Trucking Capacity Allocation: A Case Study of a Thai Beverage Manufacturer

Oran Kittithreerapronchai, *Member, IAENG,* and Wattana Yamprayunsawat

***Abstract*—Manufacturers have increasingly employed a logistics provider or a carrier to transport their products. This practice enables manufacturers to focus on their core competency, to leverage against transportation fees, and to reduce their operational capitals. At the same time, a carrier benefits from economies of scale and creates values to manufacturers as a freight delivery specialist. In general, a manufacturer and a carrier agree upon a number of daily shipments. A carrier, in turn, allocates its dedicated trucks to serve agreed shipments. One important issue of such practice is high variability in trucking capacity resulted from the fluctuation in a number of shipments requested by manufacturers and the failure to cooperate delivery planning between both parties. As a result, a carrier struggles between two extreme cases. On one extreme, it may allocate too many trucks thereby under-utilizing its trucking capacity and missing opportunities to create more revenues from other shipments. On the other, a carrier may have insufficient trucks thereby incurring a contract penalty. The economic trade-off between opportunity cost to utilize allocated trucks and contract penalty can be viewed as the Newsvendor problem, an inventory control model with a stochastic demands. This article generalizes the concept allowing a carrier to serve other customers when agreed shipments exceed manufacturer's requests. We modeled this generalization as a multi-channel demand Newsvendor problem and illustrated the model using the transportation data of a beverage manufacturer and a large carrier. The analysis of the model showed that the carrier can reduce its transportation costs by a better delivery planning and increase revenues by an exploring shipment from other potential customers.**

***Index Terms*—Logistic provider in Thailand, Transportation contract, Simulation model, Newsvendor with multiple demand classes,**

I. Introduction

THE awareness in outsourcing and supply chain management has led to the development of logistic service business as manufacturers have increasingly employed a logistics provider to transport their products to customers. This practice enables manufacturers to focus on their core competency, to leverage against transportation fees, and to reduce their operational capitals. At the same time, a logistics provider benefits from economies of scale and creates values to manufacturers as a specialist in terms of freight delivery, materials handling, and customs services. The adopting rate of logistic services has been accelerated as manufacturers have increasingly sourced raw materials and supplied their products globally. Hence, a specialist who can offer comprehensive transportation services and bypass different regulations is greatly sought after. In 2004, the most frequently used logistic providers according the survey in large American manufacturers are warehouse management, shipment consolidation, freight payment, carrier selection, and direct transportation service [1]. As one of the dominate modes of transportation, a trucking logistic provider, such as a motor carrier, has expanded in recent years [2]. As the popularity of a carrier increases, many manufacturers ensure availability of trucks required and reduce transportation costs by contracting trucks. This practice is welcomed by a carrier as the contract ensures steady incomes and benefits resource planning.

Nevertheless, one important issue of such the practice is high variability in trucking capacity resulted from the fluctuation in a number of shipments requested by manufacturers and the failure to cooperate delivery planning between both parties. As a result, a carrier struggles between two extreme cases. On one extreme, it may allocate too many trucks thereby under-utilizing its trucking capacity or missing opportunities to create more revenues from other shipments. On the other, a carrier may have insufficient trucks thereby incurring a contract penalty or hiring another carrier to fulfill the request. The economic trade-off between opportunity cost to utilize allocated trucks and the contract penalty is similar to the Newsvendor problem, an inventory control model with a stochastic demand, as a trucking capacity can be viewed as a perishable item that is sensitive to time [3]. This article aims to explore this trade-off and to illustrate an economic model using transportation data of a manufacturer and a carrier. Before discussing related literatures and formally stating the problem, it is important to understand how a manufacturer selects a suitable carrier.

A. Selecting and contracting a carrier

Having realized the need of outsourcing, a manufacturer usually undergoes several steps according to Bottani and Rizzi [4] before selecting and contracting a carrier. These steps include comparing its current logistic services with the professional ones, requesting the quotation from candidate carriers, and evaluating each candidate based on merits and flows. In addition to the quality of services, a manufacturer must consider the compatibility and reputation of a carrier and negotiate for a suitable price. Once an agreement is reached, both parties should specify contractual terms such as origins, destinations, a number of daily shipments, shipping classes of products, additional services, and terminating causes [2]. This written form contract ensures a clear understanding of roles and responsibilities and enables both parties to sustain a long term relationship. In fact, researchers and practitioners agree that the length of a contract plays an essential role in building a relationship in terms of the justification for committed resources and the return of investment.

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After a contract is approved and signed, the communication between a manufacturer and a carrier are very important as the streams of information are periodically updated. Several days before the due date, a manufacturer informs a projected number of shipments and their pairs of origins and destinations to a carrier. The carrier, then, plans appropriate routes and allocates trucks for the projected shipments. On the delivery date, the manufacturer confirms the exact shipments as the demands are fully realized. If the number of shipments requested by the manufacturer exceeds the trucking capacity of the allocated trucks, the carrier may negotiate with the manufacturer to postpone some shipments. If these shipments are important and/or time sensitive, the manufacturer may refuse. As a result, the carrier usually outsources the shipments to another carrier or allocates trucks from another fleet to honor the contract. Hence, an additional expense is incurred. If the manufacturer, on the contrary, requests shipments less than the trucking capacity of allocated trucks, the carrier is responsible for a truck driver's salary and loses an opportunity to generate more revenues. In both cases, the manufacturer plays little role in risk management. In fact, the manufacturer has an incentive to overstate a number of projected shipments as a precaution against uncertainties. The manufacturer historically informs an accurate number of shipments on the delivery date. Consequently, some carriers ignore the projected number of shipment and focus solely on the confirmation. This practice causes difficulties in developing an efficient delivery plan.

II. Literature Review

Literatures related to the trucking capacity allocation can be grouped in two categories: logistic services and supply chain contract.

A. *logistic services*

Logistic services have become indispensable and inseparable parts of a modern supply chain management. Arguably, logistic service providers offer a wide variety of services, including one that is customized to an individual user's specific needs. Africk and Calkins [5] classified logistics providers by capital assets into two groups:

- Asset-based providers; and
- Non-Asset-based providers.

Despite the recently increasing number of non-asset-based providers, such as consulting services or flow integration services, the majority of logistic providers are asset-based providers such as transportation carriers, vehicle tracking services, and public warehouses. These providers bring knowledge and experience in managing asset that ensures strategic effectiveness and enhances operational efficiency and pass savings and values to the users [1]. As a result, logistic service providers have been embraced by many manufacturers in developed countries, especially in North America and Europe. The survey and the comparison of practices by Lieb *et al.* [6] on hundreds of manufactures who are long term users of logistic providers confirmed this tread. The studies concluded that the uses of logistics providers in these regions are similar. In particular, the manufacturers require integrated services so that they can concentrate on the core competencies. However, Western Europe manufacturers have a positive attitude and a higher adaptation rate of logistic services than their USA counterparts because of the long history, changes in regulation, and needs of specialized services to move freight across borders. In developing countries, the adaptation rate, on the contrary, is low as the availability of logistic services depends on the state of economic development. In some counties, logistic services are limited to trucking, warehousing, or customs brokerage. Knowledge, experience, and asset become key barriers for the expansion and result in the cluster in the logistic service market. In Thailand, foreign logistics providers, for example, dominates logistic service business as the local providers have limited technology and are concentrated on small and median business partners [7].

In addition to the development of logistic services, some literatures discuss the criteria to select and evaluate the most suitable logistic service providers. As the selection of logistics providers relies on multiple criteria and consists of many dimensions [8], researchers have proposed methods to account for intangible criteria such as *fuzzy theory* [4] and *Analytic Network Process* [9]. They concluded that the most common critical criteria are service cost, quality of service, historical performance, level of information technology, appearance of physical assets, long term relationship, and compatibility. Interested readers may consult the literature survey by Razzaque and Sheng [10] that summarized several important aspects of logistic service providers such as business drivers, benefits, obstacles, and critical factors in a successful implementation.

B. *Supply Chain Contract*

Another stream of researches is the supply chain contract that addresses the cooperation of different parties in a supply chain using a contract. The goal of supply chain contract is to model a contract so that each party can optimize its own goal individually, while the entire supply chain is also optimized as if parties were vertically integrated [11]. The majority of early works have been focused on a purchasing contract as the most popular form of supply chain contracts [12]. Researchers have studied various contract types often encountered in retail business such as *revenue sharing contract* [13], *buy-back contract* [14], *wholesale price contract* [15], and *quantity flexibility contract* [16]. These contracts share common structures; a buyer and a supplier operate in uncertain market demands, and they must commit resources or assets based on forecasted, not realized demands. These structures lead to the economic trade-off between over-committed resources and lost sales, similar to the Newsvendor problem. The analysis of these contracts shows that contracts affect the cooperation of the parties. Recently, Drake and Swann [3] proposed a demand risk-sharing, called *percent deviation contract*. The contract is motivated by the sequential decision process in which a buyer provides an initial estimation of future demands, and the transportation company may use this information to acquire truckload carriers in advance. When the demand is realized, the company may choose to satisfy additional demands at a high cost or to fulfill only the previously-acquired level. In addition to the analytic framework, some researchers have studied empirical impacts of contracts on a company. For example, Lundin and Hedbergy [17] presented a case study of a Swedish grocery retailer and compared benefits of different contract types in terms of trucking costs, utilization, and coordination costs.

Motivated by our interview with a motor carrier who provides a dedicated truckload service to manufacturers, we applied the percent deviation contract to the carrier who can delay or expedite some non-essential shipments. We also consider an option in which the carrier can sell excess trucking capacity to other customer. Having stated contributions, the remaining of this paper is organized as follows. Section III layouts the problem description and states assumptions required to derive a special case –a carrier dedicates its trucks to a single manufacturer– and a general case –a carrier can service both a manufacturer and secondary customers. Section IV presents a case study of using the transportation data of a beverage manufacturer and discusses a numerical study based Monte-Carlo simulation. Section V outlines directions for future research.

III. Problem Description

At the beginning of the time horizon, a manufacturer agrees with a carrier to reserve Q shipments per day with reservation fee $r\,Q$. On each day, a manufacturer realizes and requests D^1 shipments from the carrier who must fulfill $\min\{Q, D^1\}$ shipments with its dedicated fleet. For each fulfilled shipment, its receives transportation revenue p^1 from the manufacturer, while incurs operation cost c. For any shipments that exceed the number of agreed shipment, the carrier has to hire an external fleet at cost h per shipment. As a gesture of the partnership, however, the carrier will absorb this additional hiring cost if the manufacturer request is within managerial limit $\overline{Q}$. If the manufacturer's request, however, greatly exceeds the number of agreed shipments, particularly $D^1 > \overline{Q}$, the manufacturer will compensate g^1 per shipment. On the contrary, the carrier has an excess trucking capacity of $\max\{\underline{Q} - D^1, 0\}$ shipments if a daily manufacturer's request is below the number of agreed shipment, where $\underline{Q}$ is an accepted managerial limit. In this case, the carrier can use some of its excess trucking capacity to serve secondary customers who require D^2 shipments and yield alternative revenue p^2 (i.e., $p^2 < p^1$) per shipment as shown in Fig.1.

Fig.1 represents the revenues per shipment and the costs per shipment that a carrier receives and incurs at a given number of agreed shipments Q. On the revenue side, the carrier receives the transportation operation revenue proportionally to a number of actual shipments that are realized on the delivery date, whereas the reservation revenue is a constant. The carrier may receive the revenue from penalty if a number of actual shipments exceeds the managerial limit $\overline{Q}$ or may obtain the alternative revenue if a number of actual shipments is below the managerial limit $\underline{Q}$. The evidences of managerial limits $\underline{Q}$ and $\overline{Q}$ come from the fact that a carrier can manage some of its trucking capability. Particularly, a carrier may give an incentive to a driver to delivery more shipments without an addition truck if the actual shipments exceed his regular trucking capacity. Furthermore, a truck planner may use available time for preventive maintenance and truck reposition if there are few requests from a manufacturer. Given the number of agreed shipments Q, the larger

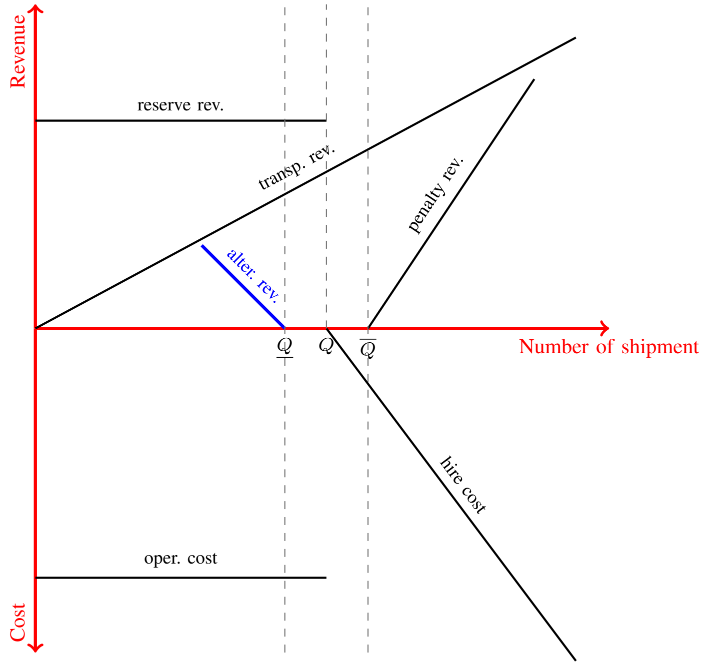

Fig. 1: Revenues per shipment and costs per shipment related to contracted number of trucks Q

difference of managerial limits (i.e., $\overline{Q} - \underline{Q}$), the greater total profits. On the cost side, the carrier pays constant operation costs such as fuel and salary regardless the number of agreed shipments. As the number of actual shipments exceed this level, the carrier has to hire an external fleet and incurs an additional cost. It is important to note that hiring an external fleet should not, on average, generate substantial revenue or incur significant cost; otherwise, the contract is terminated as stated in Assumption 1.

Assumption 1. *A carrier does not, on average, gain profit or incur cost from outsourcing to other fleet.*

The justification of Assumption 1 comes from contrapositive arguments. Suppose the assumption is not true, there are two cases: a carrier gains profit or incurs cost. If a carrier, in the former case, profits from the hiring an external fleet, it can reduce exposure from upswing of manufacturer's demands. This is considered as an unsustainable economic arbitrary because the carrier has incentive to reduce a number of agreed shipments without any risk of losing revenue, yet the same level of service is archived. Therefore, a manufacturer will eventually switch a carrier. If a carrier, on the other hand, always incurs cost from this outsourcing, it may stop hiring other fleet and eventually terminate a contract. In both cases, the invalid assumption leads to the termination of the contract. This assumption is very helpful when we derive the optimal reserved shipments.

Without loss of generality, we can assume that shipping demands of a manufacturer and secondary customers, denoted by D^1 and D^2, are derived from probability distribution functions (pdf) $f^1(\cdot)$ and $f^2(\cdot)$ and cumulative distribution functions (cdf) $F^1(\cdot)$ and $F^2(\cdot)$, respectively. In addition, $r < c$, $p^1 + r > c$, and $\underline{Q} \le Q \le \overline{Q}$; otherwise, a solution is trivial. For the purposes of derivation and insight, we simply the managerial limits $\underline{Q}$ and $\overline{Q}$ as stated in Assumption 2.

Assumption 2. *A carrier can maximize its total profit by minimizing the difference of managerial limits, particularly* $\underline{Q} = Q = \overline{Q}$

Under Assumption 2, we can express all revenue and cost components of the problem and show that a special case of this problem is the Newsvendor problem as follows:

$$\begin{aligned}
&\Pi(Q, D^1, D^2) \\
&= \text{transp. rev.} + \text{reserve rev.} + \text{penalty rev.} + \text{alter rev.} \\
&\quad - \text{oper. cost} - \text{hire cost} \qquad (1) \\
&= p^1 D + r\,Q + g\,\max\{Q - D^1, 0\} \\
&\quad + p^2\,\max\{D^2, \min\{Q - D^1, 0\}\} - c\,Q \\
&\quad h\,\max\{D - Q, 0\} \\
&= (p^1 + g - h)\max\{D - Q, 0\} \\
&\quad + (p^1 + r - c)\min\{D, Q\} \\
&\quad + (p^2 \ + r - c)\max\{D^2, \min\{Q - D^1, 0\}\} \\
&\quad + (r - c)\max\{Q - D, 0\} \qquad (2)
\end{aligned}$$

The last expression comes from arranging components in Expression 1 in terms of agreed shipment Q, realized manufacturer's demand D^1, and secondary customer's demand D^2. We consider the analysis of Expression 2 into two cases by a number of demand channels.

A. Special Case: Single-Channel Demands

If a carrier has no benefit to access secondary customers, i.e., $p^2 = 0$, we can further simplify the last expression by applying Assumption 1, particularly $p^1 + g - h = 0$. Hence, Expression 2 becomes:

$$(p^1 + r - c)\min\{D, Q\} + (r - c)\max\{Q - D, 0\}. \qquad (3)$$

This expression is similar to the trade-off between the cost of lost sales and the cost of overstock in the Newsvendor problem [18]; therefore, one can compute the critical ratio:

$$F^1(Q^*) \quad = \quad \frac{p^1 + r - c}{p^1} \qquad (4)$$

Expression 4 implies that the cdf at the optimal agreed truck Q^* depends on the parameters in the contract. It is important to note that the cdf consists of solely the distribution of manufacturer's demand because of Assumption 1.

B. General Case: Multi-Channel Demands

If a carrier can access secondary customers, Expression 2 becomes a Newsvendor problem with multiple demand classes in which a carrier could sell the identical services to other customers at different prices and channels. Such problem was proposed and analyzed by Şen and Zhang [19]. They showed that the optimal order quantity must satisfy:

$$(p^1 - p^2)(1 - F^1(Q^*)) + p^2(1 - G(Q^*)) \quad = \quad c - r \qquad (5)$$

, where $G(\cdot)$ is the cdf of the convolution of pdf $f^1(\cdot)$ and $f^2(\cdot)$. The left hand side of Expression 5 is the total expected opportunity cost from both channels, whereas the right hand side is the net operation cost incurred by a carrier. Hence, this expression can be interpreted as the balance between the expected opportunity cost and operation cost. Unfortunately, Expression 5 has no closed form expression as cdf $G(\cdot)$ is, in general, difficult to compute. As a result, we use industry data to validate the concept and report numerical results in the next section.

IV. A Case Study

The carrier in the case-study is one of the large carriers in Thailand that owns more than one thousand trucks. The carrier provides a variety of transportation services to different business units ranging from on-call consolidation shipments to long-haul dedicated shipments. Each business unit manages its trucks independently and rarely shares trucks with the other business units. We found that a business unit that specializes in consumer products and targets at beverage manufacturers is an excellent candidate for our model because of its existing contract and high frequency of shipments.

A. Beverage Manufacturer Transportation Network

The carrier is granted with the transportation contract by a national beverage manufacturer to provide a dedicated fleet with 18-wheel trailer trucks to transport raw materials, work-in-process, empty pallets, and labeled finished goods. The manufacturer plans projected number of shipments quarterly and pays a lump payment of realized shipments monthly. The contract specifies that the carrier must transport each type of freight individually as full truckload throughout relevant facilities, which consists of suppliers, manufacturing plants, distribution center, and major modern trade customers. All facilities are located with 150 kilometers from Bangkok, as shown in Fig. 2.

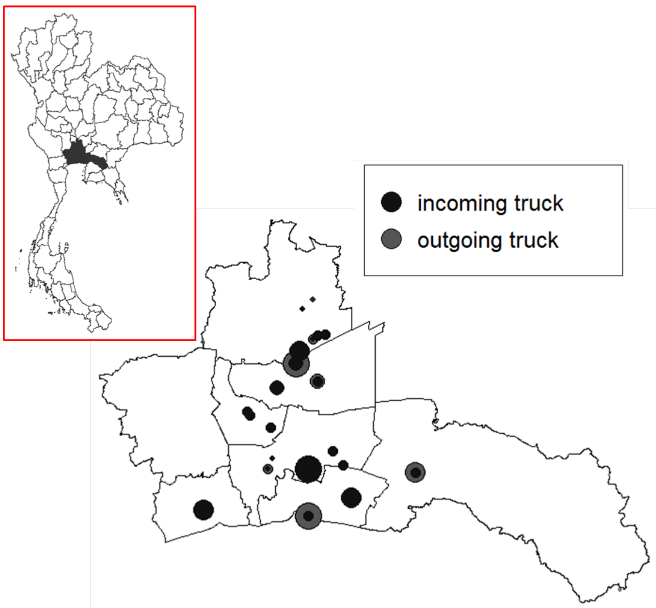

Fig. 2: Locations of supply and demand nodes

The node size in Fig. 2 represents a number of shipments at a particular location. The majority of activities occurred in Greater Bangkok Area and Ayutthaya province, 100 kilometers north of Bangkok, in which manufacturing plants and distribution centers are located.

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The manufacturer provides the overall pick-up and delivery locations and schedules to the carrier one day in advance. The carrier has to plan and, then, informs each truck driver about its own scheduling in the morning before the actual delivery. A driver operates six days per week from Monday to Saturday and transports three shipments per day on average. The numbers of shipments requested by the manufacturer during March and June are shown in Fig. 3 and 4.

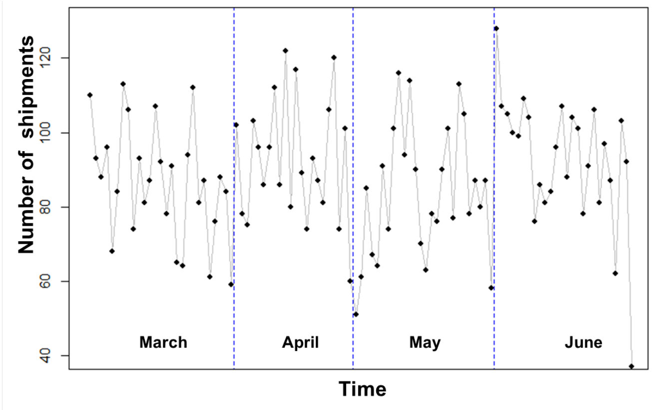

Fig. 3: Daily numbers of trips requested by a manufacturer during March - June

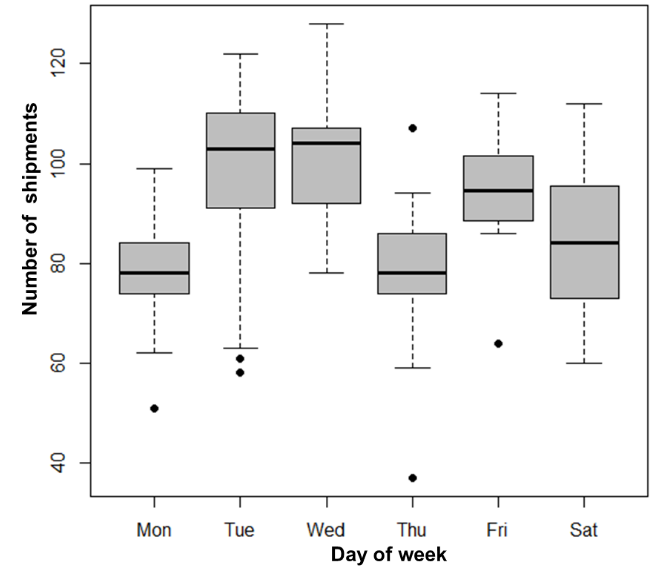

Fig. 4: Distribution of numbers of trucks requested on each day of week

In Fig. 3, we observed that the number of trips requested spiked at the end of each month because the manufacturer postponed the request to the next billing cycle. Within a week, Fig. 4 shows that the numbers of shipments requested on Tuesday, Wednesday, and Friday are significantly higher than those on Monday and Thursday. Moreover, there is a high fluctuation on Saturday because of some unusual overtime and urgent shipments on Saturday. Based on these observations, we adjusted the requests for the end-of-month declines and the weekday seasonality using regression and de-seasonal techniques and depicted its adjusted distribution as shown in Fig. 5.

Fig. 5 shows the histogram of adjusted requests and the normal distribution curve with the same mean and standard

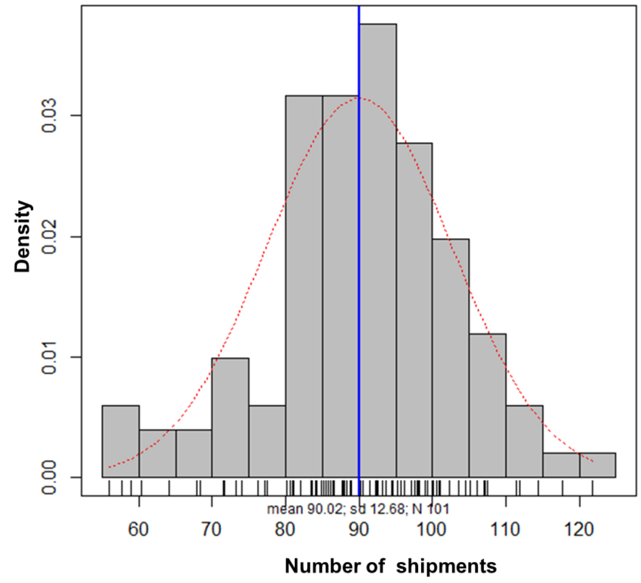

Fig. 5: Histogram of adjusted numbers of shipments for the end-of-month effect (β) and the day of week effect (α_i)

deviation. We observed that the histogram is asymmetric particularly at the left-hand-side. A possible explanation of this observation is that those requests occurred on public holidays. Using the Anderson-Darling test, we can assume that the adjusted request is normally distributed with p-value = 0.2176 and constructed a simple time series model as shown in TABLE I.

TABLE I: Weekday seasonality effect and a model for predicting numbers of truck required

Day of week (i)	Mon	Tue	Wed	Thu	Fri	Sat
value (α_i)	0.865	1.091	1.148	0.879	1.061	0.952

$$\hat{D} = \alpha_i \mathcal{N}(\bar{x} = 90.02, sd = 12.68) + 35.114\,\mathcal{I}(\cdot),$$

where α_i, $\mathcal{N}(\bar{x}, sd)$ and $\mathcal{I}(\cdot)$ denote the multiplicative factor on day i of the week, normal distribution with mean $\bar{x}$ and standard deviation sd, and the index function on the end of a month, respectively.

It is interesting to note that the average number of shipments requested by the manufacture after the de-seasonality is 90.02 which is roughly similar to the number of daily shipments specified in the estimation, i.e., 90 shipments. Before we use a Monte-Carlo simulation embedded with the data from the case study, we need to model the manufacturer response to evaluate the effects of number of agreed shipment and managerial limits.

B. *Manufacturer Response*

Since a manufacturer is allowed to react when the realized demands by the delay or expedition of non-essential shipments, such as shipments ahead or behind the due date. This decision of a manufacturer is a function of managerial limits $\overline{Q}$ and $\underline{Q}$, realized demands, and ratio of non-essential shipments as suggested in Algorithm 1.

Algorithm 1 reflexes the capability to manage non-essential shipments within its own network. Particularly, a manufacturer could delay non-essential shipments up to $u-\overline{Q}$ shipments from period i to period $i+1$ if $d_i > \overline{Q}$ or, on the other hand, could expedite shipments up to $d_{i+1}-l$ shipments

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Algorithm 1 Shipment Adjustment: given d, $\underline{Q}$, l, $\overline{Q}$, and u

for $i = 0, 1, \ldots, |d| - 1$ **do**
  if $d_i > \overline{Q}$ **then**
    $s_i \leftarrow \min\{d_i, u\} - \overline{Q}$
    $\acute{d}_i \leftarrow d_i - s_i$
    $\acute{d}_{i+1} \leftarrow d_{i+1} + s_i$
  else
    if $d_i < \underline{Q}$ **then**
      $e_i \leftarrow \max\{0, \min\{d_{i+1} - l, \underline{Q} - d_i\}\}$
      $\acute{d}_j \leftarrow d_i + e_i$
      $\acute{d}_{i+1} \leftarrow d_{i+1} - e_i$
    end if
  end if
end for
return $\acute{d}_i$

from period $i+1$ to period i if $d_i < \underline{Q}$. It is worth noting that the algorithm requires $\underline{Q} < l < \overline{Q} < u$.

C. Numerical Results

Having discussed the transportation data in the case study, we embedded the time series model and the manufacturer response into Monte-Carlo simulation coded in R/RStdio [20], [21] to analyze the results in Section III. Each scenario, which represents a different set of contracts and parameters of secondary customers, is repeated 100 replications using Intel® Core™ i3-3227U RAM 4GB. In each scenario, the manufacturer agrees to pay the reservation fee (r), transportation fee (p^1), penalty fee (g^1) at 2.5, 2.0, and 3.0 unit per shipment to the carrier, respectively. Furthermore, the operation cost (c) and the hiring cost (h) are 3.0 and 5.0 unit per shipment. The expected total profits ($E[\Pi]$) and its standard variation (sd_Π) are reported as shown in TABLE II.

TABLE II: simulation results ($r = 3.0, p^1 = 2.0, g^1 = 3.0, c = 3.0, \text{and} h = 5.0$)

	minor parameters		contract			
	p^2	Distribution	Q	$\underline{Q}$	$\overline{Q}$	$E[\Pi] \pm sd_\Pi$
$A_{\infty\%}$	0	$\mathcal{N}(0.0, 0.0)$	90	0	10000	10262.4 ± 1052.4
$A_{40\%}$	0	$\mathcal{N}(0.0, 0.0)$	90	54	126	10297.1 ± 1053.6
$A_{10\%}$	0	$\mathcal{N}(0.0, 0.0)$	90	81	100	11449.3 ± 1155.5
$A_{00\%}$	0	$\mathcal{N}(0.0, 0.0)$	90	90	90	12722.5 ± 1287.1
$B_{\infty\%}$	0	$\mathcal{N}(0.0, 0.0)$	101	0	10000	11628.9 ± 1186.4
$B_{40\%}$	0	$\mathcal{N}(0.0, 0.0)$	101	60	142	11638.9 ± 1187.2
$B_{10\%}$	0	$\mathcal{N}(0.0, 0.0)$	101	89	113	12280.9 ± 1246.8
$B_{00\%}$	0	$\mathcal{N}(0.0, 0.0)$	101	101	101	12753.8 ± 1301.2
$C_{\infty\%}$	1	$\mathcal{N}(0.9, 9.1)$	101	0	10000	11628.9 ± 1186.4
$C_{40\%}$	1	$\mathcal{N}(0.9, 9.1)$	101	60	142	11638.9 ± 1187.2
$C_{10\%}$	1	$\mathcal{N}(0.9, 9.1)$	101	90	112	12422.5 ± 1259.4
$C_{00\%}$	1	$\mathcal{N}(0.9, 9.1)$	101	101	101	13008.3 ± 1324.4
$D_{\infty\%}$	1	$\mathcal{N}(0.9, 9.1)$	102	0	10000	11692.8 ± 1192.8
$D_{40\%}$	1	$\mathcal{N}(0.9, 9.1)$	102	61	143	11692.8 ± 1193.8
$D_{10\%}$	1	$\mathcal{N}(0.9, 9.1)$	102	91	113	12460.9 ± 1264.3
$D_{00\%}$	1	$\mathcal{N}(0.9, 9.1)$	102	102	102	12990.6 ± 1323.3

Sixteen scenarios in Table II are grouped by alphabets and their subscripted percentages. The subscripted percentages denote managerial limits of which the manufacturer allows to deviate from the agreed the number of shipments. The alphabet represents a number of agreed shipments and parameters of secondary customers:

- **Scenario A** is referred to the scenario in which a number of agreed daily shipments is 90, and the carrier has no access to secondary customers;
- **Scenario B** is similar to Scenario A, but the number of agreed daily shipments is optimized at 101, i.e., $F^1(101) \approx \frac{2.5+2.0-3.0}{2.5}$;
- **Scenario C** is similar to Scenario B, but the carrier can serve secondary customers –a number of daily shipment is normally distributed and independent from manufacturer's ones– and receives 1.0 unit per shipment; and
- **Scenario D** is similar to Scenario C, but the number of agreed daily shipments is 102 which satisfies Expression 5 given the set of parameters.

For example, Scenario $A_{10\%}$ indicates a scenario that the number of daily agreed trucks is 90 and the manufacturer is allowed to change up to 10% of the number of agreed shipments or the carrier must support, if requested, between 81 and 100 shipments daily. We established a baseline for the analysis using Scenario $A_{\infty\%}$ as the carrier, currently, operates in this manner. In Table II, we observed that selecting the optimal agreed number of shipments (Scenario B) and accessing the secondary customers (Scenario C) improve the expected total profits. In addition, the less percentage of the deviation of agreed number of shipments, the greater of the expected total profits. Therefore, we coined a term, *ratio of deviate shipments*, to measure and study the effect ratio of the deviate truck ($1 - \underline{Q}/\overline{Q}$) and the number of agreed trucks (Q) as shown in Fig. 6.

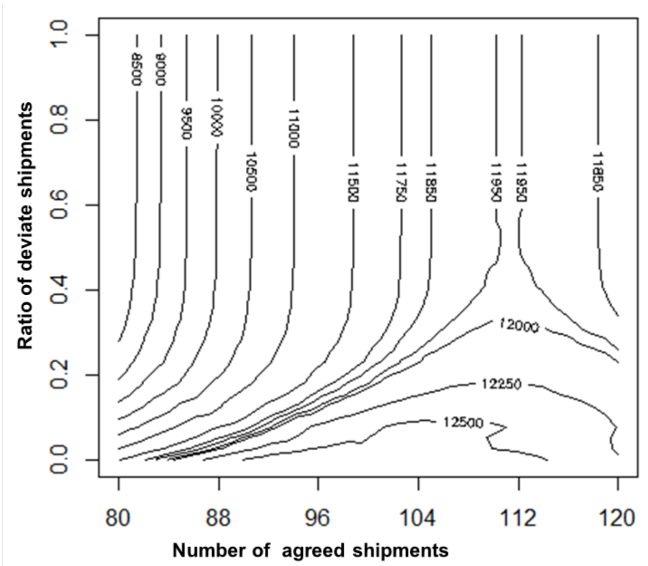

Fig. 6: Expected profit with respected to number of reserved trucks (Q) and the ratio of deviate truck ($1 - \underline{Q}/\overline{Q}$)

The figure confirms the observation and implies that the gradual changes in the number of agreed shipments and the ratio of deviate shipments have incremental effects on the expected total profits. In fact, the number of agreed shipments has no significance in terms of the expected total profits if the ratio of deviate shipments exceeds 0.35. This means that the number of agreed shipments significantly influences the carrier's profitability.

V. Conclusions

We presented a case study of the trucking capacity allocation in perspective of a motor carrier which must decide the number of agreed shipments and allocate its available trucks

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with a contracted manufacturer. Because of the fluctuation in shipments, the carrier faces an economic trade-off between the opportunity cost of allocating too many trucks thereby under-utilizing its trucks and potential contract penalty of insufficient trucks. Due to their services and partnership, they can manage realized demands by the delay or expedition of non-essential shipments. In addition, an option to which the carrier can sell excess trucking capacity to other customers is considered. With additional restrictions, we showed that the economic trade-off can be viewed as the Newsvendor problem and applied its classical results and the percent deviation contract proposed by Drake and Swann [3] to determine the optimal number of agreed shipments and enhance the flexibility of a contract, respectively. To illustrated this finding, we embedded the transportation data and the manufacturer's response into Monte-Carlo simulation and studied its numerical results. The analysis of the model showed that the carrier and the manufacturer should emphasize on the number of agreed shipments than the allowed number of deviated shipments. Once a number of agreed shipment is established, the carrier may improve its revenue and its trucking capacity by accessing secondary customers.

A. Future Works

Empirically, trucking-capacity contract requires serious negotiation and usually is tailored to the need of a specific buyer. As a result, insight derived from a simple contract is limited and unable to apply to complex. When a carrier, for example, can serve secondary customers, a manufacturer may ask to modify terms of a contract such as higher transportation costs payment in exchange of reducing the reservation fee.

In this article, the responses of a carrier as a seller and a manufacturer as a buyer are given based on their current operations and known reaction. In some industry – such as retail business– a retailer usually has higher negotiation power than a supplier. Hence, the responses and available options may be different. This leads to the leader-follower relationship and sequential decision making. Furthermore, the information that each party held may create advantages over its counterpart. Such asymmetry information leads to the Bayesian game aspect of the problem.

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