

### **Supplier–customer negotiation model: the vendor receives a bonus for holding the inventory**

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#### **ABSTRACT**

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This article proposes a model based on economic order quantity (EOQ) for the negotiation between supplier and customer when a benefit is derived to the supplier from taking responsibility for the inventory holding costs. In turn, the customer can afford a smaller batch size since the holding savings enable it to place a greater number of orders.

Taking the original situation in which the customer supports both holding and ordering cost as an initial point, the paper analyses the benefits for the supplier and customer in a new situation in which the supplier supports the holding of the inventory. The customer would agree to change to the new scenario due to the savings in the holding cost. The provider would also agree if a bonus is achieved as compensation for the investment in holding costs.

The model provides clues for a win-win negotiation between a supplier and a buyer.

#### **KEYWORDS**

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Inventory costs; optimal batch; EOQ model; inventory management model.

## **1. Introduction**

The first models of inventory system management were published at the beginning of the last century. Their purpose was to minimize the overall inventory management costs. Harris (1913) developed one of these early pioneering models, known as the economic order quantity (EOQ) model, which still enjoys great popularity. This model and extensions of it were collected together in the book “Quantity and Economy in Manufacture”, published by Raymond in 1931. Years later, Whitin (1953) proposed a significantly revised approach in “The Theory of Inventory Management” and in “Inventory control research: a survey”, published in 1953 and 1954, respectively.

Since then a large number of proposals have appeared, designed to deal with special situations or needs arising from the current context. The model assumes that all the costs are charged to the customer and optimizes the total inventory management costs. More recently some adaptations that take both points of view (customer and supplier) into account have been published. For example, Yang et al. (2007) commented on the current requirement for the economic order quantity (EOQ) to be attuned to the economic production quantity (EPQ) to combine both manufacturers’ and suppliers’ best interests. Gümüs et al. (2008) provided another approach, seeking a win-win relationship between the customer and the supplier by finding a point of equilibrium between the inventory managed by the latter (the vendor-managed inventory, or VMI) and the quantity required by the former. Yadollahi et al. (2017) proposed deterministic models strive to optimize the safety stock levels in line with the planned service levels at the retailers. Toptal & Çetinkaya (2015) examined the optimal length of the selling period in the context of a novel inventory replenishment problem faced by a supplier of a new, trendy, and relatively expensive product with a short life.

Against this background, Marimon & Llach (2013) proposed a model that provides clues to conducting the negotiation about the lot size in a win-win environment between a supplier and a buyer in the particular situation in which the vendor provides a reward when an order is placed. The fundamental assumption is that the responsibility for the entire process of inventory replacement is taken by the supplier instead of the customer. There is a complementary situation to the previous one, which occurs when the holding cost is supported by the vendor and the customer only pays for each order placed. This situation is very common nowadays, since, in the middle of the last century, the advantages of decreasing the batch size order quantity were spread all across the world

through paradigms such as just in time, lean production or agile production (Chapman & Carter, 1990; Thomas & Griffin, 1996; Maloni & Benton, 1997). Particularly, this practice has spread throughout the automotive industry, in which the relationship between a supplier and an assembler is based on long-term agreements established in a win-win negotiation (Dyer, 1996; Holweg, 2007). The provider receives a bonus that vouches for the investments that this kind of contract requires (e.g., a long-term contract with stable conditions in terms of price, quality and quantities). In these cases a common supplier strategy is to move the inventories near to the assembly line (this is the investment required). Therefore, the holding cost is transferred from the customer to the supplier. It allows the replenishment frequency to increase; consequently, the batch size decreases. Moreover, the smoothing of the material flow allows an improvement of the supplying service in terms of reliability and the strength of the relationship between the supplier and the assembler.

There are more situations to which the model can be applied. Its application will be feasible when the supplier finds other benefits from holding the inventory of its customers (e.g., having a better understanding of the final consumer due to the fact that the supplier controls and monitors the demand evolution and obtaining valuable information on its final market).

The aim of this paper is to propose a model to establish a batch size policy that enables negotiation in a win-win agreement between a supplier and a customer. In this agreement the holding inventory cost is the responsibility of the provider, which in return obtains a bonus or premium.

To accomplish this aim, we present two different scenarios:

- Scenario “1” is the original EOQ situation in which both holding and ordering costs are supported by the client (it is analysed in the second section of the paper).
- Scenario “2” is the situation in which the holding cost is supported by the supplier, which is willing to pay for it due to an extra annual benefit or annual bonus (B) that it obtains. This scenario is analysed in the third section.

Scenario “1” is used as a baseline to compare with the situation after the agreement (scenario “2”) and to assess the incremental benefit that the two actors obtain in the agreement, changing the initial batch size replenishment policy for another batch size policy. This comparison is made in the fourth section, which provides the conditions that have to be accomplished to reach the agreement between supplier and customer. The fifth

section reviews the model through a practical example that helps to provide an understanding of the rationale behind the analysis proposed. Finally, some conclusions are drawn.

## **2. Scenario “1”: the basic model of economic order quantity (EOQ)**

This is the original scenario for the EOQ (Harris, 1913), in which the client is responsible for both costs: ordering and holding. The model involves the following parameters:

- D: Annual demand
- e: Cost of placing an order
- i: Holding cost (measured as a percentage)
- v: Purchasing cost (per unit)

In his original version, Harris (1913) only analysed two types of costs: holding and ordering costs. In this way the function of the total annual costs is obtained in the function of the batch size (Q). The optimal quantity that minimizes the total annual management inventory cost is

$$Q_1 = \sqrt{\frac{2De}{iv}}$$

(1)

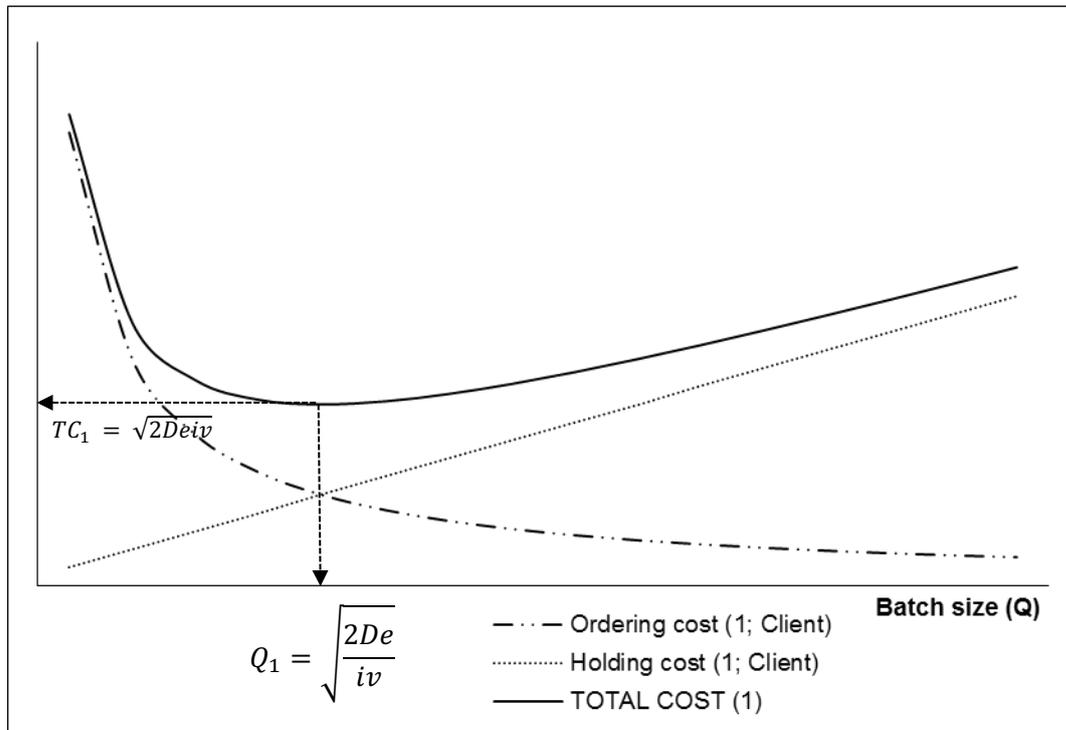
in which the subscript “1” refers to scenario 1. In this case the total cost payable by the customer is

$$TC_1 = \sqrt{2Deiv}$$

(2)

wherein, again, the subscript “1” means scenario 1.

Figure 1 shows the composed total cost (adding the annual holding cost and annual ordering cost) payable by the customer. There is no reference to the supplier in this first scenario.



**Figure 1.** Inventory costs as a function of the batch size in scenario “1”.

Number “1” in the legend means scenario “1”, and “Client” means that the cost is charged to the client. In this scenario the word “Supplier” does not appear.

### 3. Scenario “2”: the holding cost is supported by the supplier.

In scenario “2” the holding cost is supported by the supplier; as compensation, the supplier receives an extra annual bonus B.

Some assumptions are proposed:

- The ordering cost remains invariant across the two scenarios. This is very likely, because nothing relevant has changed in scenario “2” that might suggest a modification of this.
- The unit annual holding cost remains the same in the two scenarios. This is also quite reasonable to assume due to the fact that the associated cost of managing the inventory depends intensively on the nature of the product.
- The annual bonus B achieved will remain invariant to the batch size.

First, the analysis that the customer performs to assess the decision on whether to accept the agreement is shown in the first subsection. Second, a parallel analysis from the supplier perspective is discussed (second subsection). Finally (third subsection), the

confrontation of the two views offers the conditions that guarantee both actors a better situation in scenario “2”, allowing an agreement to be reached.

The first and second subsections analyse how each actor (supplier and customer) achieves a better position in scenario “2”. In addition, the overall situation in “2” is better than the original scenario “1”: the global cost is lower in “2”. In other words, the *status quo* of scenario 2 generates a benefit (B) that appears due to the new kind of relationship established between the two partners.

### 3.1. The customer view

The customer will accept a new scenario if its total cost (TC) in the new situation (scenario “2”) is lower than that in the current situation (scenario “1”). Note that the first subscript refers to the scenario (“1” or “2”) and the second to the actor (customer or supplier). Note also that the net cash flow for the customer is the total cost.

The subscript “customer” is redundant in the original situation, since all the costs are payable by the customer. Nevertheless, we keep both subscripts to be consistent with the notation used for scenario “2”.

$$TC_{1, \text{Customer}} > TC_{2, \text{Customer}}$$

(3)

$$\sqrt{2Deiv} > TC_{2, \text{Customer}}$$

(4)

Due to the fact that the only cost for the customer is the holding cost,

$$\sqrt{2Deiv} > \frac{D}{Q_{2, \text{Customer}}} e$$

(5)

Operating, it is found that

$$Q_{2, \text{Customer}} > \frac{1}{2} \sqrt{\frac{2De}{iv}}$$

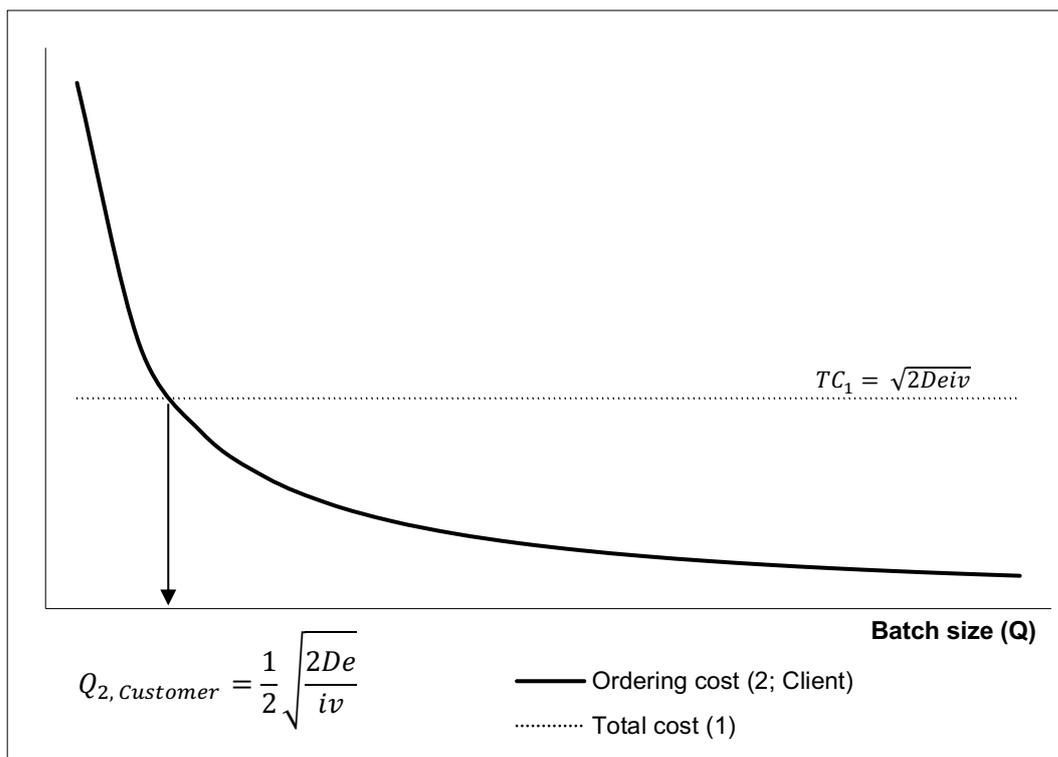
(6)

In turn, it implies that

$$Q_{2, \text{Customer}} > \frac{1}{2} Q_1$$

(7)

The customer will agree to change to the new scenario if the new batch size is greater than half the size in the original scenario. This condition provides the minimum batch size and is imposed by the customer. In other words, the customer will be able to place at least twice the number of orders that it was placing in scenario “1”. The savings on the holding cost compensate for the higher costs of ordering.



**Figure 2.** Ordering costs for the customer in scenario “2”.

The figure shows the dotted line of the total cost of the previous scenario (scenario “1”). The inventory costs were completely supported by the client. This is the acceptable threshold for the customer to change its current situation, and it yields the minimum batch affordable for the customer in the hypothetical scenario “2”.

### *3.2. Supplier view*

This subsection analyses the supplier decision: accepting scenario “2” or remaining in the original situation. The baseline is scenario A again, in which no costs are payable by the provider. In the new situation (scenario “2”), the supplier holds the stock, but in return it receives an annual bonus B. In this case the starting point for the negotiation of scenario “2” will be a nil net cash flow (CF). We need to talk about the net cash flow and not only the costs, since the supplier receives positive contributions to the cash flow (the bonus) and negative contributions (costs). Therefore, the necessary condition imposed by the supplier is:

$$CF_{1,Supplier} < CF_{2,Supplier}$$

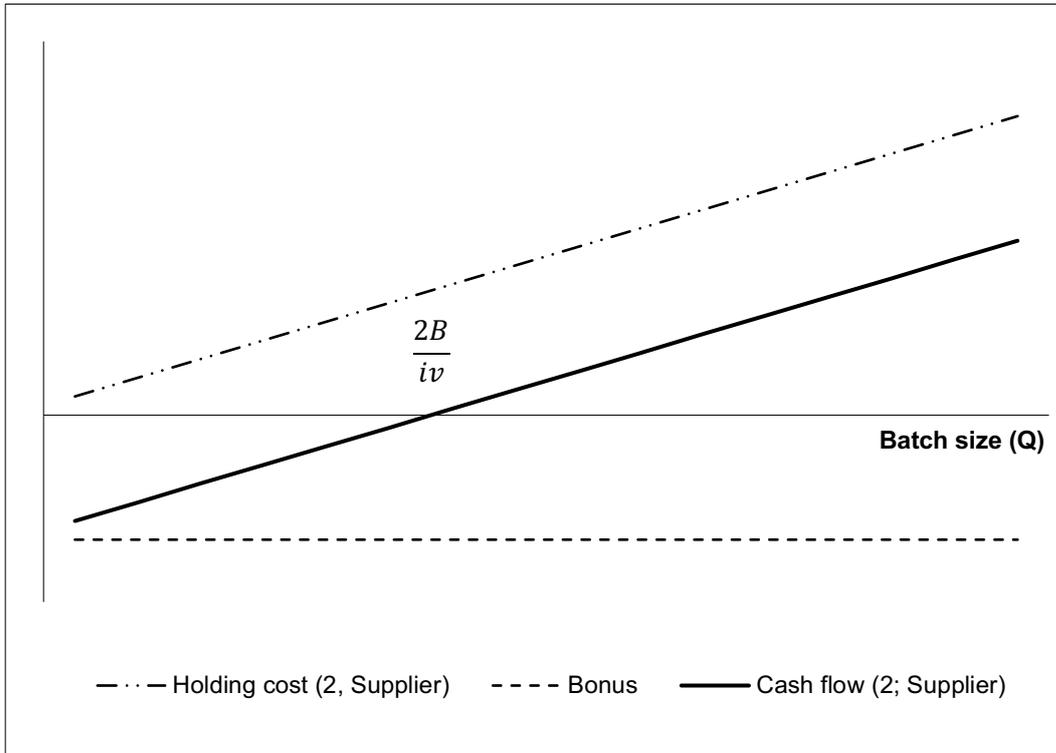
(8)

$$0 < B - \frac{Q_{2,Supplier}}{2} iv$$

(9)

$$Q_{2,Supplier} < \frac{2B}{iv}$$

(10)



**Figure 3.** Holding cost, bonus and cash flow for the supplier in scenario “2”.

Following our notation, number “2” in the legend of Figure 2 means scenario “2” and “Supplier” means that the cost is charged to the supplier. In this scenario the word “Client” does not appear.

The supplier will agree to accept the new scenario when the batch size is less than  $2B/iv$ , which is just the size that makes the holding cost minus the bonus equal to zero (this is, the total net cash flow equal to zero). This is shown in Figure 3 at the point at which the net cash flow cuts the threshold of zero. This condition is imposed by the supplier and establishes the maximum batch size.

#### 4. Comparison of the two scenarios.

Table 1 summarizes the analysis of both the client and the provider in terms of costs, total cash flow and batch size. For scenario “1” only one column is needed, since the supplier is not considered. The notation uses one subscript for the batch size variable (“1” or “2” referring to the scenario). Scenario “2” is composed of two columns. One summarizes the analysis from the customer view and establishes the minimum batch size, whereas the other summarizes the supplier view establishing the maximum batch size.

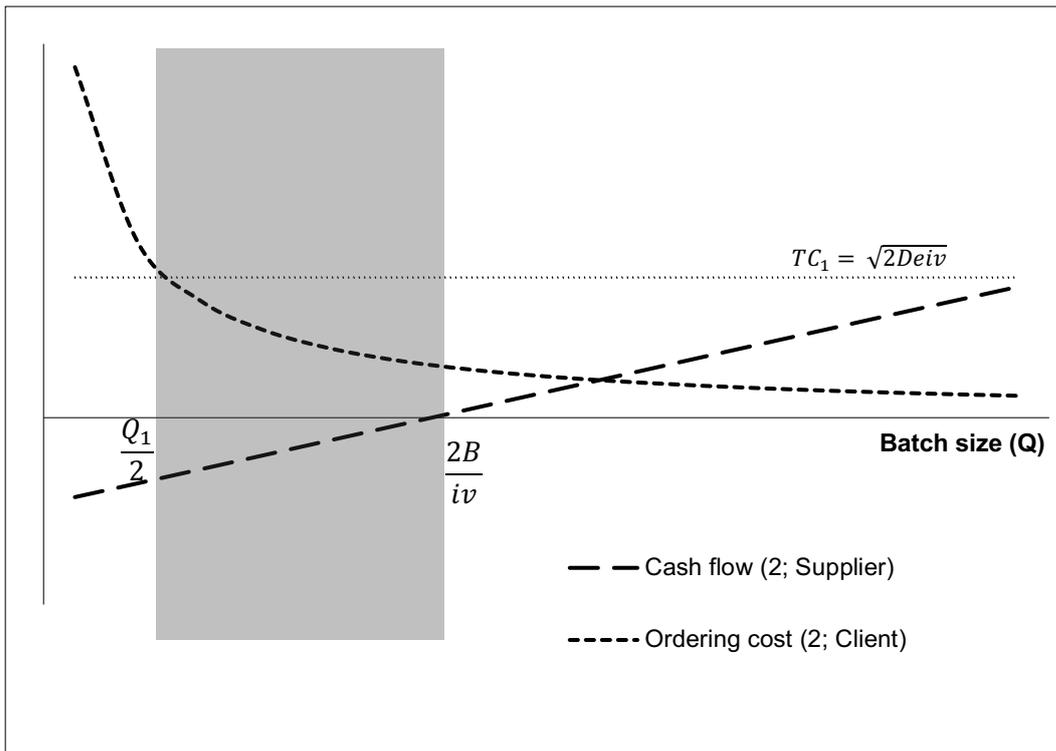
	Scenario 1	Scenario 2	
	Client	Client	Supplier
Holding cost	$\frac{Q_1}{2}iv = \frac{1}{2}\sqrt{2Deiv}$	0	$\frac{Q_2}{2}iv$
Ordering cost	$\frac{D}{Q_1}e = \frac{1}{2}\sqrt{2Deiv}$	$\frac{D}{Q_2}e$	0
Total cost	$\sqrt{2Deiv}$	$\frac{D}{Q_2}e$	$\frac{Q_2}{2}iv$
Cash flow	$-\sqrt{2Deiv}$	$-\frac{D}{Q_2}e$	$B - \frac{Q_2}{2}iv$
Batch size	$Q_1 = \sqrt{\frac{2De}{iv}}$	$Q_2 > \frac{1}{2}Q_1$	$Q_2 < \frac{2B}{iv}$

**Table 1.** Costs and batch sizes for the two scenarios considered.

To make the negotiation possible, both actors need to reach a better situation after the agreement: their respective cash flows in scenario “2” should be greater than those in scenario “1”. The customer needs a batch greater than  $Q_1/2$  and the supplier a value below  $2B/iv$ . Thereafter, the necessary condition to start a negotiation is:

$$\frac{Q_1}{2} < Q < \frac{2B}{iv}$$

(11)



**Figure 4.** Area of feasible negotiation.

Let us analyse the minimum value of B that makes the negotiation feasible. This will happen when this area is so narrow that it is reduced to a vertical line.

$$\frac{Q_1}{2} = \frac{2B}{iv}$$

(12)

$$B = \frac{1}{4} Q_1 iv$$

(13)

$$B = \frac{iv}{4} \sqrt{\frac{2De}{iv}}$$

(14)

$$B = \frac{1}{4} \sqrt{2Deiv}$$

(15)

$$B = \frac{1}{4} CT_1$$

(16)

The minimum bonus B that the supplier needs to assume the holding cost of the inventory is a quarter of the total cost that in scenario “1” was the responsibility of the customer. To make it feasible, a reward or bonus B for the supplier is required when scenario “2” is considered. This bonus first makes it worthwhile for the supplier to support the holding cost and second allows the client to increase its ordering cost, keeping the total inventory cost lower than in the original situation in scenario “1”.

As suggested, this bonus is the benefit for the supplier in terms of a larger and stable term agreement, more favourable price conditions, frequency of replacement, cooperation in product development, sharing information or other kinds of conditions. Lee et al. (2004) analyse some results of the cooperation between clients and providers that can be components of this bonus (e.g., improving the forecasting accuracy, increasing the information available as a result of sharing systems between purchaser and provider, etc.)

## **5. Practical example**

To facilitate the comprehension of the model, we show below an example of a situation in which the customer orders batches from the supplier of a size suggested by the economic batch formula proposed by Harris (1913). Assume that the annual demand ( $D$ ) is 120 units, the ordering cost ( $e$ ) is €3,000 and the unit cost of the component ( $v$ ) is €5,000. In addition, the storage cost ( $i$ ) is 25% per year. With these parameters, the customer orders 5 batches of 24 units each from its supplier during the course of the year. In this way both the annual cost of placing orders (5 batches \* €3,000 each batch) and the cost of storing the stock (12 storage units \* €5,000/unit \* 0.25) are €15,000: thus, €30,000 in total.

At this point the supplier offers the customer a change in the inventory provisioning strategy, proposing to supply from an idle installation owned by the supplier contiguous to the customer location. Accordingly, the inventory will be managed by the supplier and the customer will receive any order placed immediately, without any delivery time. From the practical point of view, it means that from now on the holding cost will be supported by the supplier. In consideration, the customer will assure a long-term contract and other benefits that the supplier estimates to amount to €20,000 per year. These benefits (bonus) include issues such as shared information about the product, about the market and even about technology.

On the basis of this information, the customer calculates how many orders could be placed with the original €30,000 (the total cost that supports scenario “1”). The maximum number of orders that it can afford is 10, implying that the minimum batch size is 12 units. On the other hand, the supplier also undertakes an analysis. Due to the fact that the supplier does not incur any cost in the current situation, it will agree to the new contract (scenario “2”) if the net cash flow is greater than zero. In other words, the holding cost that it now supports must be lower than the bonus “B” (€20,000). The average stock that it will be able to hold is 16 units (16 units \* €5,000 \* 0.25 = €20,000). Therefore, the maximum batch size is 32 units.

Therefore, the agreement is feasible, establishing a new batch size policy between 12 and 32 units. Within these limits both agents achieve a better position than in the initial or current situation. The second practical conclusion drawn from this case is that the minimum bonus that makes the agreement feasible for the supplier is €7,500 (€30,000 / 4), according to expression (16). If the bonus is less than that, the provider cannot be

compensated for the holding cost in the worst situation from its point of view (when the batch size is 32 units).

## **6. Conclusion**

A new model that provides the framework for an agreement between a customer and a supplier is proposed that leads to the establishment of a new batch size in the replenishment policy. The model provides the necessary condition that has to be achieved to guarantee the agreement that allows the initial or original size batch used, in which the customer takes charge of all the inventory costs (i.e., holding and ordering costs), to be changed to a new batch size policy in which the holding cost is supported entirely by the supplier. If the necessary condition is accomplished (the customer needs a batch greater than half the initial size batch and the supplier a value below  $2B/iv$ ), then the agreement is possible, resulting in a better situation for both the customer and the supplier in terms of the inventory cost.

Therefore, the model proposes a batch size interval in which the agreement is possible. Another question concerns the relative power of the two actors in this plot. When the power of the provider and the buyer is unbalanced, the negotiation will end up near an extreme.

The paper also analyses the minimum amount for the annual bonus ( $B$ ) that makes the agreement feasible. It is shown that this is a quarter of the total cost in the original situation (scenario "1") supported by the customer. This is really a logical consequence of the aforementioned necessary condition expressed in expression (11).

In addition, if the necessary condition is accomplished and the agreement is set, other advantages are obtained for the provider and for the customer, although they were not intended. The provider is able to develop more reliable demand forecasting systems and improve its understanding of the maturity cycle of the product, enabling it to optimize its investments related to the manufacturing process and gain better knowledge of the customer preferences and necessities. On the other hand, the customer improves the replenishment reliability, increases its knowledge of the component or product purchased and enjoys a more competitive purchasing price.

Finally, our study shows that, despite the enduring validity of the model of optimization of inventory management costs proposed by Harris (1913), there is a large number of new scenarios in which the supplier and customer can jointly achieve win-win strategies that

will globally improve the value chain but will not penalize economically either of the operators involved.

The limitations of the model are in accordance with the assumptions listed at the beginning of section 3 and the general constraints imposed by the original EOQ model. Relaxing these constraints will provide clues to developing wider-scoped models suitable for common situations between customers and providers.

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