Integration of Contract and Spot Market Carrier under Demand Uncertainty

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Abstract

Demand uncertainties give challenges in transportation service procurement. Many companies only using long-term contract carrier which does not provide flexibility under the instability of transportation demand. This research aims to understand the behavior of transportation planning using two transportation sources namely contract and spot market carrier in terms of product availability in the market and the transportation cost. The contract carrier refers to the long-term agreement between a shipper and a carrier while a shipper is also available to purchase their transportation in the spot market in order to satisfy the excess demand. The simulation study is developed to capture the behavior of the system subject to the uncertainty of the demand, distribution process, and the complexity of the system. The results show that the utilization of spot carrier increases the availability of the product in the market, yet it also increases the total transportation cost and reduces the utilization of the trucks.

Keywords
Long-term contract, spot market, Transportation sourcing, Simulation study, and Supply chain management.

1. Introduction

Uncertainties occur in many aspects in the supply chain including the distribution process. Peidro *et al.* (2009) mentioned that uncertainty is the difference between the required number of information to perform the process and the available information. The demand from the customers is hard to predict. Moreover, the traffic and congestion results in the delay, long queuing in the process, and instability of the travel time. Thus, it may result in a lack of transportation supply. The cost implication of having a delay in the process includes a cost to reschedule, loss of sales, and excess or insufficient inventory. One of the methods to overcome uncertainties is by enabling a flexibility (Angkiriwang *et al.*, 2014). The flexibility in the distribution process can be in the form of a flexible schedule, flexible capacity, and flexible route (Song and Dong, 2011). There are still few studies addressing the flexible sourcing of transportation.

The development of third-party logistics changes the perspective of having their fleets to outsourcing all of the transportation, because it is believed to give more benefit to the company (Alp *et al.*, 2003). Many shippers are reserving a certain capacity for their shipment using a long-term contract to obtain a negotiable fare for the delivery (Qin *et al.*, 2012) and to maintain a close relationship between a buyer and a supplier (Serel *et al.*, 2001). Nevertheless, in the capacity commitment, the shipper does not have the flexibility to increase the capacity of their contract in accordance with the unexpected increase of the demand. Re-arrangement of the contract involves complicated and long negotiation processes. Thus, the contract itself does not guarantee that the shipper is able to satisfy all the demand. Tibben-Lembke and Rogers (2006) predict that in the future, logistics will have media for exchanging the information to facilitate the shipper and buyer to buy or sell their logistics services. This opens new options for the logistics sourcing strategy.

In this paper, we analyze the performance of the shipper by combining two sources of transportation which are purchased from a long-term contract and from a spot market. Our work considers a big manufacturing company in

Indonesia and studies its transportation sourcing strategy. The performance of the shipper is determined from the product fill rate, the utilization of the dedicated fleet, and the total transportation cost.

2. Literature Review

2.1 Flexibility under Demand Uncertainty

In general, the source of uncertainties is divided into three namely demand, process, and supply (Lee and Billington, 1993). The market demand depends on several factors such as cost, quality, service level, reliability, availability, flexibility, delivery speed, location, sourcing, supplier relations, environmental impact, recycling, and a whole range of other things (Waters, 2003). The consideration of shipment volumes is important to support the decision of shipper (Remli and Rekik, 2013). There are two common strategies to manage the uncertainty in the supply chain which is reducing uncertainty by managing the integration among supply chain elements or coping with uncertainties by increasing flexibility (Simangunsong *et al.*, 2012). Sreedevi and Saranga (2017) mention three different flexibility which consists of supply flexibility, logistics flexibility, and manufacturing flexibility. Product flexibility able to handle the rapidly changing requirements from customers. The product modularity enables the manufacturer to achieve a quick response and high flexibility by having numerous features, size, or color of their products (Zhang *et al.*, 2014). Flexibility also applied in the production strategy. It refers to the ability to increase and decrease the volume of production closely related to the inventory level (Jin *et al.*, 2014). There are many studies involve the variation of routes, transportation network, and flexible material handling to overcome the uncertainty of demand. Supply flexibility including flexible supply base, supply contract, and collaborative supplier relationships enables to overcome the instability of upstream demand (Sreedevi and Saranga, 2017). Moreover, logistics flexibility refers to the ability of a firm sourcing system to accommodate various inbound and outbound activities (Manders *et al.*, 2016). Although many studies addressing different aspects of flexibility, transportation sourcing flexibility have rarely been focal to a study.

2.2 Transportation Sourcing

Transportation sourcing is one of the strategies to manage the flexibility of delivering the product to the customers (Angkiriwang *et al.*, 2014). The issue in transportation sourcing has become consideration of few researchers. There are studies that involving one type of carrier. Many studies focus only in sourcing the transportation using long-term contract (Caplice, 2003; Lim, 2008; Lim *et al.*, 2012; Huang and Xu, 2013; Hu *et al.*, 2016). They focus on determining the suitable logistics provider in order to get the minimum transportation cost. There also studies that consider the combination of transportation sources. The optimization in mixing using in-house and outsource transportation are studied by Krajewska and Kopfer (2009), Lee *et al.* (2007), Ma *et al.* (2010), and Gurler *et al.*, (2014). Krajewska and Kopfer (2009) show that the combination of own fleet and several outsourcing types can reduce the cost of transportation. Gurler *et al.,* (2014) mentioned the utilization of two types of transportation resource. Both of the resources are obtained from third party logistics. The excess usage of the carrier will automatically charge a new price. Several studies model the on the spot carrier as a penalty of not fulfilling the demand (Stojanović and Nikolić-Đorić, 2014; Kuyzu *et al.*, 2015; Tempelmeier and Bantel, 2015; Zhang *et al.*, 2015). Moreover, Stojanović and Nikolić-Đorić (2014) accommodate three types of transportation source namely own-account, contract, and common fleet.
In this study, we enhance the flexibility of sourcing the transportation using contract and also on the spot market. The spot carrier is used when there is an excess demand that needs to be fulfilled by the shipper. We analyze the behavior of the system if we increase the usage of the spot carrier.

3. Methodology

Taking into account the aim of the research, which is to understand the behavior of the distribution system while using two types of carrier, we develop a simulation study as the research method. The main advantages of using simulation model are its ability to deal with very complicated models of correspondingly complicated systems, more cost-effective than conducting the real simulation process, and have flexibility and ease of use (Persson and Araldi, 2009). Thus, the simulation study is recommended to model the distribution systems which are complex as they involve many interconnectedness with the uncertainty of the environment (Bolkovska and Petuhova, 2016). The study of the tactical or operational level can be modeled using discrete-event simulation (DES) (Tako and Robinson, 2012). The simulation is developed and performed using ARENA® software.
There are several steps in conducting simulation experiments. The first step is developing the model. It involves the identification of the problem based on the observation in the real distribution system. The input of the simulation model including the demand pattern of each customer, the distribution process, and the supply chain configuration. The occurrence of the demand in each customer is stochastic and follows normal distribution pattern. The second step

involves the verification of the logic and calculation in the simulation model. The verification is conducted using a debug check and a manual calculation of the performance measures. Then, we generated simulation experiments after the model is confirmed to be valid. We generate the combination of control variables which consists of a dedicated number of long-term contract trucks and the increasing allowance procured from the spot market. Each of the scenarios is run for one-year period with 3 replications.

4. Model Development

The simulation study models a delivery of product from a manufacturer to 75 retailers using land transportation. The retailers are spreading across the island and categorized into two groups following their distance from the manufacturer namely short-distance (less than 100 km) and long-distance (more than 100 km). The assignment of the trucks is divided into three different times which are every 10:00, 14:00, and 16:00. The short-distance retailer demand becomes the priority and will be released at the first assignment time. This method enables the trucks to do more than one delivery in one day. The transportation of the product is done by two types of carriers which are the long-term contract carrier and the spot carrier. The contract carrier provides a certain number of trucks dedicated to the manufacturer. The congestion during the travel time results in the lack of the transportation supply. If such a condition occurred, the delivery will be accommodated using external transportation that is procured from the spot market. All the trucks provided by those two carriers are having the same capacity which is 30 tons.

The major differences of those two type of carriers are the fare and the responsibility to manage the truck utilization. Scott (2015) mentions that the average price in the spot market is 62% higher than the corresponding contract prices. In this study, we model the procurement of the spot carrier is 50% more expensive than the price of the current long-term contract carrier.

The experiment consists of several numbers of trucks available from the agreement with the carrier [250, 300, 350]. The maximum daily number of spot market truck requests [0, 50, 100, 150, ..., 600] is determined in order to make a room for the contract to return and fulfill the remaining order. The logic for all the scenarios is the same.

The evaluation of the scenarios is using two performance measures which are the product fill rate that represents the service level of the company and the total transportation cost. The product fill rate (F) is calculated using equation as follow:

$$F = \frac{A-S}{A} \quad (1)$$

A : total demand quantity of all retailers (tons)
S : total stock out quantity of all retailers (tons)

The total transportation cost consists of the total cost of using long-term contract carrier and total cost of procuring transportation in the spot market. The total transportation cost (T) is the following.

$$T = p_c \times D_c + p_{ots} \times D_{ots} \quad (2)$$

p_c : price of using contract carrier (Rp/km)
D_c : total distance of contract carrier (km)
p_{ots} : price of using the spot carrier (Rp/km)
D_{ots} : total distance of the spot carrier (km)

5. Result and Discussion

The simulation of each scenario has a duration of one year and replicated 3 times. The analysis is conducted in two parameters namely product fill rate and total transportation cost. The results of each parameter are drawn in the graphs. The percentage of the spot carrier is obtained by dividing the total number of the spot trucks with the total number of trucks utilized in each scenario. The increasing number of a dedicated number of trucks is divided into three which are 250, 300, and 350.

Product fill rate calculates the product availability in the retailers. The higher fill rate value means the higher capability of the manufacturer to satisfy the demand of the customers. The result of the product fill rate is depicted in Figure 1. The increasing number of contract carrier results in higher fill rate. Moreover, the additional number of fleets from spot market helps in fulfilling the demand in the retailers. It is proven by the increase of the fill rate while using the same dedicated number of contract fleets. As the number of the spot carrier increases, the value of the fill rate increases but not in the same deviation for the different number of contract trucks.

The total cost reflects the sum of the cost for each type of carrier. The more dedicated number of contract carrier results in higher cost. Moreover, if we allow a few numbers of the spot carrier into the system, the total cost in slightly increase. The escalation of the total cost becomes much higher if companies procure more transportation from the spot market.

The results suggest that the additional allowance of the spot carrier to the system can increase the product availability in the retailers and also increase the total cost respectively. The higher number of trucks used results in the lower utilization of the dedicated carrier. Thus, the optimum strategy is difficult to obtain because there are tradeoffs among the parameters unless we develop a standard of the system.

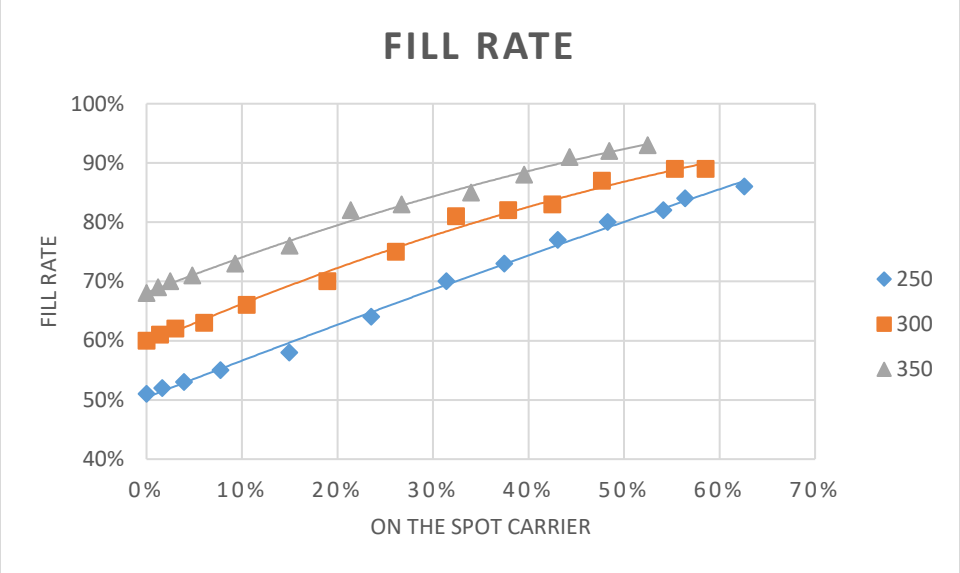

Figure 1 Shipper's Fill Rate with Different Number of Trucks

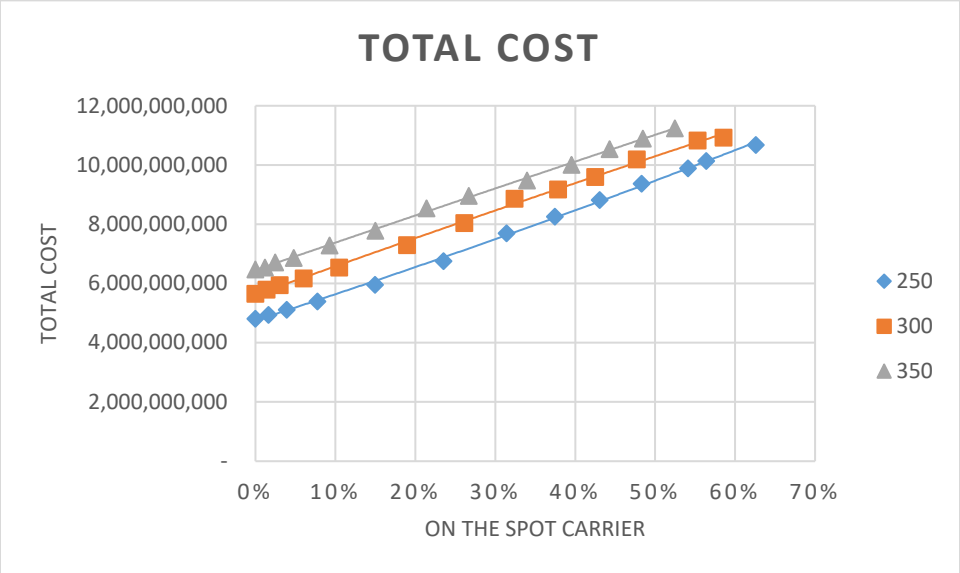

Figure 2 Shipper's Total Cost with Different Number of Trucks

6. Conclusion and Future Work

In this study, we model the delivery system involving one vendor and multi retailers. We solved the transportation planning strategy involving two types of carrier which are procured from long-term contract agreement and from the spot market. The procurement of dedicated capacity only does not guarantee the accomplishment of the demand. The using of additional carriers is undeniable due to the uncertainty of transportation demand. The spot carrier is useful when there is an excess transportation demand which can increase the service level of the shipper. Nevertheless, a higher number of trucks procured from spot market also increase the cost of transportation. The shipper needs to determine their goals in order to have high product availability with low cost of transportation.
This study can be extended in various ways. The development of transportation demand leads to an increase in travel congestion (Ha *et al.* 2018). Thus, the evaluation of transportation sourcing should accommodate the different results in the reliability of the system. The different performances of the spot carrier have not been accommodated. In practice, the selection of carrier from spot market requires the decision in several carrier's attributes that need to be aligned with the goals of the shipper.

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