
Investigating Opportunities and Challenges of Consolidation in Hub and Spoke Logistics Networks

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Abstract

Over the past decade, the world has witnessed increasingly complex logistics systems in order to cope with the requirements and challenges of the globalized business environment. However, conventional logistics planning efforts focus on limited parts of the logistics network e.g. last mile distribution planning based on the milk-run problem, planning the long-haul logistics, and more recently integrated logistics planning between more than two tiers of the supply chain. From a broader perspective, logistics network from suppliers to end-customers is a huge many-to-many construct with inherent complexities of a cost-deriving nature. To reduce the planning complexities and the associated cost of logistics, the concept of hub-and-spoke has been developed and widely used. However, majority of the hub-and-spoke literature focuses on hub location and network design problem at a strategic level while scholar research is limited on related tactical and operational planning problems. Hub-and-spoke networks provide the opportunity to reduce logistics cost through effective consolidation of freights and customer orders. This paper investigates potential issues in hub-and-spoke networks and how consolidation helps reduce the associated logistics cost. Literature is reviewed and potential benefits and challenges of consolidation problems are illustrated through a developed conceptual framework. Different building blocks of the conceptual framework are discussed in more detail based on real case problems in practice.

Keywords: consolidation, freight transport, distribution planning, hub and spoke, logistics

1. Introduction

Freight transportation is a value adding process to move products and commodities from an origin point such as a manufacturing plant to a destination spot like a customer door.

Over the past decade, diversity of products in terms of material and size, long distance between production and consumption points, overcapacity costs, the empty container problem and finally fast changing and geographically dispersed demands, have shifted the focus of logistics planning from simple solutions such as direct shipment to highly complicated distribution networks. Transportation is neither cheap nor storable to be used in future, that is why applying different types of optimization in either strategic, tactical and operational levels can save a lot for a business.

Hub and Spoke is a type of multi staging shipment approach in which hubs are usually cargo loading/ unloading and handling centres connecting spokes where the actual transport happens. The range of operations in hubs depends on the type of hub and freight, as well as the planning strategies. Besides handling operations, hubs may also be used for temporary or medium-term storage, and where different modes of transport meet.

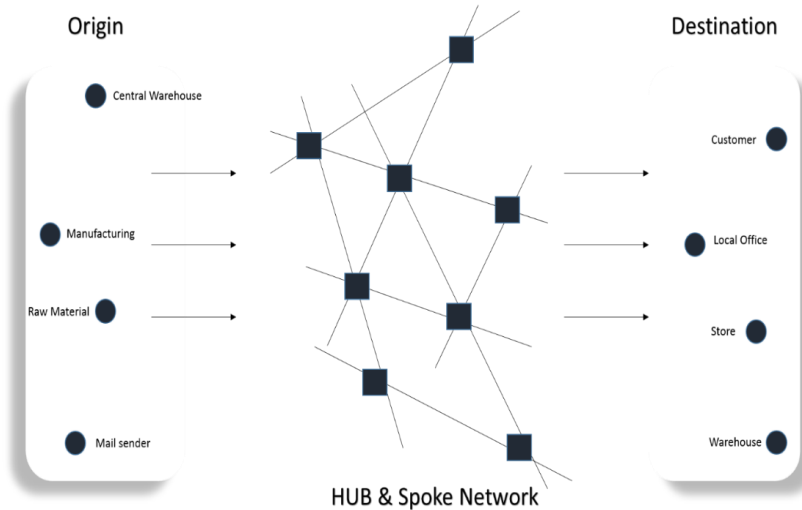
The main goal of a hub and spoke network is to minimize the total transportation costs by maximizing the resource utilization through freight clustering and consolidation. Furthermore, it facilitates the order postponement strategy by temporarily storing half of the consignment until the other half arrives. Hub and spoke network architecture also allows the freight flow to pass the most optimum path whether the distribution model is many-to-few, few-to-many or many-to-many.

Figure 1 demonstrates a hub and spoke distribution network. Freights/consignments start their journey from an origin point such as a central warehouse or a manufacturing plant, and pass through the network while moving along the spokes and are handled in hubs, until they finally get to a destination point like a store or local office. Although in the real world, regular freights rarely go through door-to-door transportation, the number of hubs and spokes that every freight passes to get to destination differ from others.

A very tangible example of hub and spoke is the mail/parcel delivery network as it is a perfect many-to-many distribution model where the mail articles might originate from a huge number of pickup points and be delivered to a massive number of delivery point. For instance according to the Australia Post (Auspost) annual report in 2013, more than 4580 million mail articles were delivered by Auspost to 11 million delivery points in the whole of Australia (Auspost, 2014). This volume of demand and number of pickup/delivery points does not obviously allow the carriers to stick to door-to-door transportation; hence logistics providers

need to enhance their efficiency and effectiveness inside the distribution network using different levels of optimization.

Figure 1: A representation of a hub and spoke network



The main goal of this research is to address the advantages and challenges of Hub and Spoke distribution networks by a special focus on the “consolidation” problem, through looking into the most referenced and reputable academic works in the last three decades. The term “consolidation” includes several types of solutions and approaches by which a distribution network works with a better resource utilization rate and less frequency. This not only results in higher efficiency and economic benefits, but also less environmental and social impacts, which altogether mean a more sustainable logistics system.

The first implication of consolidation is in freight transport and usually happens inside the warehouses or once different freights meet in a hub. Freight consolidation is a regular handling operation in transport hubs especially for many-to-many distribution models such as mail/parcel delivery. Freights break into the clusters based on their next and final destination, as well as other factors such as commodity type, weight, or value. Each cluster then gets consolidated with the similar clusters branched from other freights. As a result, the new configurations of the freights are more consistent and purposive. Moreover, resource utilization and planning become more flexible and economic.

In addition to freight, consolidation can also apply to customer orders. Although it

seems to be a very complex problem, consolidating the customer orders from a long-term perspective will save a fortune for the companies. Imagine an online shopping website selling regular electronic tools and devices with a range of products made in different countries around the world such as China, Taiwan, Japan, and US. Usually when a customer makes an order including several items (from different suppliers) each item is being delivered by a separate delivery service which means more frequent transport and less efficiency and environmental responsibility.

However, this distribution strategy does not mean that business players are not aware of the benefits that they may earn by consolidating the order items into one consignment and sending them through a single delivery service. In fact, what makes them cope with the extra expenses and stick to the first strategy is the lack of awareness of the potential consolidation challenges such as the variety of the products and sourcing complexities, different pre-planned order points to suppliers, intensive delivery time window, complicated inventory and warehouse management, expensive consolidation operations, lack or shortage of location and resources for consolidation, as well as the lack of knowledge about the possible solutions for the complicated consolidation problems.

This research contributes to the business world dealing with the aforementioned issues by developing a comprehensive conceptual framework to address the opportunities and challenges of the consolidation at the strategic, tactical, and operational levels. The remainder of this paper continues with a brief literature review in the next section, followed by the presentation and discussion of the conceptual framework. The paper concludes with suggestions for future research.

2. Literature Review

As mentioned in the previous section, compared to other aspects of hub-and-spoke networks such as hub location problem, consolidation has had less discussion in literature. Crainic in 2000 addresses the freight consolidation and grouping as main operational tasks in terminals, and the most significant difference between hub-and-spoke and door-to-door transportation (Crainic, 2000). In the same year, Grunert and Sebastian put consolidation into two categories of the transport network design issues i.e. Service Network Design and Terminal Policies, while the former mostly covers the tactical level of issues and the latter points to

operational level (Grünert & Sebastian, 2000).

Consolidating the small shipments into a single big cargo helps the less-than-truckload (LTL) services to minimize their overcapacity across a hub-and-spoke network (Cunha & Silva, 2007). In this context, the number of hubs and assignments of the spokes have the key strategic and planning role in efficiency (Cunha & Silva, 2007; C.-C. Lin, 2004). Without consolidation LTL services have no choice by trying other strategies such as “go when full” which is not a safe play considering tight time windows and unpredictable route factors (Crainic, 2000).

Distribution planning in general and consolidation in particular cannot be considered apart from inventory and warehouse management. Separating the planning of warehouse location and capacity from tactical decisions such as service level and from even the operational activities may lead to suboptimal logistics and distribution solutions (Askin, Baffo, & Xia, 2013). Consolidation process includes the fast unloading, re-grouping (based on the next destination or type) and combining the shipments in temporary (or short-term) storing environments such as a cross-dock network, or even the more long-term strategies such as actual warehouses (Boysen & Flidner, 2010; Buijs, Vis, & Carlo, 2014). Furthermore, many hub-and-spoke and consolidation problems points to the trade-off between transport and inventory costs in order to achieve the best possible efficiency (Askin et al., 2013).

Consolidation by nature always needs a sort of load handling mostly done by humans. Hence hub crew management is one of the most important issues in hub-and-spoke networks (Grünert & Sebastian, 2000; Guihaire & Hao, 2008).

Moreover, there are massive number of references which address the consolidation in a tight relation with the routing problem (Schmidt & Gazmuri, 2012). By routing, both vehicle and freight routing are taken into account (Boysen & Flidner, 2010; Conway & Gorman, 2006; Cuda, Guastaroba, & Speranza, 2014; C.-C. Lin, Lin, & Lin, 2003). Vehicle/freight routing are the critical part of logistics planning which highly affect the network performance and facilitate the consolidation. The routing problem is usually aligned with a time window by which additional levels of complexity such as delay cost is added to the main problem (Schmidt & Gazmuri, 2012).

The effects of consolidation on system performance elements depend on the consolidation strategy and the number of consolidation points (Ha, Khasnabis, & Jackson, 1988). Although consolidation puts the distribution network at more efficiency advantage due to

economy of scale and better resource utilization (Conway & Gorman, 2006), it may also disturb the effectiveness of logistics system by multiple load handling. Moreover along with consolidation points, lot size of the transport (Conway & Gorman, 2006) and service scheduling (Boysen & Fliedner, 2010) are other determining factors which may significantly affect the delivery time and the service quality.

3. Main Consolidation Challenges

In previous sections, the role and importance of freight consolidation in hub-and-spoke networks were addressed. Moreover, different aspects and related subjects of consolidation in different business levels were briefly discussed. This section suggests a conceptual framework for opportunities and challenges of freight consolidation.

To achieve this goal, 56 scientific papers plus other referential materials were deeply reviewed and then summarized in an Access database. It was to earn extra power in querying the reviewed materials and clustering them into different groups based on the adverse subjects. Furthermore considering the subject of this paper, a rate of contribution was allocated to each reference. Another column contained the approach of the research and another one stored the areas of strength for any of them. This made the further returns to the references, very efficient.

After reviewing quite a decent number of references, an overall scheme of the conceptual framework gradually began to surface. It was not much difficult to recognize how different researches have addressed the freight consolidation in different ways and level of granularity.

Accordingly, this research first describes the main challenges of the consolidation, and subsequently suggests a conceptual framework addressing these challenges in three levels of strategic, tactical and operational.

3.1 Hub Location

One of the most significant and well-discussed strategic issues in hub-and-spoke networks is focusing on hub/terminal location problem. Since a hub-and-spoke network tries to keep the volume for handling and consolidation in hubs (Jeong, Lee, & Bookbinder, 2007), the number of hubs, their location and connectivity (O'Kelly & Miller, 1994) will highly influence the network efficiency and effectiveness (Cunha & Silva, 2007). In fact, optimal location of hub

facilities will easily affect tactical and operational planning and actions.

3.2 Logistics Network Design

In reality, even hub location problem is a part of bigger picture namely logistics network design well described by almost one-third of reviewed references. Network design mostly implies to the strategic challenges of the logistics systems which highly impacts tactical and operational challenges such as hub optimal location problem, spoke assignment, empty-container flow, routing and scheduling (Askin et al., 2013; Grünert & Sebastian, 2000). The main goal of logistics network design is to minimize the logistics cost through having an optimal consolidation network as well as planning advantages (Buijs et al., 2014; Crainic & Roy, 1988; Gelareh, Maculan, Mahey, & Monemi, 2013). Also, logistics networks are also designed to serve a specific purpose e.g. a seasonal demands (Goetschalckx, Vidal, & Dogan, 2002).

3.3 Hub Design and Layout

Rapid transshipment, sufficient capacity and high quality handling operations are the most important targets of hub/terminal design (Buijs et al., 2014). Number and location of hub entrance/exit (also called strip/stag) doors and their loading/unloading assignments (Boysen & Fliedner, 2010; Buijs et al., 2014) highly affect hub congestion (M. H. Lin, 2013) and operational actions such as truck scheduling. It is also vital for hubs to provide sufficient capacity for temporarily storing the freights for further processing. Moreover, hubs should provide an appropriate staging area for freight handling while keeping the internal processes efficient and effective (Buijs et al., 2014). Hub design is of strategic challenges in regards to its nature involving infrastructure and high level design factors.

3.4 Logistics Network Planning

Planning in hub-and-spoke networks includes both transport leg and terminal operation. Assigning transport capacity to routes is the major decision making point in transport legs (Buijs et al., 2014). It involves the selection of services for each route, managing the traffic in entrance and exit gates (Crainic, 2000), responding to variable demands (C.-C. Lin, 2004), frequencies setting and timetable development (Guihaire & Hao, 2008). Network planning by nature is a mid-level decision making and as of tactical challenges needs to be overcome in hub-and-spoke

networks.

3.5 Services Scheduling

Scheduling is an operational matter that hub-and-spoke networks have to deal with. It helps those hub resources such as workforce and facilities to be allocated in a better fashion to transport vehicles. Furthermore, it diminished the waiting time for shipment handling and assist the trailers and trucks to stick with the time window. A good scheduling plan is quite aware of traffic, avoids delay and congestions (Rietveld & Brons, 2001) while minimizing the overcapacity (Irnich, 2000). The optimum resource utilization is achievable through dynamic service scheduling (Buijs et al., 2014). Scheduling problems are being handled with different techniques and tools such as interactive decision support systems (DSS) (Crainic, 2000).

3.6 Routing Problem

Vehicle Routing Problem (VRP) points to problem of picking and sequencing a collection of routes from origins (e.g. depots or customers) to destinations (e.g. cities, distributors or end customers) in order to design an optimal pick-up and delivery process while meeting the pre-defined goal (Laporte, 1992). Routing problem has focused on finding the shortest path, shortest time, minimum costs, least traffic path and so forth (Sarraj, Ballot, Pan, Hakimi, & Montreuil, 2013) whilst coping with a series of rules and policies (Crainic, 2000). Routing problem can be considered a strategic issue when it is based on lot sizing issues (Conway & Gorman, 2006), a tactical issue and sub-category of network planning when it is for long-distance freight transport (Crainic & Laporte, 1997), and operational when it deals with quite many ad-hoc re-routing and re-scheduling tasks (Sarraj et al., 2013).

3.7 Collaboration between different Transport Systems

Consolidation process requires different actors, from terminal and warehouse holders to carrier companies, to work together in an integrated logistics environment. Since different logistics companies provide different regular and supplementary services, service levels and prices, availability, capability and alignment with environmental performance (Sarraj et al., 2013), to be an efficient strategy within the time window, consolidation process needs to occur at the top of a collaborative logistics systems (Andersen, Crainic, & Christiansen, 2009b). It is

even more complex in a global environment where governmental rules and policies, as well as tax, insurance and environmental regulations vary for different actors. Besides service integration between the logistics actors, for consolidation process to happen, a decent level of information sharing is a must (Sarraj et al., 2013). Collaboration and coordination by nature are among tactical challenges which need the attention of mid-level decision makers.

3.8 Crew Assignment and Scheduling

Hubs need to be well-equipped and have enough resources and workforce to provide the distribution network with high quality services (Grünert & Sebastian, 2000). Scheduling, allocating and optimizing the workforce for the operations in both hubs and spoke are crucial challenges which need to be done for the benefit of the whole distribution system (Buijs et al., 2014; Guihaire & Hao, 2008).

3.9 Optimization Problems

Consolidation problem is often very complicated since its role is to make some sort of trade-off between transport cost, inventory cost and time scheduling (Boysen & Fliedner, 2010) while each of these factors depends on too many others. In fact most of consolidation-related issues are as of optimization problems (Wang, 2008). As a result, algorithmic developments are needed in order to solve most of the suggested models (Grünert & Sebastian, 2000). Optimizations are usually established and applied at the top of the strategy, and formulize the operational procedure, that is why they are categorized in the tactical group.

3.10 Empty Vehicles/Containers Planning

Logistics is the knowledge of facilitating the material flow across a transport network. Empty container problem is and has always been one of the main barriers for the logistics systems to work more efficiently by causing discrepancies between supply and demand of the vehicles in hubs (Crainic, 2000). Since empty vehicle planning is also typically a sort of resource planning, it should be placed into the tactical category.

4. Conceptual framework

The remainder of this section continues with a table, categorizing and summarizing the

consolidation challenges in three levels of strategic, tactical and operational. In table 1, all the addressed and referenced challenges of the consolidation are listed under the appropriate category, and their corresponding references are added.

As table 1 demonstrates, there are a few challenges which cannot absolutely be placed in one and only one category. For instance, vehicle/container routing problem is one of those which is usually considered as a tactical challenge when the problem points to the pre-planned long-distance transports whilst it is an operational challenge when the system deals with a more dynamic real-time routing and scheduling problems.

Table 1 - Strategic, tactical and operational challenges of the consolidation

Level	Challenges	Key References
Strategic	Hub location	(Askin et al., 2013; Cunha & Silva, 2007; Jeong et al., 2007; Melachrinoudis, Messac, & Min, 2005)
	Logistics network design	(Andersen, Crainic, & Christiansen, 2009a; Askin et al., 2013; de Camargo, Miranda Jr, Ferreira, & Luna, 2009; Goetschalckx et al., 2002; O'Kelly & Miller, 1994)
	Hub design and layout	(Boysen & Flidner, 2010; Buijs et al., 2014; M. H. Lin, 2013)
Tactical	Logistics network planning	(Boysen & Flidner, 2010; Crainic & Roy, 1988; Cunha & Silva, 2007; C.-C. Lin, 2004; M. H. Lin, 2013; O'Kelly & Miller, 1994)
	Collaboration between different transport systems	(Andersen et al., 2009b; Sarraj et al., 2013)
	Routing problem (for long distance and pre-planned transports)	(Conway & Gorman, 2006; Cuda et al., 2014; Gelareh et al., 2013; Sarraj et al., 2013; Schmidt & Gazmuri, 2012)
	Optimization Problems	(de Camargo et al., 2009; Irnich, 2000; Ma, Miao, Lim, & Rodrigues, 2011; Nero, 1999; Wang, 2008)
	Empty vehicle/container planning	(Crainic, 2000; Crainic & Roy, 1988; Grünert & Sebastian, 2000)

Operational	Services scheduling	(Boysen & Fliedner, 2010; Campbell, 2013; Crainic & Roy, 1988; Gelareh et al., 2013; C.-C. Lin, 2004; Ma et al., 2011; Rietveld & Brons, 2001)
	Routing problem (for ad-hoc re-routing and re-scheduling)	(Boysen & Fliedner, 2010; Crainic & Laporte, 1997; Crainic & Roy, 1988; Irnich, 2000; C.-C. Lin, 2004; C.-C. Lin et al., 2003)
	Crew assignment and scheduling	(Buijs et al., 2014; Grünert & Sebastian, 2000; Guihaire & Hao, 2008)

5. Conclusion and Future Research

Hub and spoke network is a specific type of logistics networks in which hubs play the role of storage and handling centres while spokes is the actual transport leg. In a simple view, hub can be a temporary/long-term warehouse and spoke is an existing transport route.

The main goal of a hub and spoke network is to minimize the total cost of the transport by improving the resource utilization through freight clustering and consolidation. These all cause the less frequent transport services, consequently more economic benefits and less environmental impacts.

This research aims to address and describes the main consolidation challenges to be used in a real world projects. These challenges are categorized in three different. Accordingly, eleven challenges are identified and described, and finally categorized in one of the three levels of strategic, tactical and operational. Strategic challenges are those which are mostly related to the network/hub design and network big picture. Tactical ones are mainly the mid-level planning and collaboration challenges which are usually affected by strategic decisions in the network. For example, hub design and layout influences the transport planning. Operational challenges are in fact the day-to- day operations and tasks around the network which are more dynamic and flexible to change.

After reviewing the most significant resources in hub and spoke/consolidation issues, Network Design, Hub Location, and Hub Design and Layout are considered as of strategic challenges. Transport Planning, Empty Vehicle Planning, Vehicle Routing problem (long distance), Optimization Problems and Collaboration between The Logistics Systems are the

main role players in tactical level. Finally Services Scheduling, Routing and Scheduling, and Crew Assignments are as of operational challenges of the consolidation.

A very first future research can be to examine the result of this paper in a real world logistics system by actual data. Weighting and prioritizing the addressed challenges can give a very clear picture of the determining factors and barriers of the consolidation, to the system decision-makers. The interrelation between strategic, tactical and operational challenges can be another potential research at the top of the results of this paper. It is critical for every system to identify and measure the effects of every decision/component on other procedures /components across a logistics network. Another potential future research can address the best solutions/approaches to take on the consolidation challenges at their best.

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