Inbound Freight Consolidation: A Simulation Model to Evaluate Consolidation Rules

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Introduction

A graduate student mails letters home to his mother everyday. The problem is he simply can’t afford the post. To save money on stamps the student has decided to implement a consolidation program.

The graduate student has two options for consolidation: temporal consolidation (over time) or spatial consolidation (over space). To consolidate temporally, he holds today’s letter for shipment with tomorrow’s. By waiting one day, he is able to mail two letters in one envelope and save the cost of one stamp. To consolidate spatially, he meets his sister at the post office where they combine letters into one envelope and again save the cost of one stamp.

If the graduate student waits to send letters home to mom, how long should he wait? If he and his sister decide to meet at the post office, which post office should they meet at?

The case of mailing letters home to mom is not far removed from the choices that many companies face today in shipping. This paper presents consolidation options for a large industrial company importing goods from China into the United States. The paper will first introduce the key benefits and costs of consolidation. Second, it will describe the company case and introduce the different spatial and temporal consolidation options. Finally, results from the simulation model present the tradeoff between time and cost for different consolidation options.

Benefits of Consolidation

Economies of scale are possible throughout freight logistics. In general as shipment sizes increase, per unit freight rates decrease. In the case of shipping freight overseas, per unit rates are greater for less-than-container shipments than for full-container shipments. In the case of shipping packages home to mom, the US Postal Service charges about $4 to ship a 1-pound package priority mail, but only about $8 to
ship a 5-pound package priority mail. Freight rates in this case decrease from $4/lb for the 1-pound package to less than $2/lb for the 5-pound shipment.

In addition to achieving better freight rates, consolidation also reduces the number of shipments, which in turn reduces fixed cost. For the graduate student, currently hard at work on his thesis, a walk to the post office costs him precious time. Through consolidation he reduces the number of mailings, and in turn the number of trips to the post office. In the case of an industrial company, each shipment requires paperwork, tracking, brokerage, and receiving regardless of the size of the shipment. Reducing the number of shipments reduces the company’s fixed cost.

**Costs of Consolidation**

Despite the benefits, consolidation is not without cost. For the graduate student, the timeliness of his letters is critical. His mother is paying for tuition and she gets upset if she doesn’t know what going on. Although the student saves money on economies of scale and fixed costs, he still must balance the tradeoff between cost and timeliness? For an industrial corporation, longer lead-times equal extra inventory and reduced time to market. The tradeoff between time and cost is directly related to the value of the goods being shipped. Measuring this tradeoff is the key to choosing any shipping strategy.

While temporal consolidation consumes time, spatial consolidation consumes distance. Although the student and his sister both live in Boston, the post office nearest to his house is different from the post office nearest to her house. Spatial consolidation thus requires one of them to travel farther than if they shipped individually. If an industrial company wishes to consolidate two ports into one, factories that normally ship to the first port will travel a greater distance to the second port. Differences in distance must be accounted for when measuring the cost of consolidation.

Finally, consolidation requires coordination. If the student and his sister are to meet at the post office, they need to coordinate a time and a location. Coordination takes time and effort. If factories are consolidating freight at the port, do they need to talk to each other; is there sensitive information that shouldn’t be shared between the two factories? Coordination costs are difficult to measure, but they should not be ignored.
Rules can help reduce coordination costs. For instance, the student and his sister could set a rule to meet at post office “A” at 3:00 pm every Wednesday. Likewise, an industrial company could set rules for its suppliers to deliver freight to Port “A” on Monday and Thursday, if factory inventory is greater than “X” volume, or if factory inventory is older than “X” days. This paper uses simulation to evaluate such consolidation rules.

**Industry Case**

The sponsor for this thesis, a large industrial corporation, produces a bulk of its products in China. For this reason, the research project focused on consolidation options for the company’s inbound freight from China to the US. The industrial company has about fifty suppliers in China, although five of the suppliers represent the majority of the freight volume. The company’s suppliers are shipping from six China ports, with the majority freight flowing through Ningbo and Shanghai. The company imports through seven or eight US ports, with the majority of the freight flowing through Chicago and Atlanta. The company’s had eight DC’s throughout the US. Exhibit 1 provides a graphical representation of the supplier, port and distribution center locations used in this case.

The product being shipped is dense industrial parts and equipment. Due to the nature of the product, the freight “weighs out” before it “volumes out”. For this reason, the paper focuses on weight and does not set constraints for volume. Demand is more or less stable year round, and for simplicity the simulation model assumes no seasonality. The company’s annual China to the US freight volume is approximately 3,000,000 kgs / year.

**Spatial Consolidation Options**

The industrial company is considering four spatial consolidation cases: Direct Shipment, China Port Consolidation, US Port Consolidation, and Full Consolidation (a combination of China Port and US Port Consolidation). The consolidation cases are described and diagramed below. Temporal consolidation options for each case will be presented in the results section.
Direct Shipment

Under direct shipment, there is no spatial consolidation. Factories ship by truck to the China port closest to them. From the China port goods are shipped by ocean to the US port closest to the final distribution center. The goods are then picked up at the US port and trucked to the distribution center. Factory consolidation is analogous to the student and his sister shipping from independent post offices.

China Port Consolidation

Under China port consolidation, factories ship by truck to their assigned consolidation port (in this case, Shanghai). From Shanghai, the goods are shipped by ocean to the US port closest to final distribution center. The goods are then picked up at the US port and trucked to the distribution center. China port consolidation is analogous to the graduate student and his sister meeting at the post office. Please note that due to the feasibility of long distance trucking in China, the model assumes that factories in northern China do not consolidate in Shanghai.
Under US port consolidation, factories ship by truck to the closest China port. From the China port goods are shipped by ocean to the assigned US consolidation port, in this case Los Angeles. From LA, goods are shipped by long-haul truck to the distribution center. US port consolidation is analogous to the student and his sister shipping packages independently to their mother, who then combines the packages and distributes the contents to aunts, uncles, and grandparents who live in the area.

Under full consolidation, factories ship by truck to their assigned China consolidation port. From the China port, goods are shipped by ocean to the assigned US consolidation port. From the US consolidation port, goods are shipped by long-haul truck to the distribution center. Full consolidation is a combination of China port and US port consolidation. Full consolidation is analogous to the graduate student and his sister meeting at the post office to ship one package to their mother, who then distributes the contents of the package to aunts, uncles, and grandparents who live in the area.
**Temporal Consolidation Options**

Temporal consolidation options are divided into two parts:

1. Max Wait Time: How long we are willing to wait?
2. Cutoff Value: What we are waiting for?

Let’s take an example: A company decides to have factories ship (a) if factory inventory is older than 7 days, or (b) if factory inventory is greater than 10000kgs. In this case, the factory max wait time is 7 days, while the factory cutoff value is 10000kgs.

For this paper, we assume that the cutoff value is always equal to 16000kgs. Max wait time is thus the only active temporal consolidation option. Constraints for full truck shipments and for 20’ full container ocean shipments are assumed to always equal 17000kgs. Partial order shipments are also permitted.

A summery of the settings for each consolidation case is found in Exhibit 5 below. Active temporal consolidation options are listed in bold italic in Exhibit 5.

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**Exhibit 5: Spatial and Temporal Consolidation Setting**

<table>
<thead>
<tr>
<th>CONSOLIDATION CASE</th>
<th>DIRECT SHIPMENT</th>
<th>CHINA PORT</th>
<th>US PORT</th>
<th>FULL</th>
</tr>
</thead>
<tbody>
<tr>
<td>China Port Consolidation?</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>US Port Consolidation?</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Factory Cutoff Value</td>
<td>16000kgs</td>
<td>16000kgs</td>
<td>16000kgs</td>
<td>16000kgs</td>
</tr>
<tr>
<td>Factory Max Wait Time</td>
<td>1-14 days</td>
<td>1-14 days</td>
<td>1 day</td>
<td>1 day</td>
</tr>
<tr>
<td>China Port Cutoff Value</td>
<td>16000kgs</td>
<td>16000kgs</td>
<td>16000kgs</td>
<td>16000kgs</td>
</tr>
<tr>
<td>China Port Max Wait Time</td>
<td>1-14 days</td>
<td>1-14 days</td>
<td>1-14 days</td>
<td>1-14 days</td>
</tr>
<tr>
<td>US Port Cutoff Value</td>
<td>16000kgs</td>
<td>16000kgs</td>
<td>16000kgs</td>
<td>16000kgs</td>
</tr>
<tr>
<td>US Port Max Wait Time</td>
<td>1 day</td>
<td>1 day</td>
<td>1-14 days</td>
<td>1-14 days</td>
</tr>
</tbody>
</table>
**Results**

Let’s first examine how different temporal consolidation settings affect transit cost and transit time. Each point in Exhibit 6 and Exhibit 7 represents a combination of two temporal consolidation settings: China port max wait time and US port max wait time. Transit cost refers to all of the costs (fixed and variable) that a company incurs from the end of production until the goods arrive at the distribution center. Transit time refers to the time from the end of production until the goods arrive at the DC.

**Exhibit 6:** Direct Ship, Temporal Consolidation Options vs. Transit Cost

**Exhibit 7:** Direct Ship, Temporal Consolidation Options vs. Transit Time

The steep downward slope in Exhibit 6 shows the benefits of consolidation through economies of scale and reduction of fixed costs. From Exhibit 6, we can infer that longer max wait times result in larger shipment sizes, reduced per unit transportation costs, and reduced fixed costs. The upward slope in Exhibit 7 shows the cost of temporal consolidation. As max wait times increase, transit times increase across the board. These two exhibits shows that savings from consolidation comes at the cost of time.

To examine the transit cost vs. transit time tradeoff more precisely we combine the results from Exhibits 6 and 7 for all four consolidation cases into one graph (Exhibit 8). The points in Exhibit 8 represent the transit cost vs. transit time tradeoff for all active temporal consolidation options described in Exhibit 5.
From Exhibits 8 and 9 we find that direct shipment and China port consolidation offer slower transit times at lower costs, while US port and full consolidation offer faster transit times at higher costs. But most strikingly, the combination of temporal consolidation options across consolidation cases seems to form a continuum of transit time vs. transit cost options.

In the case at hand, US port consolidation and full consolidation function like different modes of transportation. In these cases, long-haul truck service from LA expedites goods that would still be on the water or rail to provide dramatic improvements in transit time. Nevertheless, long-haul truck service comes at a premium to rail and ocean service.

As we see in Exhibit 9, without temporal consolidation shipping choices are limited. Temporal consolidation is the means to adjust the transit time vs. transit cost tradeoff. Simulation modeling provides a clear picture of the wide range of cost vs. time options available through consolidation. The questions for the company remain: What are its priorities? How is does it value the tradeoff between cost and time? Can it find a balance that fits its strategy?