu, Zhong, & Jiang, 2022).

Students have discovered that moving freight by public transport decreases pollution emissions to a significant degree. Amsterdam’s cargo tram project demonstrates how its implementation lowered delivery emissions by 30% below those generated by conventional freight trucks (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024). The movement of urban delivery service to electric buses and metro systems enables cities to extend sustainability initiatives while reducing air contaminants (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023).

1. Reducing Traffic Congestion

Urban traffic congestion has worsened due to the explosive growth of e-commerce and last-mile deliveries which brought numerous delivery vehicles onto urban roads (Macario & Spandou, 2019). The urban traffic flow improves by 15% despite a freight traffic reduction by 10% (Solecka, 2020). Cargo transportation through public transit systems combats congestion because it uses existing transportation routes instead of adding new road vehicles (Meng, Liu, Zhong, & Jiang, 2022).

1. Cost Savings and Economic Benefits

Public transportation systems that incorporate freight deliveries produce appropriate cost reductions of 20–40% per delivery by conserving fuel along with labor and vehicle maintenance expenses (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023).

The partnership between transit agencies and logistics companies creates income opportunities that establish profitable financial systems for both (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024). The Tokyo metro freight research demonstrates that combining goods delivery within public transport boosts operational efficiency and reduces transportation costs (Solecka, 2020).

The current shortage of urban area prevents sustainable expansion of logistics hubs and delivery centers (Macario & Spandou, 2019). Converting existing transit stations into compact distribution facilities makes the best use of available space while lowering warehouse rental expenses (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024). Multi-modal integration between public transport and walking systems with cycling and electric delivery vehicles presents itself as an effective strategy for implementing last-mile logistics (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023).

### 2.1.1 Early Adoption and Experimental Projects

Various cities worldwide have established transit-integrated freight initiatives which prove both successful and productive for logistics operations.

Amsterdam, Netherlands:

During Amsterdam's cargo tram project urban transportation of goods became possible as the initiative decreased air pollution through emissions reduction. Through this initiative freight transportation reduced by 30% and decreased last-mile shipping expenses considerably (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024).

London, UK:

The metro service of Transport for London (TfL) introduced tests of parcel delivery which utilize vacant railway space for overnight logistics operations. Research data demonstrates these delivery systems would remove 20% of the delivery vans currently operating in busy city centers during peak hours (Macario & Spandou, 2019).

Tokyo, Japan:

Parcel deliveries through e-commerce in Japan happen through their rail-based freight platform which uses public transport networks to deliver final-mile sections (Solecka, 2020).

Stockholm, Sweden:

The city applies a multi-modal freight strategy that combines trams buses and boats to handle logistics transportation. The research demonstrates that these procuring systems create environments where emissions decrease along with better traffic management and superior delivery operation outcomes (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023). The advancement of technology now enables public transport to integrate with freight delivery for an efficient supply network (Solecka, 2020).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City** | **Mode Used** | **Year Started** | **Key Outcomes** | **Source** |
| Amsterdam | Cargo Tram | 2007 | 30% reduction in emissions & costs | Kpperschmidt de Oliveira et al. (2024) |
| London | Metro (TfL) | Pilot phase | 20% reduction in delivery vans | Macario & Spandou (2019) |
| Tokyo | Metro Freight | Ongoing | 25% improvement in last-mile efficiency | Solecka (2020) |
| Stockholm | Multi-modal (Bus, Tram, Boat) | Ongoing | Lower congestion & emissions | Bhaskaran et al. (2023) |

Table 1:Summary of Early Transit-Integrated Freight Projects

The implementation of transit-integrated freight became more feasible because technology advanced in the following areas:

1. Real-time Logistics Management:

The implementation of AI algorithms for route optimization allows efficient distribution of public transport cargo space (Meng, Liu, Zhong, & Jiang, 2022). As part of IoT-enabled tracking systems parcels gain real-time security and monitoring benefits during transit (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024).

1. Blockchain for Secure and Transparent Logistics:

Blockchain technology enhances parcel tracking security in addition to freight transactions transparency through its implementation between retail businesses and transport departments alongside logistics organizations (Macario & Spandou, 2019). Scientists now study ways to instruct self-driving public vehicles about carrying items along with riders (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023). The implementation of electric public transportation vehicles decreases operational expenses which simplifies the adoption of freight-on-transit models according to (Solecka, 2020). Transport regulations face difficulties due to their insufficient coverage of mixed-use transit systems according to (Meng, Liu, Zhong, & Jiang, 2022). Research about consumer and commuter acceptance toward freight operations on transit systems remains insufficient (Macario & Spandou, 2019).

## 2.2 Evolution of Urban Freight Logistics: From Traditional to Integrated Models

The origination of public transport systems focused on passenger care but recent population growth and online retail demand has encouraged specialists to study freight-oriented public transit potential. Integration of freight into buses and trams and metro systems and public transit networks developed as a solution against transportation congestion along with carbon emissions from limited delivery capabilities of traditional last-mile operations (Daramola, 2021). Research on this developing concept depends on lessons from past examples alongside contemporary experimental programs that show possible implementation approaches and obstacles.

### 2.2.1 Historical Evolution of Freight-Integrated Public Transport

Several transportation systems throughout history have already merged passenger and freight delivery services. In the early 20th century urban freight relied heavily on rail networks because passengers shared tram and metro systems for transporting goods (Daramola, 2025). Some key historical examples include:

### 2.2.2 London’s Underground Freight Services (1920s–1990s)

Newspaper and mail deliveries constituted the main reason for which the London Underground system operated historically. During the mid-20th century freight compartments disappeared from service since road-based logistics alternatives became prevalent in the market (Zhang, Sadagopan, & Qin, 2025).

### 2.2.3 New York Subway’s Parcel Service (Mid-20th Century)

During the time period New York City Subway tested carrying mail and other packages as part of its freight operations (Zhou & Zhang, 2020). The logistics industry evolved to prioritize dedicated delivery fleets which caused the freight transport service to diminish.

### 2.2.4 Amsterdam’s Cargo Trams (2000s–Present)

Amsterdam established freight tram systems as part of its initiative to minimize congestion together with emissions reduction named “City Cargo” in 2007 (Galambos, Palomino-Hernandez, Hemmerlmayr, & Turan, 2024) The trams successfully deliver groceries and retail products thus decreasing the need for road freight activities. Public transportation has proven itself as an effective freight solution throughout history but modern circumstances involving passenger requirements along with regulatory barriers make its implementation more complex today (Zhang, Sadagopan, & Qin, 2025).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City** | **Period** | **Mode Used** | **Purpose** | **Reason for Discontinuation** |
| London | 1920s–1990s | Underground (Mail & Newspapers) | Overnight deliveries | Rise of road freight |
| New York | Mid-20th Century | Subway Parcel Service | Mail and small parcel delivery | Competition from trucks |
| Amsterdam | 2000s–Present | Cargo Tram | Retail and grocery deliveries | Still operational |

Table 2:Historical Freight-Integrated Public Transport Models

### Shift Toward Shared Mobility and Freight Integration

Continuous development in smart cities and digital mobility patterns has elevated the co-modality principle into a core element for freight-on-transit models which focus on transportation infrastructure sharing. Research suggests that the implementation of Freight-on-transit systems enables a 20% reduction in urban congestion through redirecting road traffic to current transportation infrastructure (Daramola, 2021). Ride-hailing and cargo hitchhiking services have improved urban delivery networks.. Public transport policies now endorse urban freight usage in both European and Asian regions. Freight transport through informal bus and shared taxi networks prevails regularly throughout developing countries because public transport acts as a multifunctional system. Although South Asia and Africa employ public minibuses as unregulated transport systems for carrying passengers together with goods (Daramola, 2021).

## 2.3 Modern Implementations of Freight on Public Transport

### Metro and Rail-Based Freight Integration

The rail and metro systems are undergoing a resurgence to handle cargo shipping because they provide dependable service along with efficiency and eco-friendly advantages. Key examples include:

*London (TfL Freight Plan, 2025*):

The Transport for London organization (TfL) has examined bringing freight services back into metro transportation for overnight parcel delivery (Khan, 2019). Laboratory studies indicate London standing to benefit from transit-integrated freight service which would reduce peak traffic congestion by 15–20% (Khan, 2019).

*Tokyo Metro Freight Pilots*:

The growth of e-commerce in Japan encouraged Tokyo Metro to start testing package delivery services during lower traffic periods (Zhang, Sadagopan, & Qin, 2025). A 25% increase in operational efficiency at the last mile of delivery has been achieved through reduced road shipments (Chen, et al., 2025).

### Bus-Based Urban Freight Models

Urban cities that heavily depend on their bus networks have started using bus vehicles for delivery logistics systems. Examples include:

Retail delivery services across Burdwan operate through the network of public buses in India.

Local buses from Burdwan have started to carry retail products between markets (Daramola, 2021). The program cut logistics expenses by 35% along with decreasing fuel usage numbers.

Stockholm’s Multi-Modal Bus and Tram Freight Plan is a prime example of this system. Stockholm initiated tests using hybrid buses for cargo movement as part of its strategy to provide urban deliveries through cargo trams (Stad, 2018). Using this model allows to deliver food products and pharmaceutical items which helps create less traffic congestion on roads.

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| --- | --- | --- | --- | --- |
| **Continent** | **City** | **Mode(s) Used** | **Key Outcome** | **Source** |
| Europe | Amsterdam | Cargo Tram | 30% emissions cut, reduced van traffic | Kpperschmidt de Oliveira et al. (2024) |
| Asia | Tokyo | Metro Freight | 25% last-mile efficiency improvement | Solecka (2020) |
| Africa | Johannesburg | Bus, Minibus Taxi | Affordable, improved freight mobility | Mbatha (2024) |
| Europe | London | Metro (TfL) | 20% fewer delivery vans, less congestion | Macario & Spandou (2019) |

Table 3: Summary of Modern Freight-on-Transit Projects by Continent

### 2.3.3 Cargo Hitchhiking and Shared Freight Solutions

The urban freight landscape now includes cargo hitchhiking as a method that allows parcels to use transport capacity which would otherwise go unused.

*Germany: Cargo Hitchhiking on Long-Distance Buses*

The introduction of bus parcel deliveries by long-distance operators has reduced the need for independent freight transportation systems (Chen, et al., 2025). The implementation of this new system delivered between 25% and 30% discount on costs for logistics administrators.

*Netherlands: Shared Freight Models in Public Transit*

The public transportation systems in the Netherlands are testing Artificial Intelligence-based solutions for parcel management which optimize train-tram carriage efficiency (Zhang, Sadagopan, & Qin, 2025).

## 2.4 Challenges in Adopting Public Transport for Freight

The implementation of public transport-integrated freight distribution deals with several significant obstacles which hinder its adoption.

#### 2.4.1 Infrastructure and Capacity Constraints

The majority of public transport service vehicles do not provide designated spaces for transporting goods (Balti, 2024). Transit infrastructure needs modifications because the distribution of weight and safety aspects present restrictions (Chen, et al., 2025).

#### 2.4.2 Operational and Scheduling Conflicts

The operation of freight services should continue without interrupting the schedules for passenger transportation (Daramola, 2021). The high number of public transport passengers during peak hours reduces available cargo space which makes scheduling difficult.

#### 2.4.3 Regulatory and Policy Barriers

The regulations enacted for urban transit systems in numerous regions specify passenger-only use of transportation vehicles (Zhang, Sadagopan, & Qin, 2025). Federal governments need to develop fresh policy systems that promote shipments through public transportation networks.

#### 2.4.4 Public Perception and Acceptance

Surveys show that public transit users have three main worries about sharing transportation with cargo: safety concerns, cleanliness standards and lack of comfortable space (Chen, et al., 2025). Regional and transport-specific factors determine how much people accept this approach.

## 2.5 Public Transport as a Freight Solution: Key Theories and Models

Multiple theoretical foundations support the development of public transport-integrated urban freight logistics through their implementation and assessment process. Public transport-integrated urban freight logistics receives guidance through frameworks which focus on sustainability alongside co-modality and efficiency to unite passenger transport and freight transport systems. This part analyzes the central theoretical frameworks which guide transit-integrated freight logistics through co-modality theory as well as the sustainable urban logistics framework and transport-oriented development (TOD) and digital mobility concepts.

### 2.5.1 The Co-Mobility and Shared Infrastructure Theory

Per the co-modality theory transportation systems function best when designed for multiple objectives so they unite passenger traffic with freight logistics for maximized operational performance (Mepham, 2013). The co-modality theory promotes using public transit systems for cargo transportation which eliminates the necessity of extra freight vehicles in cities.

Researchers have discovered that co-modality helps decrease urban congestion by 15–20% since some logistics operations transition from road delivery systems to public transit networks (LIU & YU, 2024). The optimization of unused transit capacity through co-modality practices leads to resource savings along with cost optimization benefits (Lin & Zhang, 2024). The Amsterdam cargo tram network demonstrates co-modality's practical use by transporting parcels through trams after regular operating hours thus decreasing delivery traffic and pollution (Pietrzak & Pietrzak, 2021).

### 2.5.2 Sustainable Urban Logistics

The sustainable urban logistics framework includes environmental sustainability as well as economic effectiveness and social advantages for freight transport planning (Newman, Davies-Slate, Conley, Hargroves, & Mouritz, 2021).

*Key Aspects of This Framework:*

* Carbon Emission Reduction

Research shows freight management through transit integration systems produces a 40% reduction in CO₂ emissions beyond typical delivery truck emissions Stockholm illustrates public transit integration benefits for goods transportation (Chen, et al., 2025).

* Cost-Efficient Logistics

Transport systems which connect to public transit minimize expenses for fuel consumption together with operational costs to turn logistics operations more economical (Feng, Duan, Ke, & Yang, 2022). Cities using freight-on-transit methods achieve up to 30% savings on their final delivery expenses (Brady-Phillips & Holmes, 2024).

* Social and Urban Mobility Benefits

Logistics integration between transport systems helps decrease traffic in cities which results in both better journey times for commuters and higher efficiency in public transport (Kikuta, Ito, Yamamoto, & Yamada, 20).

Public transport-integrated freight has become an essential urban strategy for reaching carbon neutrality under sustainable urban logistics principles that conform with worldwide climate policy requirements.

### 2.5.3 Transport-Oriented Development (TOD) and Logistics Integration

Urban planning through Transport-Oriented Development (TOD) historically aims to enhance land use effectiveness around transportation junctions (Yang, Xu, Shankar, & Chen, 2024). TOD has evolved to include transport considerations during the last two decades by advocating the integration of urban logistics hubs at transit stations as a method to enhance delivery efficiency. The integration of logistics hubs with metro stations at Guangzhou rail transit station complexes resulted in a 25% reduction of delivery times along with better traffic performance (Wang & Chen, 2025). Singapore and Japan have demonstrated through TOD-based logistics hubs that transit stations function effectively as urban distribution centers for optimized last-mile logistics operations (Nutayakul & Weerawat, 2025). The analytical model emphasizes integrating urban freight distribution through transportation modes such as buses and trams and rail which then connect directly to nearby bike-sharing and pedestrian delivery networks.

### 2.5.4 Digital Mobility and Smart Logistics Concepts

Modern technology advancements in AI together with IoT and blockchain systems are enabling public transport-integrated freight logistics to adopt digital mobility frameworks. Such advancements boost the capabilities of tracking and route optimization and security management in logistical operations (Idrissi, Lachgar, & Hrimech, 2024).

*Technological Innovations Supporting Transit-Integrated Freight*

* AI-Powered Logistics Optimization

Machine learning forecasting models determine how freight should be distributed through public transport networks so they operate with maximum effectiveness (Feng, Duan, Ke, & Yang, 2022).

The AI-assisted route optimization system helps organizations schedule delivery times which both reduce delay time and follow passenger transit patterns (Vujadinovic, et al., 2024).

* IoT and Blockchain for Secure Cargo Handling

Connected sensors through the Internet of Things monitor both tracking and the status of packages traveling through transit networks (Taj , et al., 2023).

The implementation of blockchain networks within logistics creates transparent shipment tracking which results in secure non-tampered documented deliveries (Ok, Barnty, & Joseph, 2025).

* Autonomous Public Transport for Freight

The research sector in Taiwan and throughout Europe studies how autonomous public transportation systems together with metro systems can support automated package delivery during the final transport stage (Innovation, 2024).

New technologies enable expanded use and real-time observation of assets which resolve major worries about container security and delivery planning conflicts.

### 2.5.5 Research Gaps in Theoretical Frameworks for Transit-Integrated Freight

Several research gaps exist even though theories for transit-integrated freight have developed.

1. Lack of Empirical Studies on Retail-Specific Logistics Integration

Research focusing on city-wide logistics has been conducted yet investigations into how notable business facilities (including major retail chains) should implement transit-oriented freight solutions remain scarce (Arvianto, Sopha, Sri Asih, & Imron, 2021).

1. Insufficient Simulation-Based Validation

Most theoretical models concentrate on creating policies instead of testing public transport-based freight operational simulations in real-life conditions (Su, Ghaderi, & Dia, 2024).

1. Comprehensive Policy Guidelines

Study development faces substantial resistance because most urban polices lack explicit rules for combining transit systems which serve both passengers and freight transport needs (Kervall & Palsson, 2022).

1. Public Perception and Stakeholder Acceptance

Few experts have examined how people using transport systems feel about sharing their vehicles with freight deliveries (Balamurugan, Paul .J, & Gopi, 2019).

Future research should focus on:

1. Current research needs to demonstrate retailer-adapted case studies regarding their logistics adoption patterns.
2. Large-scale pilot testing of simulation models through experimental implementations will validate their performance.
3. A thorough examination of policy modifications which enable transit systems to accommodate freight must be conducted.
4. A survey of both public and commuter attitudes will measure how accepted and perceived cargo-sharing in transit vehicles is to the general public.

## 2.6 Evaluating the Benefits of Transit-Integrated Freight

Flexible freight logistics that integrates public transportation produces many advantages including sustainability benefits along with reduced costs and enhanced urban mobility and decreased congested traffic. Cities throughout the world seek methods to use current public transport systems for freight delivery to decrease dependence on traditional transportation vehicles (SOLECKA, 2014). Research findings from the global level and real-world case studies explain the main advantages of freight systems integrated with transit in this section.

### 2.6.1 Environmental and Sustainability Impact

The main environmental benefit of implementing freight cargo through public transit is its green nature. The mounting delivery vehicle numbers lead to intense air pollution problems alongside greenhouse gas (GHG) emissions in modern urban environments. The use of public transport for freight operations presents an environmentally friendly solution because it decreases the number of fuel-consuming delivery fleets (Jing, Liu, Yu, & He, 2022).

#### 2.6.1.1 Carbon Emission Reduction

Freight-on-transit transportation systems cut carbon emissions by 30–50% below regular last-mile delivery systems (Glover, 2012).

Parcel distribution through Stockholm's metro and tram system reduced fuel usage by 40% along with decreasing urban emissions by 20%.

Research conducted on Brazilian freight transport systems demonstrates the potential of adding public transport into logistics systems to achieve major carbon reduction in last-mile delivery operations (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024).

|  |  |  |
| --- | --- | --- |
| **Aspect** | **Conventional Freight** | **Transit-Integrated Freight** |
| CO₂ Emissions | High | 20-50% reduction |
| Delivery Costs | Expensive (fuel, drivers, vans) | 20-40% cost savings |
| Traffic Congestion Contribution | High | Significantly reduced |
| Public Transport Revenue | No contribution | Additional revenue stream |
| Public Acceptance Challenges | None | Medium to High |

Table 4: Comparison: Conventional Freight vs. Transit-Integrated Freight

#### 2.6.1.2 Energy Efficiency and Sustainable Mobility

Scientific evidence proves that electric buses combined with metro-based transportation systems require considerably less energy to move a single kilometer than traditional trucks or vans.  The successful implementation of cargo tram systems by cities Amsterdam and Zurich utilizes efficient energy management to cut down transportation emissions (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023).  The integration of freight transportation within current transit networks enables circular economy practices by cutting down waste outputs and maximizing energy efficiency in city delivery operations.

|  |  |  |  |
| --- | --- | --- | --- |
| **Benefit** | **Percentage Improvement** | **Cities Demonstrated** | **Source** |
| CO₂ Emission Reduction | 30–50% | Stockholm, Amsterdam, Berlin | Glover (2012), Kpperschmidt et al. (2024) |
| Delivery Cost Savings | 20–40% | London, Munich, Tokyo | Donne et al. (2023) |
| Traffic Congestion Reduction | 15–25% | Paris, London, Taipei | Glover (2012) |
| Last-Mile Efficiency Improvement | 25–40% | Tokyo, Singapore, Amsterdam | Moumen et al. (2023) |

Table 5: Benefits of Transit-Integrated Freight Systems (Selected Case Studies)

### 2.6.2 Economic and Cost Efficiency

Cost reduction stands as a primary advantage that comes from using transit-integrated freight systems. Science supports the use of freight-on-transit models to reduce logistics expenses by 20 to 40 percent which improves the economic feasibility of urban freight operations.

#### 2.6.2.1 Reduced Operational Costs for Logistics Companies

The removal of supplemental delivery vehicles enables businesses to reduce their expenses related to fuel costs along with maintenance fees and driver compensation (team, 2025).

Research conducted in London indicated transit-based parcel transportation supported by metro and bus networks reduces last-mile delivery expenses by 35 (Donne, Alfandari, Archetti, & Ljubic, 2023)%.

Transfer of freight operations through subway integration in New York City enabled metro stations to replace warehouses and reduced warehouse leasing expenses (Donne, Alfandari, Archetti, & Ljubic, 2023).

#### 2.6.2.2 Revenue Generation for Public Transport Authorities

Public transit organizations should use the empty space between journeys to earn money by enabling freight transportation (Commission, 2018).

A study conducted in Berlin demonstrated that freight operations within the transit network were able to reach 25% of the funding needed to support public transport operations (Krembsler, et al., 2024).

### 2.6.3 Traffic Congestion and Urban Mobility Improvements

Urban congestion has surged mainly due to growing e-commerce business and on-demand delivery services. The use of transit-integrated freight models stands as a practical approach to decrease delivery vehicles on roads thus enhancing urban mobility rates (Glover, 2012).

#### 2.6.3.1 Reduction in Road Congestion

A research study combined between Paris and London confirmed that moving 20% of urban deliveries through public transport systems would decrease city congestion by 15% (Glover, 2012). Metro services in Taipei successfully reduced peak-hour delivery truck traffic by 22% through their freight distribution operations which created better traffic conditions (Study on specific supply chains in professional urban freight transport and delivery services, 2007).

#### 2.6.3.2 Improved Land Use Efficiency

The consolidation of freight in transit points decreases the necessity of oversized distribution centers thus permitting better utilization of metropolitan land resources. The MRT-based freight system in Singapore proved that freight integration with metro stations could decrease logistics estate costs by thirty percent thereby enhancing urban space administration.

### 2.6.4 Social and Community Benefits

The implementation of public transport-integrated freight systems leads to better urban livability and increased safety as well as social advantages for society.

#### 2.6.4.1 Noise Pollution Reduction

Investigations have established that using metrorail and tram-based freight solutions effectively cuts down noise emissions which benefits the living standards of city residents.

Electric freight trams operating in Amsterdam delivered 40% less noise during deliveries when compared to using conventional diesel trucks for transportation.

#### 2.6.4.2 Safety and Reduced Road Accidents

A study combining results from Tokyo and Hong Kong confirmed that when urban delivery trucks decreased on roads traffic accidents linked to freight decreased by 18%. Secure transit networks for freight consolidation result in enhanced safety standards for both traffic users and pedestrians (Kpperschmidt de Oliveira, Meira , & Oliveira, 2024).

2.6.5 Future Research and Expansion Possibilities

The field of transit-integrated freight needs additional research in specific domains because the existing knowledge remains restricted. Organizations need more research on the advantages that result when individual businesses use transit-integrated freight systems (Singh, 2012).

Future investigations should prioritize developing artificial intelligence for logistics optimization and blockchain protection systems for public transport freight networks. Local municipalities require better legislative guidelines and supportive programs which enhance the smooth incorporation of freight delivery into transit transportation systems (Bhaskaran, Pappy, Rajeswaran, Suber, & Satheesh, 2023).

## 2.7 Challenges and Gaps in Transit-Integrated Freight Research

The implementation of public transport at urban freight logistics faces substantial obstacles to its widespread adoption (Martins, 2025). A number of barriers limit the implementation of public transport in urban freight logistics including operational conflicts alongside infrastructure limitations and regulatory and policy hurdles as well as public perception concerns. Development alongside policy transformation together with stakeholder mindsets evolution represents the solution to address these difficulties (Kazemi, Mohamadi, & Kianfar, 2025). A complete analysis of current barriers blocking transit-integrated freight systems from widespread implementation occurs in this section.

### 2.7.1 Infrastructure and Capacity Constraints

The main problem of freight-on-transit models exists because there is no separate infrastructure present to support both passenger and cargo transportation on public transportation systems.

#### 2.7.1.1 Space Limitations in Transit Vehicles

Accommodating freight transportation remains a challenge since conventional public transport has been created primarily for passenger use (Martins, 2025). Metro trains in London and Paris showed only a 10% maximum capacity to accept cargo transportation (Tong & Matopoulos, 2025). The restricted seating capacity of buses together with the limited space on trams makes it difficult to implement freight-on-transit models.

#### 2.7.1.2 Weight and Structural Challenges

samostat transport materials generates additional weight that promotes unfavorable effects on public transportation vehicles (Djaelani, 2025). The chemical degradation of transportation infrastructure from excessive carrying of freight products decreases vehicle durability by 20% according to research conducted in Stockholm and Singapore (Gomes, Fontul, Knight, & Breemersch, 2023).

#### 2.7.1.3 Need for Loading and Unloading Infrastructure

Present-day public transport hubs need designated shipping zones for better operational efficiency because they currently experience inefficiencies (Pakistan, 2020).

The establishment of transit-integrated freight operations at Tokyo required extensive infrastructure adjustments before launching the program (Calimente, 2012).

### 2.7.2 Operational and Logistical Challenges

Operating freight in such transportation systems creates issues regarding delivery schedules and delivery coordination and service quality preservation.

#### 2.7.2.1 Scheduling Conflicts with Passenger Transit

The official public transportation system operates through rigid time schedules that present problems when managing flexible logistics operations (Mohamed El Amrani, Fri, Benmoussa, & Rouky, 2024). Research conducted in Brazilian bus transportation systems discovered that delayed freight loading caused problems for regular bus passengers (Soza-Parra, Raveau, Munoz, & Cats, 2019).

#### 2.7.2.2 Risk of Delivery Delays

Public transport differs from dedicated delivery trucks because it does not adapt delivery routes according to demand changes (Shuaibu, Mahmoud, & Sheltami, A Review of Last-Mile Delivery Optimization: Strategies, Technologies, Drone Integration, and Future Trends, 2025). Research conducted in Berlin and Amsterdam proved that metro and tram-based freight delivery methods caused shipment delays reaching 40% more than standard delivery trucks.

#### 2.7.2.3 Security and Cargo Theft Risks

Security threats affect freight delivered through public transit networks especially in densely populated urban metropolitan areas. Research between New York and Los Angeles showed that freight left unattended in metro compartments became vulnerable to theft.

### 2.7.3 Regulatory and Policy Barriers

The biggest challenge to creating transit-integrated freight logistics comes from existing legal and policy barriers.

#### 2.7.3.1 Lack of Regulations for Mixed-Use Transit Systems

There is no legal framework in public transport regulations for freight movement resulting in disputes (Shoaib, 2025). In European urban freight policy research only 15% of investigated cities could demonstrate comprehensive legal support for freight-on-transit operations.

2.7.3.2 Government Resistance and Bureaucracy

Public transportation organizations maintain passenger services at the forefront of their priorities which causes freight integration to have minimal importance. Research conducted in China and India revealed that public authorities refused to modify transportation rules because service interruptions concerned them (Ertugrul, Mete, & Ozceylan, 2025).

#### 2.7.3.3 Funding and Investment Gaps

The implementation of freight transportation integration within transit systems demands substantial investments for infrastructure development and security measures along with scheduling systems although available funding is usually insufficient. Freight trams faced financial challenges in Germany because their startup costs were deemed too expensive making their popularity limited.

|  |  |  |  |
| --- | --- | --- | --- |
| **Challenge Category** | **Specific Issues** | **Example Cities** | **Source** |
| Infrastructure Constraints | No cargo compartments, weight limitations | London, Stockholm | Gomes et al. (2023) |
| Operational Conflicts | Scheduling issues, delivery delays | Berlin, Amsterdam | Soza-Parra et al. (2019) |
| Regulatory Barriers | No legal framework, policy resistance | European cities, India | Shoaib (2025), Ertugrul et al. (2025) |
| Public Acceptance Issues | Space sharing concerns, safety worries | Hong Kong, Singapore | Marra & Corman (2025) |

Table 6: Key Challenges in Transit-Integrated Freight Implementation

### 2.7.4 Public Perception and Acceptance Issues

The process of implementing transit-integrated freight logistics faces obstacles because of public resistance.

#### 2.7.4.1 Passenger Concerns About Shared Space

Passengers tend to avoid sharing their transit space with freight according to surveys since they worry about comfort, hygiene and safety issues (Marra & Corman, 2025). Research in Hong Kong and Singapore demonstrated that more than sixty percent of transit users objected to freight-sharing models which they wanted to be solely used by passengers.

#### 2.7.4.2 Lack of Public Awareness and Education

The majority of cities' urban population has no knowledge regarding what transit-integrated freight offers. The cities of Paris and Tokyo achieved better acceptance through public campaigns yet worldwide institutions need to enhance their educational efforts about freight integration.

### 2.7.5 Technological Limitations

AI and the IoT together with blockchain receive investigation for logistics optimization but multiple technological difficulties persist.

#### 2.7.5.1 Lack of Digital Integration in Public Transport Systems

Public transit organizations operate without proper digital systems for freight delivery coordination (Shoaib, 2025). A study on smart logistics in South Korea demonstrated that transit agencies lacked proper digital infrastructure to connect freight deliveries because only 20% of them were capable of integrating freight movements (Ertugrul, Mete, & Ozceylan, 2025).

|  |  |  |  |
| --- | --- | --- | --- |
| **Technology** | **Current Readiness Level** | **Example City/Project** | **Implementation Notes** |
| AI for Scheduling | Medium | Munich, Singapore | Operational in pilot stages |
| IoT Tracking | Low–Medium | Stockholm, Tokyo | Limited vehicle coverage |
| Blockchain for Tracking | Low | Research Stage | Few operational deployments |
| Autonomous Freight Vehicles | Very Low | Trials in Singapore, Sweden | Requires regulatory approval |

Table 7: Technology Readiness in Transit-Integrated Freight

#### 2.7.5.2 Absence of Real-Time Freight Tracking

Public transport operations typically do not provide GPS tracking for their cargo following traditional logistics standards. The Swedish and Canadian studies confirmed that vehicle freight security depends on real-time monitoring capability for tracking freight movement between destinations (Ertugrul, Mete, & Ozceylan, 2025).

### 2.7.6 Addressing These Challenges: Future Directions

Research identifies multiple approaches which help organizations confront such obstacles to execute transit-integrated freight logistics successfully.

Proposed Solutions:

* Public transportation vehicles should include designated safe areas for freight storage which must be integrated into buses trams and metro trains.
* The utilization of AI-driven scheduling platforms helps transportation systems maintain flexible scheduling which allows both passenger and freight services to operate without disturbing public transit schedules.
* The policy needs improvements: Governments should create updated transit laws that handle urban freight distribution needs.
* Educational public campaigns about the advantages of freight systems integrated with transit will help passengers to become more accepting according to our plan.

|  |  |  |
| --- | --- | --- |
| **Barrier** | **Example City** | **Suggested Solution** |
| Infrastructure Limitations | London | Design secure cargo compartments in buses and metros |
| Scheduling Conflicts | Berlin | AI-powered scheduling and load balancing |
| Policy/Regulatory Restrictions | Paris | Policy reforms, freight-on-transit legal frameworks |
| Public Perception | Singapore | Awareness campaigns and pilot projects |
| Lack of Real-Time Cargo Tracking | Johannesburg | IoT-based real-time parcel tracking and security systems |

Table 8: Barriers to Transit Freight Implementation and Suggested Solutions

## 2.8 Cargo Hitchhiking: A Specialized Model for Urban Freight

Urban freight logistics has adopted a modern sustainable method known as cargo hitchhiking to enhance its operations. The practice utilizes public transport vehicles to combine goods delivery with passenger travel while making the best use of transit system underutilized space. The model supports worldwide initiatives to minimize transportation congestion together with emission levels and delivery expenses (Bischoff, Lienkamp, Tambha, & Schiffer, 2024). A growing number of cities together with pilot projects are demonstrating that cargo hitchhiking works on multiple levels while continuing to develop.

### 2.8.1 Concept and Mechanism of Cargo Hitchhiking

The cargo hitchhiking system functions through real-time adjustments of public transport vehicle space which enables parcel transportation (Bischoff, Lienkamp, Tambha, & Schiffer, 2024).

#### 2.8.1.1 Key Components of Cargo Hitchhiking

A dynamic freight allocation system uses artificial intelligence algorithms to connect transit capacity openings with shipping requests (Nlogwiasctki & Winietrhzbeic, 2024).

Smart Cargo Compartment Systems provide secure storage units placed in buses and trams and metro trains to hold parcels (́ska, 2023). GPS and IoT-based tracking equipment tracks freight in transit to optimize both pickup and drop-off (Moumen, Rafalia, Abouchabaka, & Aoufi, 2023). The results of Munich's hybrid public transit unit analysis revealed substantial advantages from utilizing cargo hitchhiking practices for enhancing urban freight operations and cost management mostly during e-commerce and last-mile delivery processes (Bischoff, Lienkamp, Tambha, & Schiffer, 2024).

### 2.8.2 Benefits of Cargo Hitchhiking for Urban Freight

The transportation process of cargo hitchhiking delivers better economic and environmental outcomes and improved logistics when compared to regular delivery methods.

#### 2.8.2.1 Environmental and Traffic Impact

The adoption of cargo hitchhiking creates better road flow because it moves a section of city cargo onto public transit systems (Nlogwiasctki & Winietrhzbeic, 2024). Research from Amsterdam and Berlin indicates that implementing integrated freight transit systems decreased the amount of delivery vans present by 30%. The use of electric vehicles results in reduced fuel usage and lower environmental emissions that aid sustainable city travel (Asim, et al., 2022).

#### 2.8.2.2 Cost Savings for Logistics and Transit Authorities

Companies that transport freight achieve decreased expenses for fuel maintenance along with vehicle upkeep expenses (Moumen, Rafalia, Abouchabaka, & Aoufi, 2023). The municipality of Munich discovered that cargo hitchhiking could reduce final delivery expenses by 35% because companies no longer needed special delivery fleets (Bischoff, Lienkamp, Tambha, & Schiffer, 2024). Public transport agencies increase their profit by applying freight fees which supports sustainable financial operation of transit systems (́ska, 2023).

#### 2.8.2.3 Improved Last-Mile Delivery Efficiency

Transit-integrated freight hubs shorten delivery periods for services by allowing small distribution networks to operate through their infrastructure (Nlogwiasctki & Winietrhzbeic, 2024). The Metro Cargo Hitchhiking Project in Tokyo confirmed that combining goods shipping with public transportation decreased the duration of final-mile distribution by 25%.

### 2.8.3 Case Studies and Real-World Implementations

Various municipal areas have established cargo hitchhiking systems as part of their operational infrastructure.

#### 2.8.3.1 Munich, Germany: Hybrid Transport for Urban Freight

A team from Technical University of Munich evaluated cargo hitchhiking through their research on AI-based dynamic freight allocation (Bischoff, Lienkamp, Tambha, & Schiffer, 2024). Records indicate that the implementation of hybrid transportation units resulted in a 40% enhancement of operational efficiency in comparison to conventional delivery methods.

#### 2.8.3.2 Paris, France: Metro Freight Deliveries

Paris Metro initiated a freight-on-transit service by transporting packages throughout off-peak periods according to (́ska, 2023). The implemented system managed to decrease freight vehicles in urban areas by 20% leading to lower emissions while enhancing environmental quality levels.

#### 2.8.3.3 Singapore: Smart Bus Cargo Integration

The Smart Bus Cargo Project in Singapore evaluated public bus deployment of parcel storage spaces (Nlogwiasctki & Winietrhzbeic, 2024). A 30% decrease in delivery failures at the final stage along with better logistics reliability emerged from this system.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **City** | **Mode Used** | **Efficiency Improvement** | **Emission Reduction** | **Source** |
| Munich | Bus/Metro Hybrid | +40% | — | Bischoff et al. (2024) |
| Paris | Metro Freight | — | -20% | ́ska (2023) |
| Singapore | Smart Bus Cargo | +30% fewer delivery failures | — | Nlogwiasctki & Winietrhzbeic (2024) |

Table 9: Cargo Hitchhiking Implementation Results

### 2.8.4 Challenges and Limitations of Cargo Hitchhiking

The implementation of cargo hitchhiking encounters various technical, operational and policy-connected barriers.

#### 2.8.4.1 Infrastructure and Storage Constraints

Public transit vehicles usually do not support freight storage because modifications become very costly (Moumen, Rafalia, Abouchabaka, & Aoufi, 2023). The gamut of changes needed to make the London Underground system capable of storing goods as part of their Underground Freight Initiative added millions of dollars in infrastructure development costs (Asim, et al., 2022).

#### 2.8.4.2 Scheduling and Passenger Conflicts

Synchronizing commercial travel with cargo transport becomes very challenging when performing operations at peak traffic times (́ska, 2023). Freight loading activities within the Metro-Based Freight Model in New York created delays of 15 to 20 percent in train schedules which negatively affected commuter satisfaction (Asim, et al., 2022).

#### 2.8.4.3 Regulatory and Security Concerns

The existing transit policies in numerous cities lack the capability to conduct combined passenger and freight operations (Nlogwiasctki & Winietrhzbeic, 2024). Snorting parcels through shared transit systems exposes them to heightened risks of theft and disappearance (Moumen, Rafalia, Abouchabaka, & Aoufi, 2023).

### 2.8.5 Future Directions and Research Opportunities

Research suggests three separate solutions which will enhance the effectiveness of cargo hitchhiking models:

#### 2.8.5.1 AI-Driven Scheduling Optimization

The allocation process for freight to transit vehicles employs machine learning algorithms which follow up-to-the-minute passenger demand levels (Bischoff, Lienkamp, Tambha, & Schiffer, 2024).

#### 2.8.5.2 Dedicated Freight Compartments in Public Transit

Transport organizations can reduce security risks and achieve efficient deliveries through secure transportation areas in their metro and bus networks (Nlogwiasctki & Winietrhzbeic, 2024).

#### 2.8.5.3 Policy and Regulatory Reforms

Government institutions must create regulatory measures to endorse models which combine transportation functions. Public-private partnerships serve as accelerators because they unite transit agencies with logistics providers (́ska, 2023).

## 2.9 Research Gaps and Future Directions in Transit-Integrated Freight

Information technology continues to advance public transport integration for freight delivery yet numerous research fields still need attention. The development of transit-integrated freight logistics faces multiple challenges such as scarce empirical evidence along with regulatory constraints and technical limits and difficulty in multiplying these systems. The development of these solutions represents essential requirements for transport-oriented freight system enlargement and optimization. This part describes essential research limitations and suggests future research approaches. Most research works examine theoretical models while ignoring real-to-life implementation and validation procedures. Australian urban freight policy research demonstrates insufficient empirical testing of integrated transit freight models. Scientists have conducted minimal research on how simulation techniques analyze live freight movement via public transit networks.

The absence of transit-integrated freight support policies in numerous cities creates unclarified regulations about such operations. The implementation of consistent freight integration programs faces difficulties due to regional policy mismatch between metro, tram and bus network sectors. Public-private partnerships (PPPs) for transit-integrated freight show slow development because of the weak relationships between transportation providers and public transit operators.

Real-time freight tracking systems which are absent from public transport negatively impact security as well as operational efficiency. Freight scheduling algorithms based on artificial intelligence remain poorly implemented across transportation systems which consequently hinders the optimization of delivery operations. Freight storage compartments in public transit systems do not exist which leads to cargo security being at risk.

Insufficient studies about passenger opinions on freight-sharing transit systems affect how the public accepts these models. Research shows people avoid sharing transportation space with freight shipments yet scientists have not studied this behavior thoroughly.

Research concentrations should focus on closing these areas of knowledge deficiency to advance fields. Researchers should develop artificial intelligence simulations which will analyze freight movement within actual transit systems. Developing big data analytics systems to optimize freight scheduling as well as space utilization represents one of the priority research areas. IoT real-time tracking provides freight transporters with both security and operational efficiency while transporting through transit routes.

Organizations should create complete policy guidelines that cover mixed-use transit systems. Public-private partnerships (PPPs) need to be promoted for the expansion of transit-integrated freight programs. The development of context-specific municipal policies creates guidelines that strengthen freight integration resources with urban transport targets.

Designing secure freight compartments within public transit vehicles. The utilization of blockchain-based technologies enables improvement of freight security and improved traceability.

Exploring autonomous public transport vehicles for freight and passenger integration.

Large-scale surveys need to evaluate how many commuters would permit freight to occupy transit space. A testing program needs to evaluate public education initiatives for boosting community support of cargo hitchhiking systems.

### 2.9.1 Implications for Future Research

Future research must tackle operational together with regulatory matters and technological barriers to achieve maximum potential from public transport-based urban freight systems. Future research must focus on three main research objectives which include the following strategic priorities:

The development of improved simulation software allows real-time evaluation of transit-integrated logistics operations alongside delivery performance analysis.

Researchers should deploy multiple pilot projects across diverse city locations to read and evaluate scalability features and operational viability points.

Academic research should analyze policy structures which enable easy integration of freight operations into transit systems. Sustainable urban freight models are supported through public-private partnerships (PPPs).

Researchers need to perform surveys among passengers to determine their readiness to accommodate freight operations within transit areas. Evaluating consumer and retailer adoption patterns for public transport-based logistics solutions.

The study focuses on developing secure modular compartments for bus freight and tram freight and metro train freight. AI methods combined with blockchain technology and IoT systems support more effective freight tracking and scheduling. The analysis of autonomous as well as electric public transport vehicles designs for passenger-freight combination applications.

## 2.10 Conclusion

Urban freight logistics benefits from public transport systems which function as a powerful approach to cut congestion while decreasing emissions and improving the delivery performance of the last mile. Researchers identified several main findings from different studies regarding public transport-integrated logistics. Studies show that integrating freight delivery onto public transport systems brings environmental advantages since it relocates truck deliveries onto municipal transit systems.

The use of public transport systems for freight operations generates three main positive results: it decreases delivery expenses at the final stage and provides new revenue for transportation agencies while maximizing urban space utilization. Transit-integrated freight requires additional research and policy development because it faces traditional infrastructure limitations and policy implementation troubles as well as public acceptance hurdles. Modern technologies including AI-powered cargo hitchhiking together with blockchain freight security methods and IoT tracking enable better functionality of transport-based freight systems.

The implementation of wide-scale transit-based freight depends on creating standardized policies together with public-private partnerships and government incentives. The research demonstrates the emerging value of transit-integrated freight though experts agree that further investigations are needed for its complete development. Sustainable urban logistics management requires active exploration of new ways to deliver goods during the final transit stage to customers. Public transport systems integrated with freight operations establish an alternative freight method which provides benefits for environmental concerns and both economic interests and logistical requirements. The technology exists but its complete potential needs extensive quantitative study with accompanying regulatory modifications and technological upgrades for a wider implementation.

# Chapter 3: Methodology

The chapter details the research method which examines the practicality along with cost-effectiveness and environmental advantages of using cargo hitchhiking as a sustainable urban freight solution. The method of cargo hitchhiking brings parcel delivery into public transportation systems through empty space utilization in buses, and metro systems to support goods movement in urban center. City populations experience increased e-commerce demands and traffic jam issues alongside environmental concerns thus requiring immediate changes to last-mile delivery operations.

The research method implements multiple developmental stages for understanding how cargo hitchhiking supports logistics performance by lowering shipping expenses alongside environmental benefits. The methodology uses simulation models combined with cost assessment along with optimization techniques from stakeholder evaluations to evaluate performance levels in economic operational and ecological aspects.

## 3.1 Research Design

This research design implements quantitative methods with scenario modeling and empirical validation for support. The research design consists of five related steps.

1. The first step details how to develop the cargo hitchhiking model along with defining key actors and the delivery system operation.

2. Simulation Modeling – Creating a simulation environment for transit-integrated freight operations.

3. Simulation validates operational costs together with infrastructure requirements along with potential financial savings.

4. Research will be performed on stakeholder feedback process to measure how willing people are to adopt the model and obtain insights about their anticipated difficulties.

## 3.2 Cargo Hitchhiking Conceptual Framework

The cargo hitchhiking system uses current public transportation systems as infrastructure to handle urban freight needs. The model links parcel shipment frameworks to organized public transportation routes so the empty space in public transit vehicles can transport goods between logistics hubs and retail centers and small transportation warehouses. Important elements that comprise the framework are as follows:

1. The cargo compartments inside buses and metro trains as well as ride-hailing services serve as dedicated areas for safely storing parcels.
2. Strategic micro-distribution hubs function as transfer stations which serve public transport terminals for parcel handling and routing.
3. The system features a Digital Logistics Platform that shows live information about parcel booking and tracking together with schedule coordination.
4. The delivery window segments under this system have three classifications: urgent for same-day delivery, standard for next-day delivery and flexible for 2–3 days delivery periods that match transportation availability.

This setup supports multiple delivery system strategies which work toward removing or decreasing conventional delivery van operations mainly during times outside peak hours.

The Cargo hitchhiking concept establishes a system to merge logistics operations within the public transport system framework. The freight journey functions through three sequential phases according to an established design.

1. The collection stage starts by obtaining parcels directly from origin locations including stores and warehouses until they reach their closest micro-distribution hub adjacent to transit stops.

2. The mechanism of Transit Transfer includes using public transit vehicles to move parcels throughout existing routes during time periods that deviate from peak hours.

3. The last phase of delivery involves bringing parcels from destination hubs to the final destination through either recipient pickup or final delivery by micro-delivery agents including bicycle couriers and electric carts.

A central platform undertakes cargo allocation tasks and vehicle matching as well as time-slot optimization to operate under this management structure. The success of this system depends on tight coordination between transit agencies and logistics firms and retailers. The system uses special tracking elements and Quick Response codes to track packages throughout transportation which provides security measures and full tracking capabilities.

## 3.3 Simulation Modeling Approach

The cargo hitchhiking theory will get tested through a discrete-event simulation (DES) model which runs on Python. Several aspects of parcel movements and delivery times and operational impediments and cost efficiencies become visible through the simulation process.

This model follows modular time-based organization that represents an average business week duration. The simulation model features three organizational periods known as Peak Hours followed by the Midday Window and subsequently Off-Peak Period. Virtual transit schedules run parallel to a digital city framework under which the delivery requests derive from actual urban distribution requirements.

The routing algorithm relies on Dijkstra’s algorithm to determine the most efficient transit paths but it automatically selects different paths when excess passenger density makes cargo transportation impossible. Weather conditions and service interruptions exist as simulation features to duplicate real world operational hazards (rain and delivery delays). The packages receive priority labels according to their importance level which determines their placement on high-speed metro lines or reduced-speed bus systems.

### 3.3.1 Key Assumptions

1. The predefined routes together with scheduled times of public transport vehicles prevent adjustments to accommodate freight.
2. The parcel service accepts packages which are considered medium-sized measuring at or below 25 kilograms.
3. The delivery operations are scheduled during moments when stations have minimal passenger traffic and low system demands.
4. Single public vehicles possess a defined maximum package weight or counting restriction.
5. The containerization process takes place exclusively at stops which contain storage containers together with cargo handling team members.

### 3.3.2 Simulation Variables

|  |  |
| --- | --- |
| Variable | Description |
| Parcel Volume | Number of parcels per day segmented by urgency level |
| Vehicle Load Capacity | Maximum freight weight/volume allowed per vehicle |
| Delivery Distance | Travel distance between origin and destination, mapped to transit network |
| Transit Frequency | Number of available vehicles per route, per time window |
| Handling Time | Time taken to load/unload parcels at micro-hubs |
| Traffic Condition Index | Adjustment factor for real-world urban congestion and delay modeling |

Table 10:Key Simulation Variables for Transit-Integrated Freight Model

The simulation tests performance over multiple city zones using synthetic data representing a chain retail operator. It accounts for varying traffic patterns, package volumes, and transport schedules.

## 3.4 Cost Modeling and Analysis

The evaluation of cargo hitchhiking as a method depends largely on its cost-efficient nature. The research report establishes complete cost models for cargo hitchhiking as well as traditional delivery services based on freight vans and dedicated vehicles.

### 3.4.1 Fixed Costs

Infrastructure Setup: Installation of parcel compartments in public vehicles.

The building of micro-hub facilities requires installing parcel storage points in major public transport hubs. Technology Platform Development consists of creating and maintaining operational scheduling and booking systems within real-time functionality.

### 3.4.2 Variable Costs

Each station incurs labor expenses for carrying out parcel loading and unloading operations. Revenue-sharing and leasing costs that transit authorities receive as compensation for public transport services form part of the public transport compensation. The shipment's safety requires packaging that decreases transit damages while stopping thefts at each delivery stage.

### 3.4.3 Comparative Cost Metrics

The Cost Per Delivery metric uses total logistics costs divided by completed delivery parcel number to obtain its value. The reduction in van usage enables an estimation of fuel savings. The maintenance expenses decrease because vehicles receive less wear that results in lower maintenance costs. The financial model compares different break-even points and return on investments between parcel volume and transport availability scenarios. The model adds revenue-generating potential that public transport authorities can obtain as an essential part of its analytical framework. This includes:

* Logistics ventures that use transportation infrastructure are responsible for payment of freight service fees.
* Retailers can subscribe to daily transit slot services through this model.
* The implementation of incentive programs depends on environmental policy subsidies to operate.

The model will analyze modified transit vehicle total cost of ownership (TCO) by including costs associated with installing the vehicles and operations-related fatigue as well as periodic maintenance because of freight-induced wear and tear. The method will help authorities determine sustained value through well-informed decision making processes.

## 3.5 Optimization Techniques

The performance of cargo hitchhiking reaches its maximum values through basic linear optimization modeling which decides delivery assignments to public transit vehicles.

Objective:

Solve the optimization problem to decrease delivery expenses but maintain delivery time frames and avoid exceeding storage limits.

Constraints:

1. Delivery windows (urgent, next-day, flexible).

The plan includes access to official transit routes together with their operating times during the day.

1. Vehicle cargo space constraints.

Parcel priority takes into account the perishability and customer preferences of goods.

Results will help select transportation routes together with time slots and delivery boxes for integration purposes.

## 3.6 Stakeholder Feedback and Feasibility Assessment

Quantitative modeling methods fail to reveal technical barriers which impede the actual process of freight integration in public transportation. This research collects stakeholder feedback by using surveys with set questions and interviews with open-ended questions combined into its methodology.

Target Groups:

1. Public Transit Authorities need assessment of their regulatory openness while assessing their willingness to work with the project.
2. The managers responsible for retail chains need to investigate logistical achievement along with financial benefits.
3. Logistics companies will assess hybrid delivery system opportunities through surveys.

This determines the customer reception when public transport is used for delivery.

Survey Themes:

• Perceived advantages (cost, emissions, convenience).

• Barriers (scheduling, safety, passenger conflict).

• Support for pilot testing.

• Preferred delivery time slots and locations.

• Suggestions for digital platform design.

Multiple-choice and Likert-scale together with open-ended questions will be used throughout the survey. Descriptive statistics along with thematic coding will serve to analyze the gathered data. The Researcher will use grounded theory methodology to generate themes that represent qualitative feedback through coding procedures. Survey participants will provide open answers which will be divided into the following five sections: the economy, logistics, environmental viewpoint, regulatory issues and customer confidence.

Two phases of stakeholder interviews will occur for preliminary exploration before the simulation and post-simulation validation interviews. The two-step approach will build triangulation strength and enhances research finding’s reliability.

## 3.7 Evaluation Metrics

The research will evaluate the cargo hitchhiking model using the following KPIs:

|  |  |
| --- | --- |
| Metric | Description |
| Delivery Reliability | % of parcels delivered within designated time windows |
| Average Delivery Cost | Total operational cost / number of parcels |
| Emissions Reduction | Estimated CO₂ reduction compared to delivery van baseline |
| System Utilization | % of public vehicle capacity used for freight |
| Delivery Time | Average transit time per delivery |
| Consumer Satisfaction | Survey-based acceptance and convenience score |

Table 11:Performance Evaluation Metrics for Simulation Model Assessment

Results will be benchmarked against traditional logistics models to assess whether cargo hitchhiking offers significant improvements.

## 3.8 Ethical and Operational Considerations

The study will follow these ethical and operational protocols because it involves both public infrastructure alongside individual stakeholders:

1. Each participant will receive information about the survey followed by obtaining their voluntary agreement to take part.
2. The analysis will gather anonymous information only while no personal data is recorded.
3. Safety procedures will mandate that any real-world company being analyzed must complete both safety audits and operational compliance checks.

Through this model freight operations must maintain passenger comfort standards without any adverse effects.

## 3.9 Conclusion

The established methodology provides a complete systematic approach to investigate cargo hitchhiking possibilities in sustainable urban logistics operations. The simulation models optimize delivery costs while engaging stakeholders to determine public transit logistics' ability to revolutionize retail distribution. Cities can gain major environmental benefits through transport system distribution of delivery volumes because this approach lowers pollution and traffic while decreasing delivery expenses.

Through this approach modeling and cost investigation together establish the necessary conditions for upcoming deployment initiatives. Research findings will provide cities that adopt cargo hitchhiking approaches to produce strategic deployment plans and select appropriate transit routes and establish blended urban logistics frameworks. This evaluation will produce data to enable smart city development and reduced emission transportation at the national policy level.

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