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Optimal ordering quantity by retailer from supplier with transportation cost in a supply chain

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Abstract

Successful retailer-supplier collaborative relationship enhance profitability in the delivery of products or services to customers in a supply and can help alleviate pressures along all key points in the supply system. A strong alliance can bring products to market faster; reduce production and logistics costs, drive market shares, and increase sales, while maximizing profit for both partners. The success of fast-moving consumer goods from the suppliers has a direct relationship with the performance of the leading retailers, which are their main channel of distribution. The objective of this study was to establish a profit model between a single supplier and multiple supply chain collaboration that will enhance response to customer requirements. We considered the costs for various parties and use a referenced simplified framework model to obtain joint optimal pair for the outcome of coordination between the retailer and supplier. Our results showed that the value of the annual cost, with the same optimal ordering quantity, is higher when the retailer incurs transportation cost than when the supplier incurs transportation cost. This study revealed that the supplier will minimize cost when incurring transportation charges and maximize profit.

Keywords: Supply chain, Transportation cost, Supplier, Retailer, profitability.

Introduction

To combat today's supply chain challenges, smart retailers are focusing at collaborating with their supplier partners. Successful retailer-supplier collaboration can help alleviate pressures along all key points in the supply system. A strong alliance can bring products to the market faster, reduce production and logistics costs, drive market shares, and increase sales, while maximizing profit for both partners. Profitability in the supply chain involves effective supply chain management which has critical roles in steering business success through coordinated activities of the value chain partners. The success of fast-moving consumer goods from the suppliers has a direct relationship with the performance of the leading retailers, which are their main channel of distribution (Mathu, & Phetla. 2018).

Companies in supply chains continue to strive at creating efficient supply chain management (SCM) to gain competitive advantage and improve performances (Castro & Ladeira, 2012). This guarantees greater flexibility to address market changes, waste reduction, responsiveness, and improved customer satisfaction (Gao *et al.,* 2005). The relationships between interdependent companies are involved in the flow and transformation of goods, services, and other necessary information from the origin to final customer and consumer (Simatupang & Sridharan, 2002).

Collaboration occurs when two or more organizations exchange information, share responsibility to plan, manage, execute, and monitor supply chain performances (Cao & Zhang, 2011). Collaboration practices in the supply chain are commonly designated by collaborative culture, joint planning, joint problem solving, and sharing of resources and information (Oliveira, 2016). Effective information in collaboration employs various initiatives such as Collaborative Planning (CP) and e-Collaboration (Chong et al., 2009), Collaborative Agent Time (CAT) (Carle et al., 2012), Value Chain Analysis (VCA) (Francis et al., 2008), Generic Product Family Model (GPF) (Jiao et al., 2007), Collaborative Transportation Management (CTM) (Chan & Zhang, 2011), Quick Response (QR) (Choi & Sethi, 2010), Efficient Consumer Response (ECR) (Kurnia & Johnston, 2003), Continuous Replenishment Program (CRP) (Raghunathan & Yeh, 2001), Vendor Management Inventory (VMI) (Freitas et al., 2014), and Collaborative Planning Forecasting Replenishment (CPFR) (Fu, 2016). Collaborative practices are paramount to improving the performance of organizations (Min et al. 2005). Oliveira (2016) had reported that, collaborative practices in the supply chain are directly related to better performance in the quality of products and services offered, in the reduction of production and delivery times (lead time), and in facilitating operations.

Cao & Zhang (2011) also described supply chain collaboration (SCC) as a partnership process where two or more autonomous companies work together to plan and execute supply chain operations with common goals and achieve mutual benefits. While Burnette & Dittmann (2018) considered collaboration in a supply chain as an opportunity to increase the overall value of the entire chain, and propose specific business objectives between two or more parties. Likewise, Bowersox *et al.,* (2014) observed that companies that integrate in a supply network share strategic objectives and information, and plan together, thus reducing risks and increasing trust between the parties. For Jain *et al,.* (2017), collaboration combined with trust and information sharing between partners increases visibility, while reducing uncertainties and vulnerability in the chain. They also emphasized that organizations with global markets are part of a complex supply chain that requires highly coordinated flows of goods, services, information, and capital across borders. Nonetheless, "supply chain performance is positively related to collaboration" due to the perception of improvements in factors such as quality of products and services and lead time reduction (Oliveira, 2016). However, for mutual benefits for the partners, many practices are not carried out due to difference of interest between the parties and lack of alignment; suggesting that a collaborative supply chain with integrated policies must be installed as an initiative to mitigate the possible harmful effects of the lack of integration between partners (Simatupang & Sridharan, 2002). The goal of collaboration between companies is twofold namely (i) to make internal functions effective and efficient and (ii) to expand market share or make market-oriented strategies (Kumar et al. (2017)

It is essential to looked at how a collaborative relationship between the supplier and retailer to enhance profitability in the delivery of products or services to customers in a supply. In this context, the objective of this study was to establish a profit model that supply chain collaboration (SCC) enhances supplier and retailers' response to customer requirements.

In this scenario, we considered that the retail space has become highly competitive globally, as consumers are continuously searching for better services and products at lower prices (Hübner, & Sternbeck, 2013). The collaborative process between the supplier and retailer requires cooperation and information sharing (Pienaar & Vogt 2012); and are able to increase responsiveness, agility and reduction of inventories across the entire supply chain (APICS 2013).

The supplier and retailer operating expenses depend on the price obtained initially from transportation price information regarding dispatch services to dispatch quantities. While the transportation pricing structures may be encounter differently including :

i. A per unit price for each item transferred,
ii. A fixed price for each dispatch and
iii. A fixed price for each truck used.

Note that, there may be a combination of any of the pricing structures depending on the transportation mode or supplier's operational policy.

Model Formulation

In order to keep the model mathematically tractable, we consider a referenced simplified framework based on Goyal, (1976), Çetinkaya, and Lee, (2002) and Mutlu, (2006) model. Let us first define the following notations:

D: Retailer's demand per period.

C_S : Supplier's fixed replenishment cost.

C_R : Retailer's fixed replenishment cost.

h_S : Supplier's inventory holding cost per unit per period.

h_R : Retailer's inventory holding cost per unit per period.

Q: Supplier's replenishment quantity.

q_R : Retailer's replenishment quantity, i.e., dispatch quantity.

n: Number of dispatches in a supplier's replenishment cycle.

ρ : Per unit wholesale price paid by the buyer to the supplier.

Y_S : Supplier's fixed cost per shipment.

R_S : Supplier's cost for launching one truck.

P: Truck capacity.

P_S : Per unit transfer price.

Assumption of the Model

In this subsection, we give a transporter's – retailer's performance model in a supply chain in which the retailers are supplied with a deterministic and constant demand. The followings are the assumptions of the model.

a) The transporter is responsible for delivery of the products/items from the company's site to the retailer's site.

b) The retailer replenishes his inventory periodically from the supplier

c) The manufacturer's production rate is infinite.

d) There are costs associated with replenishing and holding inventory for both parties.

e) The retailer incurs a per unit purchase cost.

Note that the supplier's fixed costs representing the setup cost with instantaneously purchasing Q units. The per-time inventory holding cost and retailer's inventory replenishment cost is a fixed cost involved with ordering and receiving the quantity, q_R units, sum of administration and inspection cost. However, supplier-retailer coordination can be achieved by adjusting the value of C_R.

We aim to analyze the supplier's-retailer's performance impact on the costs involved with the link with quantity, q_R, from the company by the supplier and retailers. Also, to prove that under the transportation pricing schedules mentioned, the supplier-retailer system can be coordinated by developing win-win solutions for both parties.

The coordinated dispatch quantities must be equal to the corresponding, q_R, values of the joint optimal solutions which will minimize the system-wide costs of the supplier-retailer system, i.e., q_{SR}.

The supplier's replenishment cycle length is $\frac{Q}{D}$ and the retailer's replenishment cycle length is $\frac{q_R}{D}$. We consider that $Q = nq_R$, where n is a positive integer representing the number of retailer replenishments or dispatches, within one supplier replenishment cycle.

We consider the above information on assumption that the retailer and supplier act as a single unit and operate at their joint optimal solution.

We also considered the following assumptions;

(i) The retailer makes the final decision about the order quantity.

(ii) The retailer's decision depends on the transportation price.

For example, if the supply is less-than-truckload (LTL) or an overnight carrier, he may prefer as per unit based pricing scheme. If the supplier dedicates some of his fleet to serving a specific customer, preferably by using full truckload (FTL) shipments, he/she may charge a fixed price for each truck and/or each dispatch.

Note that; G_{SR} implies the supplier and retailers are in strategic partnership.

We consider the costs for various parties.

a) The supplier's average annual cost given a dispatch quantity q_R and volume D is expressed as

$$G_S(q) = \frac{\lceil \frac{q}{P} \rceil R_S D}{q} + \frac{y_S D}{q} + C_S D \quad (1)$$

where $C_S D$ is the unit transfer cost of the supplier. But the unit transfer cost is not important, thus, the supplier's average cost may be express as $G_S(q)$

$$G_S(q_R) = \frac{\lceil \frac{q_R}{P} \rceil R_S D}{q_R} + \frac{y_S D}{q_R} \quad (2)$$

In equation (2), the first term represents the average cost of the truck, with a minimum value of $\frac{R_S D}{q_R}$, at $q_R = kP$ for all positive integer values of k.

This function depend on q over $(k - 1)P < q_R \leq kP$ and it means that the supplier's average cost is minimized only when full trucks are dispatched, i.e., truck capacities are fully utilized.

b) The supplier must first have information about the initial transportation pricing of the retailer before coming out with the value of a joint dispatch quantity, q_{SR}, for their cost saving opportunities. This value can be obtained from $G_{SR}(q_R, n)$ depending on P_S. That is,

$$\min_{q\geq 0,\, n\epsilon Z^+} G_{SR}(q_R, n) = \frac{C_s D}{nq_R} + \frac{h_s(n-1)q_R}{2} + \frac{C_R D}{q_R} + \frac{h_R q_R}{2} + P_S(q_R) \quad (3)$$

This value of q_{SR} obtained from equation (3) have the following conditions;

If the initial pricing is based on only a per unit item charge then the supplier's average revenue is independent of q, i.e., $P_S(q_R) = P_S D$.

Under this transfer pricing structure, the transportation cost of the supplier-retailer with this term $P_S D$ is

$$\min_{q\geq 0,\, n\epsilon Z^+} G_{SR}(q_R, n) = \frac{C_s D}{nq_{SR}} + \frac{h_s(n-1)q_{SR}}{2} + \frac{C_R D}{q_{SR}} + \frac{h_R q_R}{2} + P_S D \quad (4)$$

and the supplier-retailer (n_{SR}) and q_{SR}that lead to the smallest G_{SR}, was obtain when $\frac{dG_{SR}(q_{SR}, n)}{dn} = 0$

and

$$\frac{dG_{SR}(qS_R, n)}{dq_{SR}} = 0$$

Thus,

$$\frac{dG_{SR}(q_R, n)}{dq_{SR}} = -\frac{C_s D}{nq_{SR}^2} + \frac{h_s(n-1)}{2} - \frac{C_R D}{q_{SR}^2} + \frac{h_R}{2} \quad (5)$$

But

$$\frac{dG_{SR}(q_{SR}, n)}{dq_{SR}} = 0$$

$$-\frac{C_s D}{nq_{SR}^2} + \frac{h_s(n-1)}{2} - \frac{C_R D}{q_{SR}^2} + \frac{h_R}{2} = 0$$

$$\frac{C_s D}{nq_{SR}^2} + \frac{C_R D}{q_{SR}^2} = \frac{h_s(n-1)}{2} + \frac{h_R}{2}$$

$$q_{SR}^2 = \frac{2(C_s + n_{SR}C_R)D}{n_{SR}(h_R - h_s + n_{SR}h_S)}$$

$$q_{SR} = \sqrt{\frac{2(C_s + n_{SR}C_R)D}{n_{SR}(h_S(n_{SR} - 1) + h_R)}} \quad (6)$$

$$\frac{dP_{SR}}{dn} = -\frac{C_s D}{n^2 q_{SR}} + \frac{h_s q_{SR}}{2}$$

But

$$\frac{dP_{SR}}{dn} = 0$$

$$-\frac{C_s D}{n^2 q_{SR}} + \frac{h_s q_{SR}}{2} = 0$$

$\frac{C_S D}{n^2 q_{SR}} = \frac{h_{sq_{SR}}}{2}$

$n^2 q_{SR}^2 h_S = 2C_S D$

But

$q_{SR}^2 = \frac{2(C_S + n_{SR} C_R)D}{n_{SR}(h_S(n_{SR}-1)+h_R)}$

$n_{SR}^2 h_S \left(\frac{2(C_S + n_{SR} C_R)D}{n_{SR}(h_S(n_{SR}-1)+h_R)}\right) = 2C_S D$

$2n_{SR} h_S (C_S + n_{SR} C_R)D = 2C_S D(h_S(n_{SR} - 1) + h_R)$

$n_{SR}^2 h_S C_R = C_S(h_R - h_S)$

$n_{SR}^2 = \frac{C_S(h_R - h_S)}{(C_R h_S)}$

$$n_{SR} = \sqrt{\frac{C_S(h_R - h_S)}{(C_R h_S)}} \quad (7)$$

This means that for given n_J,

$q_{SR} = \sqrt{\frac{2(C_S + n_{JSR} C_R)D}{n_{JSR}(h_S(n_{JSR}-1)+h_R)}}$

The joint optimal pair which is the outcome of coordination between the retailer and the supplier (q_{SR}, n_{SR}) is then given by

$$(q_{SR}, n_{SR}) = \left(\sqrt{\frac{2(C_S + n_{SR} C_R)D}{n_{SR}(h_S(n_{SR}-1)+h_R)}}, \sqrt{\frac{C_S(h_R - h_S)}{(C_R h_S)}}\right) \quad (8)$$

After obtaining the order quantity and the corresponding number of dispatches in the retailer- supplier replenishment cycle, we considered the following conditions:

i) If the supplier incurs the transportation charges, he must have initial information about the retailer's transportation and the wholesale pricing before coordination cost of the retailer. The retailer cost function given the initial wholesale price, $P_S(q_R) = P_S q_R$, is

$$G_R(q_R) = \frac{C_R D}{q_R} + \frac{h_R q_R}{2} + P_S D \quad (9)$$

where $P_S(q_R)$ is the initial total revenue of the supplier.

The retailer's optimal order quantity, (q_R), that minimizes the objective function is obtained by differentiating $\frac{dG_R(q_R)}{dq_R}$ and solving to zero. i.e.

$\frac{dG_R(q_R)}{dq_R} = -\frac{C_R D}{q_R^2} + \frac{h_R}{2}$

If

$\frac{dG_R(q_R)}{dq_R} = 0$

Then

$-\frac{C_R D}{q_R^2} + \frac{h_R}{2} = 0$

$$q_R = \sqrt{\frac{2C_R D}{h_R}} \tag{10}$$

We also define $\hat{G}_R(q_R)$ as

$$\hat{G}_R(q_R) = \frac{C_R D}{q_R} + \frac{h_R q_R}{2}$$

Now the supplier problem is formulated as follows:

$$\max_{q_R, n} \hat{G}_R(q_R) = \frac{\bar{P}_S(q_R)D}{q_R} - G_S(q_R, n)$$

Subject to

$$\hat{G}_R(q_R) + \frac{\bar{P}_S(q_R)D}{q_R} = \hat{G}_R(q_R) + P_S D$$

Note that $G_S(q_R, n)$ is the supplier's average annual operating cost.

Equivalently,

$$\max_{q_R, n} \hat{G}_R(q_R) + P_S D - \hat{G}_R(q_R) - G_S(q_{SR}, n) = G_R(q_R) - \hat{G}_R(q_R) - G_S(q_{SR}, n)$$

$$= G_R(q_R) - G_{SR}(q_{SR})$$

$$\min_{q, n} \equiv G_{SR}(q_{SR})$$

ii) If the retailer incurs the transportation charges given the initial wholesale price, $P_S(q_R) = P_S q_R$, and the initial transportation price, $P_S(q_R)$, the retailer cost function is given as

$$G_R(q_R) = \frac{C_R D}{q_R} + \frac{h_R q_R}{2} + \frac{C_T D}{q_R} + P_S D$$

The minimize of this function, i.e., the retailer's optimal order quantity, is given by q_R. Also, the retailer's cost excluding the purchase cost, $\hat{G}_R(q_R)$ is

$$\hat{G}_R(q_R) = \frac{C_R D}{q_R} + \frac{h_R q_R}{2} + \frac{P_S D}{q_R}$$

The term $P_S D$ does not affect any decision and the coordination mechanism is the same as in the case where the transportation charge was on the supplier.

The optimal quantity that minimizes the objective function is given by q_R. Also, recall that the retailer's cost excluding the purchase cost, $\hat{G}_R(q_R)$, is

$$\hat{G}_R(q_R) = \frac{C_R D}{q_R} + \frac{h_R q_R}{2} + \frac{P_S D}{q_R}$$

Using the above information, the supplier's problem can be formulated as follows:

$$\max_{q_R, n} \hat{G}_R(q_R) = \frac{\bar{P}_S(q_R)D}{q_R} - G_S(q_R, n)$$

Subject to

$$\hat{G}_R(q_R) + \frac{\bar{P}_S(q_R)D}{q_R} = \hat{G}_R(q_R) + P_S D$$

where $\bar{P}_S(q_R)$ is the total revenue of the supplier after negotiating with the retailer.

From the above-given constraint, we substitute the value of $\overline{P}_S(q_R)$ into the objective function, so that

$$\max_{q_R, n} \hat{G}_R(q_R) + P_S D - \hat{G}_R(q_R) - G_S(q_R, n) = G_R(q_R) - \hat{G}_R(q_R) - G_S(q_R, n)$$

$$= G_R(q_R) - G_{SR}(q_R)$$

$$\min_{q, n} \equiv G_{SR}(q_R)$$

It is clear from the analysis above that no matter who incurs the transportation charges, the supplier's main aim here is to minimize the joint cost of the retailer and supplier.

NUMERICAL ILLUSTRATION

We present some numerical examples to illustrate the theoretical results obtained in the previous sections. We are interested in the effects of the system's parameters on the coordination mechanism. In the following examples, we assume the values of the parameters of the system for the operations as $C_S = 300$, $C_R = 100$, $R_T = 30$, $h_s = 1$, $h_R = 2$, $D = 500$, $Y_T = 25$, $P_T = 5$, and $P_S = 40$. Applying equation (7), we obtain $n = 1.73$ and because the number of deliveries has to be an integer, we have $n = 2$. Substituting all system parameters, along with $n = 2$ respectively, into equation (6), gives the optimal quantity $q_{SR}, = 866$. Therefore, the optimal solution for the average long-run cost $\left[TG_{SR}(q_{SR}, n_{SR})\right]$ in equation (4) is given by $(q_{SR}, n_{SR}) = (866,\ 2)$. The corresponding optimal cost is obtained by substituting the value of (q_{SR}, n_{SR}) in equation (4) to obtain $E\left[TG_{SR}(q_{SR}, n_{SR})\right] = 64953857$. Thus, for the minimum cost, we find that the optimal solution for the average long-run cost is (866, 2) at a long-run average cost of 64953857.

Keeping the quantity and other parameters constant, the long-run average cost function for variable values of n is depicted in Table 1. The analysis of variation of average long-run cost with positive integer n of the transportation cost of the supplier-retailer shows that as the value of n increases the long-run average cost decreases (Table 1 and Fig. 1).

Table 1: Long-run average cost for variable values of n with constant q

N	$\left[TG_{SR}(q_{SR}, n_{SR})\right]$
1	129903424
2	64953857
3	43304290
4	32479723
5	25985156
6	21655589
7	18563165
8	16243955
9	14440221
10	12997321

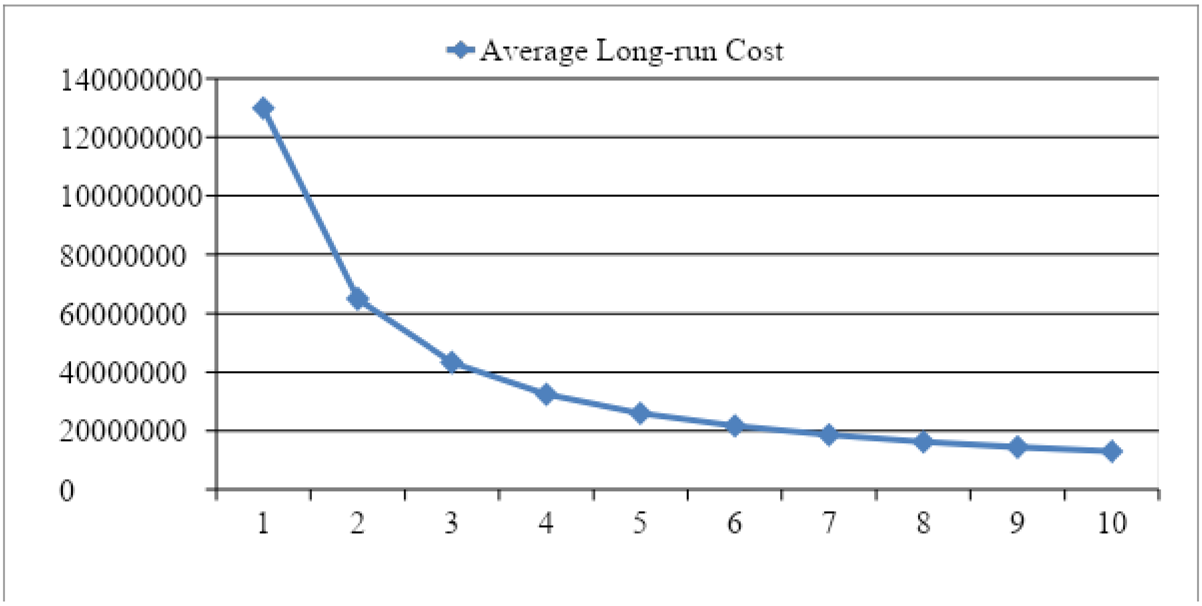

Figure 1: Variation of average long-run cost with positive integer

From equations (9) and (10), if the supplier incurs the transportation charges, the optimal ordering quantity of the retailer from equation (10) is $q = 224$ while the retailer annual cost from equation (9) given the initial wholesale price, $P_S(q) = P_S q$, is 20447. If the retailer incurs the transportation charges given the same optimal ordering quantity $q = 224$, the initial wholesale price $P_S(q) = P_S q$, the retailer's annual cost is 20458.

From the value above, the annual cost (with the same optimal ordering quantity, q) is higher when the retailer incurs the transportation cost than when the supplier incurs the transportation cost. Since our aim is to minimize cost in other to maximize profit, it is preferable for the supplier to incur the transportation charges.

Conflict of interest

The authors declare that they have no conflict of interest

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