# Shipment Consolidation

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The basic concept of logistics is to improve the efficiency and effectiveness of several operational activities, such as transportation, warehousing and storage, order processing, material handling, and other information management concerning any related data from the origin point to end user. These include either nationally shipped products or internationally shipped products. Shipment consolidation is a concept in logistics management in which two or more shipments are transported by using the same vehicle with the aim of using less resources.

shipment consolidation    sustainability    logistics    delivery    vehicle routing

# 1. Introduction

In the modern business environments, logistics are not only important in manufacturing or goods-based industries, but also for service-based industries such as shipping and delivery services [1]. Furthermore, well implemented logistics is directly linked to enhancing business performance and increasing market share. Consequently, logistics management is considered as one of the most important strategic keys in successful businesses, and if used properly it can be a huge competitive advantage as shown in **Figure 1**. The basic concept of logistics is to improve the efficiency and effectiveness of several operational activities, such as transportation, warehousing and storage, order processing, material handling, and other information management concerning any related data from the origin point to end user. These include either nationally shipped products or internationally shipped products. Integrating these techniques achieves accurately timed and cost-efficient deliveries that meet the requirements of the contract or the business plan [2].
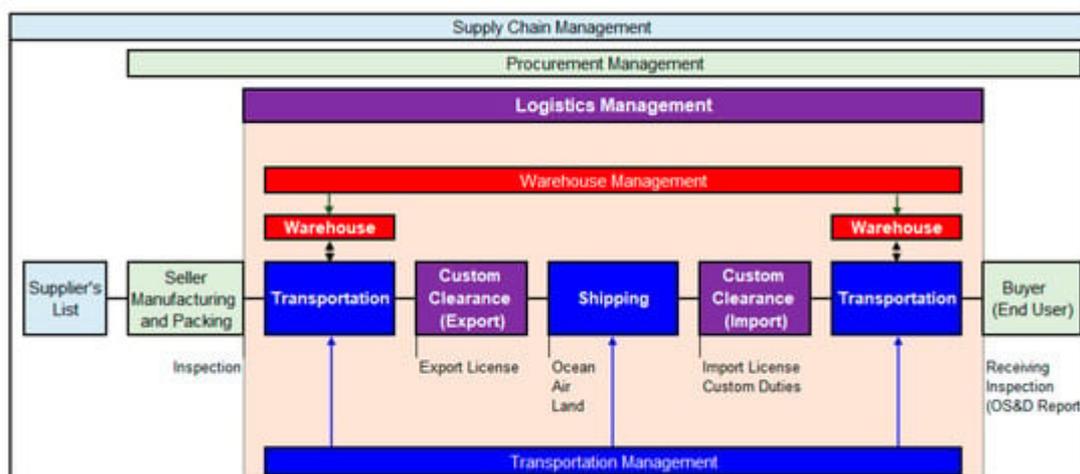


**Figure 1.** Scope of logistics management.

Logistics has been facing increasing challenges, especially in the recent years with high uncertainties due to crises such as the COVID-19 pandemic, the Russian–Ukrainian war, natural calamities, and increasing global orientation towards sustainable business practices [3]. That is why traditional methods of logistics management are no longer valid to face such challenges. Shipment consolidation is considered one of the most important modern techniques in logistics that many shippers now consider indispensable, due to its huge benefits. Shipment consolidation is combining two or more less than container load (LCL) from different shippers into single full container load shipments (FCL). As soon as the full container shipment is delivered to the desired destination, the shipments are disassembled into LCL again to be sent to its final customer. This method is very convenient as it offers better rates to the shippers than using the LCL. Moreover, shipment consolidation is not only suitable for shippers that have small shipments or few pallets but is also suitable for shipments from different locations and different suppliers to be collected in one shipment to avoid high rates. Consolidation helps small business owners to deliver their goods as this convenient solution offers them affordable prices [4]. Shipment consolidation plays an important role during crises and pandemics, as in these situations there are certain procedures and measures to be taken such as limiting cargo shipping and transportations between countries. Therefore, shipment consolidation was a supportive option during the COVID-19 pandemic, and it helped a lot of countries to overcome the crisis [5]. Shipment consolidation is cost-efficient since the shippers must pay for the full container even if the used space is less than half of the entire space. Thus, by combining multiple LCL shipments into one FCL shipment, better value for money will be achieved [6].

Traditionally, shipment consolidation was all about cost reduction purposes; however, consolidation can also contribute to greening the supply chain. Green Supply Chain Management (GSCM) can be defined as "integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life" [7]. To achieve this in logistics management, several functions can be addressed in addition to consolidation, such as purchasing, inbound logistics, outbound logistics, after-sale service and product returns, recycling, re-manufacturing, and centralised distribution [8].

Moreover, consolidation reduces the damage risk, as fewer touchpoints are offered by the consolidation model reducing the on-again, off-again handling of shipments. Comparatively, the normal freight shipping models contain many stops and multiple touchpoints which increase the chances of damaging the products. One of these models is the hub and spoke distribution method, which mainly allows delivery partners to arrange their daily delivery routes nearby a hub centre, then after finishing all the deliveries in a particular zone relocate to another hub centre for any additional or on-demand deliveries. This can also help against demand volatility [9].

However, there are some challenges that face shipment consolidation that might affect this process. The first problem is securing a carrier, due to the extra complications that come with this process. Even if a good carrier that can transport consolidated shipments was found successfully, there is still the problem of not being charged correctly for only the exact space used. This problem could be solved by dealing with the right carriers with good reputations, or some carriers offer access to their network. This offers a great help to the shippers, as dense networks make it easier to consolidate shipments either nationally or overseas [10]. Secondly, shipment

consolidation takes a lot of time and organising to be planned correctly since there are many factors that should be taken into consideration such as dimensions, estimating the price, timing, and other factors to make sure that the shipment will be delivered safely and on time [11]. Finally, there is the problem that comes when combining the LCL into an FCL as every shipment has certain requirements, such as temperature, humidity, and other factors. For example, if the container contains fast moving consumer goods (FMCG) it cannot be shipped in the same container with electronics, as FMCG have shorter expiry dates, while electronics take more time to be processed due to different customs and procedures, which makes is it hard to keep up with the time limit for the FMCG [12].

The scope of most of the works on shipment consolidation was to develop new models to control the main factors affecting the consolidation process. These factors include the pickup of the shipments, the delivery method and vehicle routing, cost analysis, and the environmental impact of the model [13]. Each paper has discussed a different model to optimise the best process for shipment consolidation to choose an efficient model to be applied to get the best out of this process. Additionally, a new research direction is to discuss more sustainable options in delivering products and combine them with the shipment consolidation methods to propose a model that is efficient and sustainable. Four shipment consolidation models will be discussed to understand the difference between them and how each model has handled the consolidation method itself. Finally, works that addressed sustainable models are reviewed.

## 2. Multi-Product Pickup and Delivery with Location-Routing and Direct Shipment vs. Shipment Consolidation

Currently, most supply chains depend on third party logistics providers (3PL) to outsource their warehousing and logistics operations to improve the efficiency of the supply chain and focus on the production operations. Such activities have been adopted successfully in many companies across multiple industry sectors, such as Wal-Mart [14], Bosch [15], Goodyear [16], and Toyota [11]. 3PL providers integrate the logistics services, warehousing, and operations aiming to meet contractors or end-users needs, such as transportation and pickup services for materials and products. This can be achieved by consolidating shipments that come from different suppliers then store all the shipments for some time and then initiating the delivery process distributing the shipments or products with a fleet of delivery vehicles. This leads to developing a distribution system with low cost and time efficiency, but due to the complexity of arrangements and coordination, optimisation models must be designed to arrange and control the distribution network. The main concern of such models is to specify the vehicle routing, determine the locations of distribution centres, and solve delivery problems that might face the suppliers or the customers.

The main research problems discussed in the literature are the vehicle routing problem (VRP), the location routing problem (LRP), and the vehicle routing problem with cross-docking (VRPCD). The previous literature models mentioned in this research introduced a multicommodity LRP and solved it with a branch and cut algorithm. In [17], a hybrid heuristic incorporating simulated annealing and artificial algae algorithm to solve the location routing problem with two-dimensional loading constraints. In [11], the problem of integrating cross-docking and vehicle routing was studied and solved through a mathematical model to find the optimal number of vehicles with main objective to reduce the overall costs. In this model, products were collected by a fleet of vehicles to a distribution

centre before delivering it to the customers. Then, in the distribution center the sorting process started, where the goods were to be delivered according to the destinations in a time-saving manner with specific routes timed perfectly to reach the customer quickly. In [18], a Tabu search algorithm was used to improve the solution methods developed by the previous authors. These improvements in the algorithms reached a range of 10% to 36% in some cases. In [19], the objective was to optimise the timing of cross-docking operations for food or fast moving goods to be delivered on time and to reduce the total costs of the system. The system costs consisted of the costs holding of the inventory, the penalty of late or early deliveries, and the delivery costs.

Moreover, most of the previous studies considered the design of single distribution centre in a fixed location, while in [20], a model with two routing types and one distribution centre was proposed. The first type of routing was for a transportation process that was initiated at the cross-dock; after that, it reached a subset of suppliers. The second type started after passing by a subset of suppliers without stopping at the cross-docks. In [21], the VRPCD was discussed relative to different routing for vehicle fleet and scheduling of trucks routes in a multi-door cross-dock system. An estimated sweep-based model was developed to consider several constraints simulating the sweep algorithm. The model was responsible for nodes assigned to vehicles to reduce the search and enhance branch. This model was validated by solving numerical examples for more than fifty transportation requests and different ten vehicle fleets, and the results displayed a reasonable running time. In [22], a mixed integer programming model was used to control the outbound and inbound scheduling of trucks in a cross-docking system. A hybrid algorithm that combines particle swarm with simulated annealing was used to help in solving complex problems in very short time. In [23], the problem of scheduling cross-docking and vehicle routes was addressed for a three-echelons supply chain network. The objective was to reduce late deliveries and delivery costs.

Last mile distribution is one of the most important research topics in supply chain and logistics management. The best example of this process is the last transportation process of the products from supply chains to its last delivery points such as retail stores. Last mile delivery is usually the routing of a fleet of vehicles to stop at a set of delivery destinations, using less than truckload (LTL) or truckload (TL). Various techniques were used throughout the literature to overcome the problems of last mile deliveries and optimise the whole process, such as solving the vehicle routing problem with split deliveries (VRPSD). Although the concept of split deliveries has many benefits in terms of cost, it does not take full advantage of using multiple vehicles to deliver multiple shipments to customers on the same day.

# 3. Sustainable Models

A great interest has been into achieving sustainability and greener transportation while creating an efficient system in terms of cost and time. This will inspire the business owners to act and reduce the damage that their companies are responsible for while also making profits to make it a win–win situation. Examining the demand and sustainability of critical metals has focused on light-duty vehicles. Heavy-duty vehicles have often been excluded from the research scope due to their smaller vehicle stock and slower pace of electrification [24]. In 2017, Tesla announced the production of electrical semi-truck with an estimated production start in 2019, but due to the pandemic there was a delay in the production plan. In 2022, Tesla announced the delivery of the first batches to

some large companies including Pepsi, Amazon, and Walmart. These semi-trucks raised the level of expectations as it will have a range of 800 km, with a Tesla Mega charger giving 640 km of charge in 30 min. The semi-truck can also use on-site 150 kW charging, taking six to eight hours [25]. There is no doubt, that the electrical heavy-duty vehicles will be considered a game changer in reducing emissions and carbon offsetting. Unfortunately, there are not enough studies to give an exact number or percentage for emissions compared to diesel trucks as the Tesla vehicles are still new to the market, but certainly this will contribute toward more sustainable delivery model [26].

Another model is the parcel delivery model that identifies the different parameters in the delivery model while considering many combinations of traditional operators (e.g., trucks and vans that use fossil fuel) and green operators (e.g., electric or hybrid vehicles, bikes, and cargo bikes), investigating their business models and behaviours from a managerial perspective [27]. The aim of this model is to form an operational point of view on how to mix low-emission and traditional logistics, especially in urban areas. In [27], a Monte Carlo-based simulation optimisation framework was developed for analysing mixed-fleet board policies related to managing freight delivery in urban areas, clarifying their cost mix (economic and environmental). In [28], the impact of shipment consolidation on home delivery in the retail industry was assessed; the results confirmed the positive role of shipment consolidation on delivery time, total cost, and fuel consumption.

Recent works on the role of logistics in Industry 4.0 have recognised major challenges including cost reduction and resource management [29], which is why shipment consolidation can play a role in enabling Industry 4.0 adoption in logistics management. Shipment consolidation can be seen as an agile method as it improves collaboration in the supply chain and promotes trust among several players [30]. According to [31], shipment consolidation can be beneficial for upstream suppliers and also can achieve Pareto improvement of both economic and environmental sustainability.

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