

# A Buyer Vendor Coordination Model

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**Abstract.** The research in this paper develops the model for buyer vendor coordination. The developed model is motivated by the real situation of an Original Equipment Manufacturers (OEMs) that supply component automotive industry, repair shop, and automotive dealer (Single Vendor Multiple Buyers) in Indonesia. The fact we got from the case study we observed is that the joint economic lot sizing problem is no longer applicable. This is due to the fact that automotive industry as the buyer operates in Just in Time Environment and has higher bargaining power. Therefore, the OEM has to produce as it is required by the automotive industry. In other side in order fulfill the demand for repair shop and automotive dealer, the vendor do demand consolidation before determining when they have to start production and how many product they have to produce. Based on the case study that we observed, in order for the vendor to meet the target profit, they have to decide about the selling price of the product to be sold for automotive industry, repair shop and automotive dealer. Therefore, the model developed in this paper is trying to answer about the selling price of the product to each type of buyer. Numerical example to show the applicability of the model is shown. In term of managerial implication, the research in this paper can be used by the company as a basis for decision purchasing contract with their buyers.

**Keywords:** Buyer Vendor Coordination, JIT Environment, Purchasing Contract, OEM, Selling Price

## 1. INTRODUCTION

The research in this paper is motivated by the result on an observation in a spare part manufacturer (vendor) that supply its product to automotive manufacturer (buyer) where the automotive manufacturer operates under Just-in-Time environment. This vendor also performs as an OEM where they supply the product to the dealer and repair shop. Their buyers can be divided in to two: 1) automotive manufacturers (1st buyer); 2) dealer (2nd buyer); 3) repair shop (3rd buyer). Based on the information that has been given by the vendor during the observation, it is known that one of their buyers which is 1st buyer operates in Just-in-Time environment. In this situation, the vendor's production lot size is following the requested demand from

the buyer. In addition, the vendor has to deliver the product in small quantities to minimize the buyer's holding cost. This result is actually in line with Khan and Sarker (2002) and Wang (2010) have been stated which is "in Just-in-Time (JIT) environment the buyer prefers to have frequent delivery of small quantities of items by the vendor". David and Eben-Chaime (2003) has also stated that in pull production management system such as JIT, the delivery of the product to the buyer has to be as requested. Therefore, according to David and Eben-Chaime (2003), it is uneconomical. Especially when the vendor is trying to have more buffer to response the demand quickly, unless the vendor is applying lean manufacturing concept to be more responsive. Kelle and Miller (1998) also stated that in JIT environment, the situation where the buyer prefers to have

small lot size and frequent shipment is called as buyer's dominance. Early researches on determining lot size in JIT manufacturing were conducted by Pan Liao (1989) and Ramasesh (1990). However, the coordination between buyer and vendor was not discussed yet in their research.

For the case of spare part manufacturer that has been mentioned above, the make-to-order contract is implemented to the 2nd buyer and 3rd buyer. It is noted that according to the information from the company it is known that the price offered to the 1st buyer is greater than the price offered to the 2nd buyer or the 3rd buyer. The reason is that for the 2nd and the 3rd buyer, the vendor can do demand consolidation of one dealer to other dealer and also from one repair shop to other repair shop until the quantity reach its economic production quantity.

Ideally, the decision related to the delivery quantity has to be discussed between supplier and buyer or it is called as buyer-vendor coordination. Sarmah et al. (2006) categorized the coordination model in to four. One of them which will be the focus on the research in this paper is vendor's perspective coordination model or it called as decentralized model Toptal and Çetinkaya (2008). This model is trying to maximize vendor's profit through either by:

1. Producing with different lot size policy by giving incentive to the buyer such as vendor offering quantity discount (Banerjee, 1986a). Other research was conducted by Lee and Rosenblatt (1986) who conducted the research on integrated inventory model by assuming that in order to maximize the vendor's yearly net profit, the vendor adopted the KQ policy. KQ is the buyer order quantity, where K is the integer number to reach the optimality from the vendor's point of view. Banerjee (2005) conducted the research to determine the lot sizing for make-to-order contract production and selling price concurrently in order to achieve the targeted profit.
2. Producing on lot for lot policy which this policy is usually found where the buyer operates in JIT environment. The pioneer of the researches related to buyer coordination in JIT environment such as Monahan (1984) by assuming that the vendor operates on lot for lot policy. Other research was also be conducted by Banerjee (1986b) who proposed a pricing model for vendor's perspective to increase the profit of the vendor. This situation is motivated by situation that if the vendor has to follow the lot's size given by the buyer, then the vendor has to find pricing strategy so that they can reach their target profit.

The opposite of decentralized model is centralized model where buyer and vendor determined the lot-size together. However, this approach somewhat is not desirable to implement as each member has its own interest (Toptal

and Çetinkaya, 2008). The motivation why the research presented in this paper is considering buyer-vendor coordination model from the vendor's perspective (decentralized model) is that from the observation that was conducted in spring manufacturer as a vendor that supply their product to automotive manufacturers (buyer) that operate in Just in Time environment where the decision regarding the lot size is determined by the buyer. This fact confirm of what Toptal and Çetinkaya (2008) has been stated which is "centralized model may not be feasible or desirable in many practical cases due to incentive conflict." In term of supply chain management perspective, the buyer vendor coordination is an enabler for improving the system profit (Li and Wang, 2007; Wo et al., 2001). In the research conducted by Sarmah et al. (2007), it is stated that each member in the supply chain have their own target profit and coordination will be interested if it helps each member to reach their target. Therefore, for decentralized model, especially where the buyer operates in Just in Time environment, as the vendor, they have to find a way in order to make them reach the target profit. Therefore, the decision related how much is the selling price of the product need to be determined.

The research in this paper is then proposed the model to determine the selling price of the vendor so that it can be used as the consideration before they are making document contract agreement between vendor-buyer. The sensitivity analysis will also be conducted in order to give a deep insight on how the effect on the changing of the margin profit to their profit.

This paper is organized as follows. Following the introduction, the mathematical formulation will be explained. After the mathematical formulation is explained the numerical example to illustrate the applicability of the model is given. Finally, conclusions are drawn.

## 2. MATHEMATICAL MODEL

This paper considers the problem in an OEM manufacturer that supply its products to: 1) an automotive manufacturer; 2) automotive dealers; 3) repair shops as it can be shown in figure 1.

The Original Equipment Manufacturer (OEM) receives order from automotive manufacturer (1<sup>st</sup> buyer) in the rate of  $D_1$  units per time period and the order has to be delivered in the lot of  $Q_1$  units. In addition, OEM also receives orders from dealers (2<sup>nd</sup> buyer) and repair shop (3<sup>rd</sup> buyer). The demand from the 2<sup>nd</sup> buyer and repair shop 3<sup>rd</sup> buyer can be consolidated with rate of  $D_2$  units per time period.

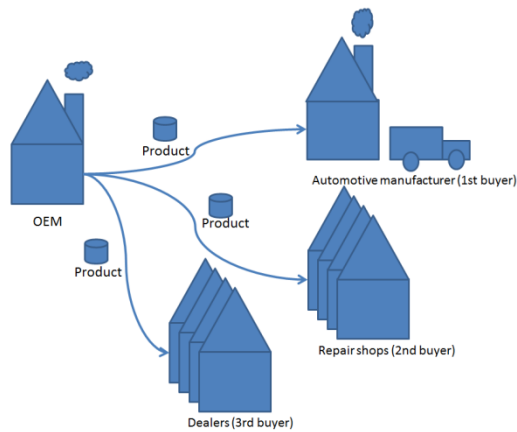


Figure 1. Problem Illustration

The OEM produce with 2 separated production lot as it can be seen in figure 2 by assuming that:

$$T_2 = nT_1 \quad (1)$$

Subject to:

$$\tau_1 + \tau_2 \leq T_1 \quad (2)$$

where

$n =$  integer,

$\tau_1 =$  production up time for fulfilling demand from 1<sup>st</sup> buyer,

$\tau_2 =$  production up time for fulfilling demand from 2<sup>nd</sup> buyer and 3<sup>rd</sup> buyer.

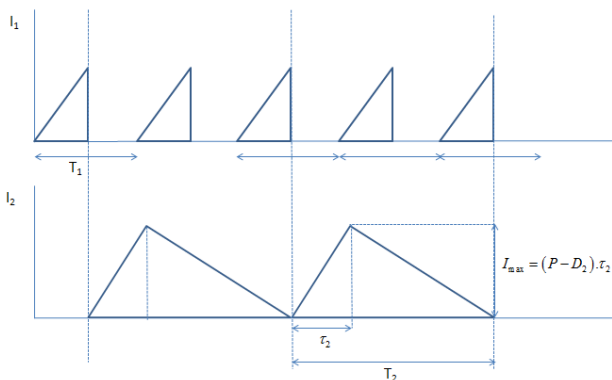


Figure 2. Inventory level of finished product at vendor

In line with JIT principles, i.e. to minimize the buyer's total inventory cost, the value of  $Q_1$  is the economic order quantity (EOQ) from the standpoint of the buyer. To meet the 1<sup>st</sup> buyer's demand, the vendor produces the part in a

batch of  $Q_1$  at a rate of  $P$  units per time. Lot-for-lot shipment is applied here, in which a batch of parts is shipped to the buyer once it is finished. However, this situation is not applied for the demand from the 2<sup>nd</sup> and 3<sup>rd</sup> buyers, in which not in a JIT environment. Therefore, the vendor is free to decide the value of  $Q_2$ .

Total cost for producing the product for the 1<sup>st</sup> buyer is then expressed by  $TC_1$  while total cost for production the product for the 2<sup>nd</sup> buyer and the 3<sup>rd</sup> buyer is expressed as  $TC_2$ . It is noted the value of  $TC_1$  and  $TC_2$  affect the cost of goods sold of the product price. Since  $TC_1$  and  $TC_2$  most probably different due to different operational setting, then the company can set different selling price to each buyer.

Notation:

$D_1 =$  demand parts for the 1<sup>st</sup> buyer, units/time

$D_2 =$  demand parts for the 2<sup>nd</sup> buyer and 3<sup>rd</sup> buyer, units/time

$Q_1 =$  production lot size for the 1<sup>st</sup> buyer, units

$Q_2 =$  production lot size for the 2<sup>nd</sup> and 3<sup>rd</sup> buyers, units

$P =$  vendor's production rate for fulfilling the demand, units/time

$S_1 =$  1<sup>st</sup> buyer's unit setup cost, \$

$S_v =$  vendor's unit setup cost, \$

$h_1 =$  1<sup>st</sup> buyer's unit holding cost, \$/unit/time

$h_v =$  vendor's unit holding cost, \$/unit/time

$C_1 =$  vendor's unit selling price for 1<sup>st</sup> buyer, \$/unit

$C_2 =$  vendor's unit selling price for 2<sup>nd</sup> buyer and 3<sup>rd</sup> buyer, \$/unit

$C_v =$  vendor's unit production cost, \$

$\tau_1 =$  production up time for fulfilling the demand from the 1<sup>st</sup> buyer

$\tau_2 =$  production up time for fulfilling the demand from the 2<sup>nd</sup> buyer and 3<sup>rd</sup> buyer

$M_1 =$  cost of goods sold for the product that has to be sold for 1<sup>st</sup> buyer

$M_2 =$  cost of goods sold for the product that has to be sold for 2<sup>nd</sup> buyer

As a buyer, the decision related to how many order that have to be ordered from the vendor is affected by the selling price  $C_1$  offered by the vendor. Therefore, the  $Q_1$

where it represents optimal quantity from buyer's perspective can be calculated using their Economic Order Quantity. The cost components that make up the total cost of the buyer includes purchasing cost, ordering cost, and inventory cost. The expression of total cost is the same as the model described by Banerjee (1986) as follows:

$$TC_{1B} = D.C_1 + \frac{D}{Q_1}.S_1 + \frac{Q_1}{2}.h_1.C_1 \quad (3)$$

Therefore to find Economic Order Quantity then we take the first derivative of  $TC_{1B}$  with respect to  $Q_1$  as follows:

$$\begin{aligned} \frac{dTC_{1B}(Q_1)}{dQ_1} &= \frac{h_1.C_1}{2} - \frac{D.S_1}{Q_1^2} \\ Q_1^* &= \sqrt{\frac{2.D.S_1}{h_1.C_1}} \end{aligned} \quad (4)$$

Related to Figure 2, the cycle time to production process to fulfill the demand for product 1 can be expressed as:

$$T_1 = \frac{Q_1^*}{D_1} \quad (5)$$

The expression of formula (1) is then can be written as

$$T_2 = n \frac{Q_1^*}{D_1} \quad (6)$$

As  $T_2 = \frac{Q_2}{D_2}$ , therefore  $Q_2$  can be expressed as

$$Q_2 = n \frac{Q_1^*}{D_1}.D_2 \quad (7)$$

The total cost for producing the product to fulfill the demand from the 2<sup>nd</sup> buyer and 3<sup>rd</sup> buyer is then can be expressed as:

$$TC_2 = \frac{D_2}{n.Q_1^*} \frac{1}{D_2/D_1}.K + \frac{1}{2}.T_2.I_{\max}.h \quad (8)$$

$$= \frac{D_1.K}{n.Q_1^*} + \frac{1}{2}.n.\frac{Q_1^*}{D_1}.(P-D_2)n.\frac{Q_1^*D_2/D_1}{P}.h \quad (9)$$

$$= \frac{D_1K}{n.Q_1^*} + \frac{1}{2}n^2.\frac{Q_1^{*2}}{D_1^2}.\frac{D_2}{P}(P-D_2).h \quad (10)$$

Substituting Eq. (4) to Eq. (10) we have the expression:

$$= \frac{D_1K}{n} \sqrt{\frac{h_1C_1}{2D_1S_1}} + \frac{1}{2}n^2.\frac{2S_1}{h_1C_1}.\frac{1}{D_1}.\frac{D_2}{P}(P-D_2).h \quad (11)$$

Therefore to find the optimal value of  $n$ , then the minimization problem is solved with the objective function and constraint as follows:

$$\min \quad TC_2 = \frac{D_1K}{n} \sqrt{\frac{h_1C_1}{2D_1S_1}} + \frac{1}{2}n^2.\frac{2S_1}{h_1C_1}.\frac{1}{D_1}.\frac{D_2}{P}(P-D_2).h$$

s.t

$$\Leftrightarrow \frac{Q_1^*}{P} + \frac{n.Q_1^*.D_2/D_1}{P} \leq \frac{Q_1}{D_1}$$

$$\Leftrightarrow \frac{Q_1^* + n.Q_1^*.D_2/D_1}{P} \leq \frac{Q_1}{D_1}$$

$$\Leftrightarrow Q_1^* + n.Q_1^*.\frac{D_2}{D_1} \leq \frac{Q_1}{D_1}.P$$

$$\Leftrightarrow n \leq \frac{D_1}{D_2} \left( \frac{P}{D_1} - 1 \right) \quad (12)$$

As according to the case study considered in the research of this paper, the vendor (OEM manufacturer) has to incorporate the different value of lot size to accommodate the different type of buyer, then the vendor has to find the selling price that has to be offered for different type of buyer in such a way that the vendor's target profit can be achieved. This situation is actually different of the idea of joint economic lot size problem, where the idea is how to determine the lot size that can minimize the total system cost (both buyer and vendor).

Given,

$$M_1 = C_v + \frac{TC_1}{D_1} \quad (13)$$

$$M_2 = C_v + \frac{TC_2}{D_2} \quad (14)$$

Therefore vendor's target profit can be expressed as:

$$\pi = \frac{D_1(C_1 - M_1) + D_2(C_2 - M_2)}{D_1M_1 + D_2M_2} \quad (15)$$

This target profit is actually a performance that have to be achieved by the company by determining the selling price.

### 3. NUMERICAL EXAMPLE

A numerical example represent the real situation when the vendor produce the spare part that has longer end-of-life.

$$D_1 = 10,000 \text{ units/year}$$

$$D_2 = 1,000 \text{ units/year}$$

$$P = 20,000 \text{ units/year}$$

$$S_1 = 50\$$$

$$S_v = 500 \$$$

$$h_1 = 10\% \$/\$ \text{ inventory}$$

$$h_v = 10\% \$/\$ \text{ inventory}$$

$$C_v = 70 \$$$

Suppose, the vendor offer to the first buyer  $C_1=87 \$$  in order to obtain target profit 20%. Therefore, following formula (4) and (6) one can obtain:  $Q_1^* = 339.03$  units and  $TC_1 = \$ 15341.19/\text{year}$ .

Then,  $TC_2$  as a minimization problem for determining  $n$  can be solved using enumerative method, by boundary on formula (12)

$$n \leq \frac{D_1}{D_2} \left( \frac{P}{D_1} - 1 \right)$$

$$n \leq \frac{10000}{1000} \left( \frac{20000}{10000} - 1 \right)$$

$$n \leq 10$$

The relationship between  $n$  and  $TC_2$  in this case can be presented in the following Table. It is noted that although the smallest  $TC_2$  found is \$ 2580.73 at  $n = 11$ , the optimal  $n$  that satisfying the boundary is  $n^* = 10$  with  $TC_2 = \$ 2602.07$ .

Table 1: Result of  $TC_2$  on various  $n$

$n$	$TC_2$	$n$	$TC_2$
1	14860.61	8	2745.31
2	7599.40	9	2653.21
3	5254.14	10	2602.07
4	4137.88	11	2580.73
5	3513.22	12	2581.73
6	3134.35	13	2599.92
7	2895.94	14	2631.61

Utilizing formula (15), one can obtain that offering the second and third buyers with  $C_2 = \$80/\text{unit}$  the target profit 20% is already achieved, since

$$M_1 = 70 + \frac{15341.19}{10000} = 71.53$$

$$M_2 = 70 + \frac{2602.07}{1000} = 72.60$$

$$\pi = \frac{10000(87 - 71.53) + 1000(80 - 72.60)}{10000 \cdot 71.53 + 1000 \cdot 72.60} = 0.2056$$

#### 4. CONCLUDING REMARK

The research presented here are mainly about the buyer vendor coordination for an OEM manufacturer that support the component to manufacturer. The decision variable in the research presented here is the selling price of the product provided by the vendor to each type of buyer. Using this value, the vendor can used it as the consideration before making a purchasing contract, i.e. during the negotiations phase between supplier and buyer.

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