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Urban Freight Consolidation Model for Post-Hauler Planning

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Abstract

Freight transportation in urban areas has increased significantly in a shorter period due to the widespread use of e-commerce, fast delivery, and population growth. Recently, a noticeable government initiative aimed at creating an effective, acceptable, and sustainable city logistics policy. This paper examines freight consolidation as a transportation strategy for optimizing last-mile delivery costs. Freight consolidation involves combining smaller shipments from various origins into a single, larger shipment for more efficient transportation to a common destination. This approach is particularly beneficial for last-mile delivery, where frequent deliveries of smaller quantities are frequently visible. Finally, we provide an illustrative example targeting urban freight stakeholders for practicing possible consolidation methodology. The result in the illustrative example shows that freight with 3-day consolidation, despite the delay penalty, is cheaper than daily shipping, and both are cheaper than 2-day consolidated shipping. The study will benefit urban businesses and freight services.

Keywords

Freight Consolidation, Urban Transport, Intermodal, Last-Mile Delivery

1. Introduction

Freight distribution is crucial for economic activities in urban centers, as it distributes goods to retailers, businesses, offices, and homes. Urban transportation, particularly freight traffic, has increased significantly due to the widespread use of e-commerce, demand-based delivery concepts, and the synchronization and harmonization of flows [1]. The World Economic Forum's report on the last-mile ecosystem, published in 2021 [2], stated that e-commerce deliveries increased by 25% in 2020 compared to 2019. Although the trend of high e-buyers is evident, some suggest this sudden increase in customer orders was due to the pandemic. Urban freight distribution depends on coordination between organizations in the logistics chain, last-mile delivery accessibility, availability of loading zones, and effective freight selection. Freight shipment consolidation is a popular concept that offers several benefits to urban businesses. Every freight passes through four phases of shipping in a supply chain. The cargo originates from the participants: 1) producers, 2) distributors or wholesalers, 3) urban central warehouse, and 4) retailers or consumers. Developing efficient and environmentally friendly distribution depends on increased knowledge of the urban environment, freight consolidation policies, and cooperation between urban businesses and authorities.

Urban logistics processes are complex, mainly due to high population concentration and economic activity, many diverse stakeholders with different and sometimes contradictory expectations [3]. Urban areas represent only 2% of the world's surface, but they consume more than 70% of total world resources and generate 75% of total world waste [4]. The urban population is increasing faster than ever, and goods distribution in city centers is more complex and harder to manage because of the limited transportation capacity of urban infrastructures and strict regulations [5]. Recently, there are various policies and restrictions in place (Urban Vehicle Access Regulations—UVAR) for urban freight transport, such as Low Emission Zones (LEZ), delivery time windows, vehicle weight and size restrictions, and congestion charging [6]. Some positive results have been achieved, but the problems in urban freight transport persist [7]. In a research survey aiming to gain insights into what smart cities need for energy-efficient and low-emission transportation, [8] found suggestions for a few innovative solutions for energy-efficient smart cities. These are three categories:

i. Urban freight consolidation and trans-shipment for last miledelivery.

ii. Choice of mode of transportation for last miledelivery.

iii. Consumer as a service provider in last-mile deliveries.

Urban transportation is often considered the most inefficient supply chain [9]. An efficient urban transportation system is essential for the functioning of cities as reported by European Commission [10]. Governments and appropriate targets have also recognized that the problem has been set for the future [11]. Traditionally, receivers, carriers, and forwarders are seen as the most relevant stakeholders, but they are often not included in the policy-making process. The existing delivery operations related to E-commerce, especially when considering last-mile deliveries in urban areas, need to be revised [12]. Among many drawbacks, the increase in urban freight contributes to the steep rise in smaller trucks traveling around urban roads, causing excessive pollution, traffic congestion, delay, and risk of accidents. One solution to mitigate the negative effects of urban freight traffic could be to consolidate freight transportation into public or private transportation. The freight consolidation service provider combines these different shipments into a single, consolidated load to streamline the distribution process. A new concept of Urban Consolidation Centers (UCCs) has been implemented in different cities. AUCC is situated at the city's border so that big trucks from shippers can easily access the UCC and deliver goods [13]. Later, small trucks are used to deliver goods to their recipient in a city. This method is only advantageous if the last-mile delivery cost is higher than using a UCC. The involvement of all relevant stakeholders is considered a prerequisite for the successful implementation of policies and for reducing potential conflicts between them [14]. To achieve the UCC implemented, decision-makers must set goals and encourage innovative concepts for urban transportation. The practice can achieve not only transportation efficiencies but also cost reductions. This paper considers a last-mile delivery service in which freight moves from a distribution center or central warehouse to multiple destinations, such as retail centers or customers, through a delivery service that uses freight consolidation.

We organize the paper into five sections. Section 1 introduces urban freight transport. Section 2 describes the freight consolidation model. Section 3 presents a case study on consolidation trade-offs with delay penalties and freight decisions in shipping to multiple locations. Section 4 proposes innovations in urban freight transport, including a discussion of social impact, intelligent transportation Systems, and digital technology in urban transportation. Section 5 includes concluding remarks and future research directions.

2. Freight Consolidation Model

Urban logistics faces numerous challenges and demands for faster and more reliable deliveries [15]. Customer expectations are rising with the demand for more efficient, environmentally friendly, cost-effective logistics services [16]. The principle of the freight consolidation approach supports economies of scale; by combining shipments that are destined for proximate locations, logistical entities can achieve cost savings through reduced fuel consumption, lower emissions, and optimized vehicle utilization. Specifically, freight consolidation arises when a shipper combines multiple shipments within a region into a single load hauled by a carrier. The load is then broken down into smaller parts and delivered by a regional carrier to its many destinations.

Conversely, a load can be picked up by a regional carrier, merged into a single shipment, and then delivered to the destination. Most intermodal freight transportation comprises pre-haulage, long haulage, and post-haulage transport links. It is common for businesses to utilize their trucks for pre- and post-haulage while using intermodal for long-haul transportation. Post-haulage activities are mainly because various urban companies, distribution centers, and warehouses typically make up the last-mile destinations. **Figure 1** shows freight transport comprising pre-haulage, long haulage, and post-haulage transport links. Freight consolidation is ideal in the last phase for shippers who frequently move a few pallets or smaller products.

2.1. Mathematical Model

This study investigates one warehouse and one retailer with multiple order cases.

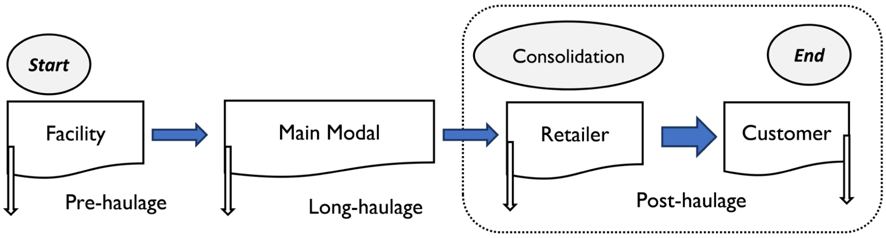


Figure 1. Intermodal Freight Comprising of pre-long-post-haulage.

Transportation cost depends on the shipping frequency and the choice between Less Than Truckload (LTL) and Full Truckload (TL) options. There is a delay penalty cost incurred based on the shipping frequency and the delay in shipment relative to customer demands. The objective is to find the best-consolidated options by minimizing transportation and delay penalty costs. Objective function and constraints can be formulated as follows:

Variables:

x_i: The decision variable representing the shipping frequency to location i.

$C_{LTL}(i)$: The cost per CWT for shipping LTL to location i.

C_{TL}: The cost per CWT for shipping using Full Truck Load to all destinations.

W_i: The weight of goods shipped per day to location i, in CWT.

P: The penalty cost per CWT per day of delay.

D: The days delayed, which is a function of x_i.

U_j: Unit demand for any item j.

Model Constraints:

i. The total weight shipped can be, at most, the full truckload capacity when shipments are consolidated.

ii. The choice of shipping frequency (x_i) directly impacts the delay penalty incurred.

iii. Total shipping items X_{ij} must meet the j unit demand, U_j.

Formulation:

Transportation Cost:

$$Z_1 = \sum_i \left(W_i \times x_i \times \min\left(C_{LTL}(i), C_{TL}\right)\right) \tag{1}$$

Where i iterates over the cities. Delay Penalty Cost:

$$Z_2 = \sum_i \left(W_i \times D(x_i) \times P\right) \tag{2}$$

Under condition

$$\sum_{i=1}^{n} x_{ij} = U_j \tag{3}$$

The delay $D(x_i)$ is a function of the shipping frequency x_i, which needs to be carefully defined based on the specific penalty structure. Total cost function is given below.

Subject to

$$X_{ij} \geq 0 \tag{4}$$

$$X_{ij} \geq U_i, i = 1, \cdots, m \tag{5}$$

The total cost, $TC = Z_1 + Z_2$

$$TC = \sum_i \left(W_i \times x_i \times \min\left(C_{LTL}\left(i\right), C_{TL}\right)\right) + \sum_i \left(W_i \times D\left(x_i\right) \times P\right) \tag{6}$$

2.2. Freight Consolidation Benefits

One of the most significant benefits of freight consolidation is cost savings. By combining multiple shipments into a single truckload, companies can leverage economies of scale and negotiate lower rates with carriers than individual less-than-truckload (LTL) shipments leads to several benefits.

Improved Efficiency: Consolidation reduces the number of delivery trips required, leading to less congestion, lower fuel consumption, and a smaller environmental footprint. Consolidation mitigates traffic congestion which leads to cutting down carbon emissions and contributes to sustainable urban logistics.

Enhanced Customer Service: While consolidation might lead to slight delays in individual deliveries, the overall cost savings can translate into lower customer prices.

Reduced handling: Traditional LTL (Less *et al.*) shipping involves multiple transfers between warehouses and terminals before reaching the destination. Each transfer point introduces a risk of mishandling, dropping, or improper stacking. Consolidation reduces these risks by minimizing handling.

Packing Optimization: Consolidated shipments can be strategically packed within the trailer, filling voids, and utilizing space effectively. This reduces movement and potential collisions between packages during transportation, which can cause damage.

Carrier Focus: A complete truckload shipment represents a larger revenue opportunity for the carrier. This incentivizes them to handle the shipment more carefully to avoid damage and potential claims that could lead to financial losses.

Environmental Benefit: Consolidation reduces the number of delivery trips required, leading to less congestion, lower fuel consumption, and a smaller ecological footprint. Fewer trucks on the road translate to a significant decrease in greenhouse gas emissions, benefiting the environment and contributing to a more sustainable supply chain.

2.3. Challenges of Freight Consolidation

Involving third-party logistics (3PL) providers can facilitate the freight consolidation strategy by coordinating between suppliers, customers, and freight consolidation services. If 3PLs serve as intermediaries for multiple clients requiring shipments to a shared destination, they can optimize the shipping frequency by minimizing total cost, which includes both transportation costs and penalty costs for delays. However, there are some challenges come with freight consolidation.

Acquiring freight: Finding carriers that are willing to transport the consolidated freight is often unavailable. Not all freight forwarders are keen to keep track of pricing, dimensions, and timing of consolidated goods.

Order Preparation Time: Consolidation shipments vary in size and frequency, ranging from small packages to full truckloads. Planning for shipment takes additional time, although it can save time during transport.

Trade-off between Cost and Speed: Consolidation can lead to delayed deliveries for some customers as shipments are grouped for a single trip. Finding the optimal balance between cost savings and customer service expectations is crucial.

Planning and Coordination: Effective consolidation requires precise planning and coordination among shippers, carriers, and potentially, a third-party logistics (3PL) provider. This complexity can lead to challenges in timing and scheduling, as the process involves aligning multiple shipments with varying origins, destinations, and delivery deadlines.

3. Consolidation Trade-off

In freight consolidation, multiple orders are combined into one shipment, and shippers can save on freight and fuel costs, reduce the number of shipments, and reduce their environmental impact. Consolidated shipping could be cargo consolidation, order consolidation, or consolidated freight. Freight consolidation can reach to maximize efficiency and cost savings for shippers. The trade-off is the consolidation with economy of scale vs. faster delivery. When shipments are consolidated, freight must wait for a combined volume to create economies of scale. The consolidation can lead to better negotiation power. However, it can cause a delivery delay or a penalty for additional logistics processes.

3.1. Case Study: Consolidation Trade-off with Delay Penalty

The study is motivated by a case of a large national clothing retailer in the United States that operates a single, central consolidation warehouse in the Midwest. The challenge the retailer receives is daily online orders from customers across the US for a wide variety of clothing items (shirts, pants, dresses, etc.) from numerous brands. These orders typically consist of a small number of items each. If the retailer shipped each order directly from supplier or manufacturer, it leads to the following costs.

i. *High transportation costs*: Many small shipments incur higher costs per unit than larger, consolidated shipments.

ii. *Inefficient delivery times*: Due to multiple handling points and potential delays, individual shipments can take longer to reach customers.

iii. *Inventory management complexity*: Managing inventory levels across a large network of suppliers becomes more challenging.

If the retailer implements a freight consolidation strategy through a central warehouse, it will face the following benefits.

Order aggregation: The central warehouse continuously collects and combines customer orders, streamlining the processing of high-volume items for faster delivery.

Item picking: Warehouse staff efficiently pick individual items from bulk inventory based on the consolidated orders.

Shipment consolidation: Picked items are grouped based on destination zip code or region to optimize truckloads.

Outbound shipping: Consolidated shipments are dispatched directly to regional distribution centers or customers.

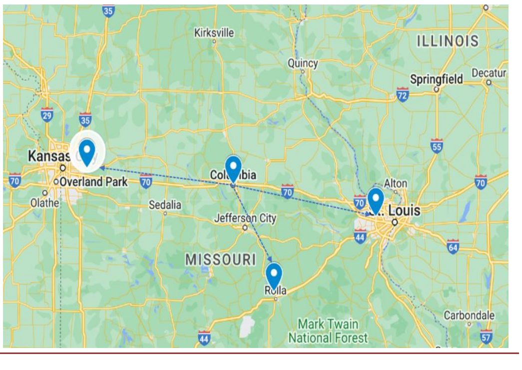
To illustrate the economic implications of freight consolidation, we present a simple case involving the shipper transporting goods from a central warehouse in Columbia, MO to three adjacent cities: Rolla, St. Louis, and Kansas City. The supplier faces a decision regarding shipping frequency—daily, every other day, or every third day—with considerations for transportation costs and delay penalties. The analysis begins with assessing total demand and transportation costs, differentiating between Less-Than-Truckload (LTL) and Full-Truckload (TL) options. The retailers order multiple items from the central warehouse over a time horizon with scheduled shipment dates and delivery time windows. The case study specifically calculates the costs associated with each shipping frequency, incorporating penalties for shipment delays, thus providing a holistic view of the economic trade-offs. Consolidating shipments allows for lower transportation costs for larger loads but incurs penalty costs due to delays. Transportation cost is $/per 100 pounds (CWT). A full truckload is considered 25,000 lb. (or 250 CWT). **Table 1** depicts the daily retail orders from customers.

Freight consolidation presents a viable strategy for enhancing last mile transportation efficiency. The central warehouse uses the last-mile service providers to ship products to the retailers at predetermined shipment dates and must deliver them within a prescribed delivery time window. Otherwise, the warehouse gets a penalty for the delay. **Figure 2** displays daily, every other day, or every third day consolidation.

Usually, retail orders are small, and their shipments are not sub-divided but can be consolidated. **Table 2** presents freight shipping cost per CWT (a hundred weight, *i.e.*, 100 lbs) for LTL and TL.

Table 1. Freight orders from warehouse to retail centers.

From Columbia, MO to 3 adjacent cities	Weight/day
Rolla, MO	80 cwt
St. Louis, MO	100 cwt
Kansas City, MO	70 cwt
Total demand per day	250 cwt



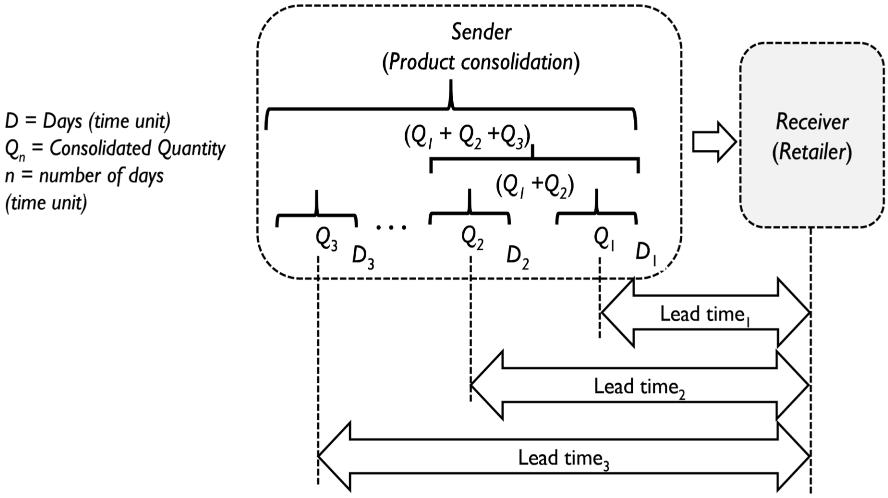


Figure 2. Freight Consolidation options (1 day, 2 days or 3 days).

Table 2. Freight shipping cost per CWT.

From Columbia, MO to City	RentSpace LTL < 250 CWT	RentFullTruck TL > 250 CWT
Rolla, MO	$1.20/CWT	$1.00/CWT
St. Louis, MO	$1.05/CWT	$0.80/CWT
Kansas City, MO	$2.00/CWT	$1.20/CWT

To calculate shipping frequency and determine how long orders should be held to minimize total cost, we leverage economies of scale. Organizations can achieve substantial cost savings and customer satisfaction by adhering to consolidation while managing minor customer order changes during the consolidation period. The case of a post-haul shipment from St. Louis to adjacent cities utilizing the freight consolidation strategies has the following three steps.

Observation 1. Step 1 finds which freight option is cheaper, whether the LTL or Full Truck, in the context of daily shipment with no delay penalty. The LTL transport cost is $341, which is cheaper.

Observation 2. With every other day shipping option (Step 2), LTL is cheaper. LTL Transport Cost = (192 + 200 + 280) for 2 days. LTL penalty: 250 cwt for 1 day delay = 250 × 0.20 = $50. At LTL, with another day shipment, the total transport Cost = ($672 + 50)/2 = $361/day.

Observation 3. With every third shipping option (Step 3), FT is cheaper. FT transport cost (for3days) = (250 + 292.5 + 300) = 842.5. Delay Penalty: 250 cwt delayed 1 days + 250 cwt delayed 2 days = 250 CWT × $0.20 + 250 CWT × 2 days × $0.20 = $150 every 3 days. Total FT transport cost = (842.5 + 150)/3 = $330.83/day.

Table 3 presents consolidated shipping option with best price between both LTL and FT freight for the illustrated case. A freight forwarder or a 3PL can also follow this approach to calculate the TDC for other shipping frequencies.

Step 1. Identify cost for everyday shipment between LTL and FT (1st-day delivery, no penalty).

Delivery: From Columbia, MO to	Rent LTL (space) (Daily shipment)	Rent Full Truck (FT) (Daily shipment)
Rolla, MO	80 × 1.20 = $96	250 × 1.00 = $250
St.Louis, MO	$105	$200
KansasCity, MO	$140	$300
Total shipping cost	$341	$750

Step 2. Identify the cost for shipping every other day between LTL and FT—two days of consolidated delivery and a penalty cost for a one-day delay.

Delivery: From Columbia, MO to	LTL (space Rent) (2-day consolidation)	Full Truck (FT) (2-day consolidation)
Rolla, MO	(80 × 2) 160 × 1.20 = $192	250 × 1.00 = $250
St. Louis, MO	$210	$200
Kansas City, MO	$280	$300
2-day consolidated cost	$682	$750

Step 3. Identify cost for shipping every third day. The cost for three days consolidated delivery, and a penalty cost for two-day delay between LTL and FT.

Delivery: From Columbia, MOto	RentLTL (space) (3-day consolidation)	FullTruck(FT) (3-day consolidation)
Rolla, MO	(80 × 3) 240 × 1.20 = $288	$250
St. Louis, MO	$315	FL: $240, Partialload = $52.5 Total: $240 + 52.5 = 292.5
Kansas City, MO	$420	$300
2-day consolidated cost	$1023	$842.5

Table 3. Consolidated Shipping option with the best price.

Shipping option	Cheaper Freight	Shipping cost (per day)
Everyday	LTL	$341/day
Every other day	LTL	$361/day
Every third shipping	FT	$330.83/day

The "Every Third Day" is the best shipping scenario. The daily Total Cost (TC), including the delay penalty, is $330.83 per day. The case study emphasizes the significance of freight consolidation in reducing transportation costs, mainly through utilizing full truckload capacities. Furthermore, it highlights the importance of strategic shipment scheduling to minimize penalties due to delays and preserve customer responsiveness. The challenge the retailer may face is the increased lead time. Customers might experience a slight delay compared to direct shipments from suppliers due to the consolidation process at the central warehouse. Customers will also require sufficient space and resources to handle the volume of consolidated shipments.

3.2. Shipping to Multiple Locations

In a broader context, companies need to analyze their specific circumstances to determine the most cost-effective shipping methods, potentially employing software or logistic experts to optimize these decisions. Figure 3 and Table 4 illustrate the variables needed to achieve an optimal logistics scenario. This instance is composed of strategic freight decisions to transport freight to several sets of retail locations.

Distance and Order Quantity Impact: The cost per CWT generally increases for LTL shipments as both distance and order quantity increase, which creates an added handling cost reflected on the last-mile delivery costs. The FT costs slightly decrease or remain stable, benefiting from economies of scale and reduced handling per unit.

Strategic Shipping Consolidation:

Most consumers and retailers are located around the city centers in the urban setting, while the central warehouse and logistics facilities are on the periphery. Consolidating shipments can significantly reduce costs, particularly for medium

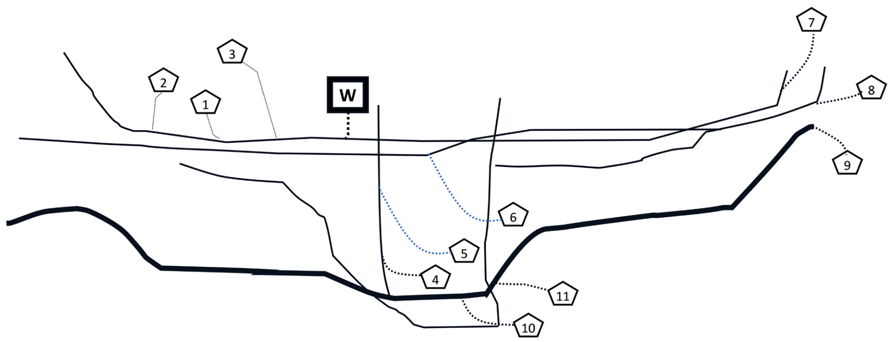


Figure 3. Freight delivery to several sets of retail locations.

Table 4. Freight decisions from central warehouse to multiple locations.

Warehouse to Locations	Distance Category	Ordering Quantity	Rent Space LTL < 250 CWT	Rent Full Truck FT > 250 CWT	Freight Selection
Location 1	Short	Small	$1.20/CWT	$1.00/CWT	LTL
Location 2	Short	Medium	$1.25/CWT	$0.95/CWT	LTL
Location 3	Short	Large	$1.30/CWT	$0.90/CWT	LTL
Location 4	Medium	Small	$1.40/CWT	$1.05/CWT	FT
Location 5	Medium	Medium	$1.45/CWT	$1.00/CWT	LTL
Location 6	Medium	Large	$1.50/CWT	$0.95/CWT	FT
Location 7	Long	Small	$1.60/CWT	$1.10/CWT	FT
Location 8	Long	Medium	$1.65/CWT	$1.05/CWT	FT
Location 9	Long	Large	$1.70/CWT	$1.00/CWT	FT
Location 10	Medium	Medium	$1.45/CWT	$1.00/CWT	FT
Location 11	Medium	Large	$1.50/CWT	$0.95/CWT	FT

to long distances. For example, shipping to Location 6 or Location 9 every other day or every third day with FT could result in lower overall costs compared to daily LTL shipments, even after considering potential delay penalties.

Choosing Between LTL and FT:

For smaller orders and shorter distances (e.g., Location 1, Location 4), LTL might be more cost-effective due to the lower overall shipping volume and the higher per-unit cost of dedicating a full truck.

For larger orders or longer distances (e.g., Location 9, Location 11), FT becomes more attractive due to the efficiency of moving larger volumes at once and the relatively lower increase in cost per additional CWT.

4. Innovative Urban Freight Transport

Innovative urban freight transport is increasingly important as e-commerce and same-day or two-day delivery continue to grow. The consolidated shipments leverage economies of scale, leading to lower overall transportation costs per item. The retailer can achieve faster delivery times by combining orders and utilizing faster shipping methods for consolidated shipments, leading to quicker customer deliveries. Often, centralized inventory at the warehouse simplifies management and provides better visibility into stock levels. As consolidation reduces the number of individual shipments, it leads to more efficient warehouse and logistics operations. The findings reveal an expected shipment delivery targeting the tradeoff between cost optimization and customer responsiveness. Daily shipments, while avoiding delay penalties, incur higher LTL costs. Conversely, less frequent shipments benefit from TL pricing but are subject to delay penalties, affecting customer satisfaction. The optimal shipping frequency, therefore, hinges on a balanced assessment of these factors, aligning with the organization's strategic objectives and customer service standards.

4.1. Freight on Public Transport

While the concept of product consolidation is in place, freight transportation using public transit systems has been explored through various innovative pilot projects worldwide. Offering insights into the feasibility, benefits, and challenges of integrating cargo movement with passenger services. These initiatives aim to reduce urban congestion and pollution by leveraging existing public transportation networks. Below, we highlight some updated and newer cases, reflecting cities' diverse approaches to incorporating freight into public transportation. Following are some of the innovative initiatives [17].

Amsterdam (2007): CityCargo Amsterdam's "CargoTram" project aimed to slash inner-city truck traffic by half and reduce pollution by 20%. While a successful month-long pilot ran with empty cargo trams, the company later dissolved [18].

Dresden (2001-2020): DVB Dresden's CarGoTram successfully supplied Volkswagen's "Transparent Factory" with automotive parts just in time for two decades. This tram-based service replaced up to 25 daily truck journeys [19].

Frankfurt (2019): A collaboration between Hermes, a CEP service provider, and Frankfurt University explored the "LastMileTram" concept. Customized boxes were transported by tram to the city center and delivered to final destinations by e-bikes. While feasible, the study found tram delivery slightly more expensive than traditional road methods [20].

Zurich (2003-present): Zurich's Cargo Tram tackles waste disposal. Regular tram service allows citizens to deposit bulky or electrical waste at designated stops, eliminating hundreds of tons of waste annually and reducing traffic flow [21].

These case studies highlight the ongoing exploration of freight on public transportation. While challenges like cost optimization remain, successful examples like Dresden's CarGoTram demonstrate its potential to reduce traffic congestion and pollution in urban environments. As technology and collaboration evolve, integrating public transportation into urban logistics strategies promises a more sustainable future.

4.2. Social Impacts

The last-mile delivery of urban freight has substantial social impacts on employment opportunities due to new demand, availability of online platforms, and increasing automation. Access to last-mile delivery services allows small businesses to offer competitive delivery options if they can enhance their ability to compete with larger retailers. Suppose small enterprises become dependent on third-party platforms for online sales and last-mile delivery services. In that case, they will not secure additional profit margins and control over the customer experience. For small businesses to compete successfully and be self-sufficient, they will need to go through a transition that includes workers developing new skills using automated systems related to digital platforms, the use of new software, and the presence of physical logistics. may need to adapt infrastructure improvements for the growing delivery demand, such as dedicated auto bike lanes and loading zones. **Table 5** illustrates the Impact of Small Local Businesses connected with

Table 5. Impact of small local businesses.

	Positive Impacts	Negative Impacts
New Logistics Jobs	Job creation due to increased demand for delivery services	Risky working conditions due to road congestion and old infrastructure.
Better service due to employment skills	Skill development with the new technologies enhances competition with larger retailers.	Potential job losses due to automation and technological advancements.
Potential new market	Access to broader markets via online platforms	Potential dependency on 3PL platforms may erode profits and customer control.

last-mile delivery.

4.3. Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) are critical for modern urban transportation, efficiency, safety, and sustainability. By leveraging data and technology, ITS can be used to pave the way for smarter, greener cities. It fosters an efficient transportation system, minimizes environmental impact, and ultimately leads to a safer and more sustainable urban environment.

Real-time Traffic Management:

Adaptive Traffic Signal Control: it utilizes real-time traffic data to dynamically adjust traffic light timings, optimizing traffic flow and reducing congestion.

Travel Time Information: Drivers receive real-time updates on traffic conditions, allowing them to choose faster routes and avoid congested areas. This reduces travel time, fuel consumption, and emissions.

Enhanced Public Transportation:

Passenger Information Systems: Real-time arrival and departure information displayed at bus stops and train stations improves passenger experience and reduces waiting times.

Multimodal Journey Planning: ITS applications integrate various transportation options (buses, trains, bikes) into a single platform, allowing users to plan efficient and seamless journeys.

Optimized Freight Delivery:

Advanced Vehicle Tracking: Real-time tracking of trucks and cargo allows for optimized route planning and improved logistics for deliveries, reducing empty trips and minimizing fuel consumption.

Intermodal Freight Management: ITS facilitates the seamless transfer of goods between different transportation modes (trucks, trains, ships), improving efficiency and reducing overall transportation times.

Improved Safety and Security:

Advanced Driver-Assistance Systems: ITS technologies like lane departure warnings and blind-spot monitoring can be integrated with vehicles, enhancing driver awareness, and reducing accidents.

Emergency Response Management: ITS can streamline emergency response by providing real-time data on accidents and incidents, allowing for faster response times and improved safety outcomes.

4.4. Digital Technology in Urban Transportation

Urban transportation systems face many challenges, including congestion, pollution, safety concerns, and inefficient resource allocation. Fortunately, the rise of digital technologies offers many opportunities to address these issues and create a more efficient, sustainable, and user-friendly urban transportation landscape. The following are the benefits of digital technology in transforming urban transportation.

Real-time Traffic Management:

Traffic monitoring and prediction: Sensor networks and data analytics platforms can track traffic conditions in real time, allowing authorities to predict congestion and dynamically adjust traffic light timings. This helps to optimize traffic flow, reduce congestion, and minimize travel times.

Connected infrastructure: Traffic lights, cameras, and signage can be interconnected to provide real-time information to drivers through navigation apps. This allows drivers to choose less congested routes and adjust their speed, accordingly, further improving traffic flow and reducing fuel consumption.

Enhanced Public Transportation:

Real-time arrival and departure information: Passengers can access real-time information on bus and train schedules, arrival times, and potential delays through mobile apps and digital displays at stations. This reduces waiting times, improves passenger experience, and encourages ridership of public transportation.

Multimodal journey planning: Mobile applications integrate various transportation options such as buses, trains, subways, bikes, and carpooling services. Users can plan seamless journeys with real-time information on travel times, fares, and connections, encouraging a shift towards a more sustainable multimodal transportation ecosystem.

Optimized Freight Delivery

Advanced vehicle tracking and routing: GPS technology and telematics systems allow logistics companies to track trucks and cargo in real-time. This enables them to optimize delivery routes, minimize empty trips, and schedule deliveries more efficiently. This reduces traffic congestion and promotes greener logistics practices.

Automated logistics hubs and warehouses: Warehouses can leverage automation through robots and smart logistics systems to streamline picking, packing, and sorting processes. This improves efficiency, reduces errors, and optimizes delivery fulfillment times within urban areas.

Shared Mobility Solutions

Ride-hailing and carpooling services: Mobile apps connect passengers with drivers of private vehicles for shared rides. This reduces the number of single-occupancy vehicles on the road, leading to less congestion and lower emissions.

Micro mobility options: E-scooters, e-bikes, and dockless bike-sharing systems provide convenient and sustainable options for last-mile transportation. This reduces reliance on private vehicles and encourages shorter car trips within cities.

Advanced Vehicle Technologies:

Electric vehicles (EVs): The transition to EVs reduces dependence on fossil fuels and significantly cuts down on urban air pollution. Coupled with renewable energy sources for charging, EVs can significantly reduce the environmental impact of urban transportation.

Autonomous vehicles (*AVs*): While still in development, AVs have the potential to revolutionize urban transportation by improving efficiency and safety. Optimized routing and reduced human error can lead to smoother traffic flow and potentially reduce accidents.

Challenges and Considerations:

Digital technologies hold immense potential to revolutionize transportation. The transformative power of digital technologies has several crucial considerations that require attention. These challenges and considerations must be thoughtfully addressed to unlock its full potential.

Data privacy concerns: The extensive data collection required for many digital solutions necessitates robust data privacy frameworks and regulations to ensure user trust. Transparent, secure data handling and storage practices would align with the highest ethical standards to enforce comprehensive data privacy frameworks and regulations.

Cybersecurity threats: Growing reliance on digital transportation systems creates vulnerabilities to cyberattacks, which can cause widespread disruptions. These attacks possess the potential to disrupt the operation of critical transportation infrastructure, ranging from traffic management systems to public transit networks. In response to this growing threat, prioritizing robust cybersecurity measures is essential to safeguard the critical infrastructures. Collaborating with stakeholders across the sectors to implement robust security protocols and investment in cutting-edge cybersecurity technologies would create a culture of cyber resilience to counteract these emerging challenges.

Equity and accessibility: Ensuring equitable access to digital technologies and the benefits of a data-driven transportation system is crucial to avoid creating transportation deserts for vulnerable communities.

In navigating these challenges, stakeholders across the transportation must collaborate to devise innovative solutions to uphold the principles of privacy, digital literacy, equity, and accessibility. Following this guideline, we can ensure that the digital revolution in transportation not only advances technological innovation but also promotes a more inclusive and equitable future for all.

5. Conclusions

Freight consolidation refers to strategically aggregating multiple shipments from diverse origins into a singular shipment to enhance transportation efficiency. The consolidated distribution methodology is particularly advantageous in last-mile transportation, where the consolidation of goods can significantly reduce logistical costs and environmental impact while maintaining or enhancing service quality. In an era where expedited delivery expectations are ever-increasing, the relevance of freight consolidation has been known yet has yet to be widely implemented. This study is a closer examination of its benefits and operational considerations.

In the illustrated apparel retailer example, the freight consolidation offers a compelling solution to optimize transportation costs, improve delivery times, and streamline operations. While a slight increase in lead time might occur, the overall efficiency and cost savings benefits often outweigh this drawback. This type of attempt is particularly suitable when dealing with numerous suppliers and a large customer base across a vast geographical area. Freight consolidation minimizes logistics risk by improving handling efficiency, optimizing packaging, enhancing transportation conditions, strategic carrier selection, advanced tracking capabilities, and specialized consolidation facilities.

Urban business leaders and city authorities must understand how global logistics trends are changing to improve urban delivery policies. As technology improves, satellite vision, road design, infrastructure, and the opportunity for consolidated freight and passenger cars can lead to new, flexible, and efficient policies. Businesses and researchers can help by sharing their benefits and challenges, leading to better support for these new policies.

Future research may explore integrating advanced technologies and data analytics to optimize freight consolidation processes further, thereby contributing to the sustainability and resilience of urban businesses. Urban policymakers must continue innovating to create a sustainable, efficient, and congestion-free urban environment. The future research in this direction would be selecting daily paths for last-mile package delivery, developing new mathematical models, and using multicriteria approaches to solve these challenging combinatorial problems. Finding solutions is a logistical challenge. The lessons learned from business leaders and freight forwarders can provide valuable insights into the future of urban freight transportation.

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Conflicts of Interest

The author declares no conflicts of interest to report regarding the publication of this paper.

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