

# APPYLING COMPETITIVE TECHNICAL INTELLIGENCE TO MONITOR LEAD-TIME EFFECTS ON JOINT INVENTORY AND PRICE OPTIMIZATION

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## Mots clefs:

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## Palabras clave:

Inventario, establecimiento de precios, tiempo de demora, inteligencia estratégica, inteligencia competitiva

## Abstract

This work has important implications for firms that implement global sourcing, given that they need to analyze pricing and purchase cost negotiations with customers. Different countries require specific measures the company should adapt to in order to effectively complete the client's demand. Through competitive technical intelligence, it's possible to analyze the environment and determine the changes that allow them to avoid future logistics problems. We study the effect of lead-time from the buyer's point of view on joint price and inventory optimization problems in a continuous time setting using an average profit-maximizing model that extends the familiar EOQ model. The behavior of the model is studied using numerical experiments that show that as lead-time increases, the optimal price increases and the optimal profit and lot size decrease. Additional numerical experiments are performed that show how the purchase cost must be decreased to allow a firm to maintain constant pricing and profit when lead-times increase.

# 1 Introduction

This research is of particular importance given the current proliferation of global supply chains with their inherently longer lead-times. Given that companies give importance to the reduction of costs, it's important for them to analyze economically the impact lead-times have on the transportation of their products. Many companies are frequently surprised by external events that gradually cause their competitiveness to deteriorate Rodriguez et al [35]. Even though, many companies have key markets in developed countries with advanced customs services, many others deal with its problems and low transportation standards of underdeveloped countries. Through competitive technical intelligence, companies can analyze the differences in each of their environment and/or industries to optimize their work and satisfy their customers' needs. Information about the environment is acquired, gathered, transmitted, evaluated, analyzed and made available as the final cognitive result that supports decision-making Rodriguez and Lopez [36]. Using this same analysis, they can monitor the changes in customs regulations to improve their transportation system periodically. The result of this analysis is the establishment of commercial agreements with customers and meeting them appropriately. This research will take into consideration these delays that are present in the transportation of goods, which affect the delivery estimate dates and the operating costs incurred in the customs department. The research will also make companies analyze the different costs in every location or transportation routes to optimize their distribution of products and minimize the operating costs. This paper presents a joint pricing EOQ model that explicitly incorporates the in-transit holding cost during the lead-time considering various function forms such as exponential, constant elasticity and linear. Basically, the paper studies the effect of lead-time on joint price and inventory optimization problems in a continuous time setting. The work is motivated by an observation that seems to have been excluded in previous works on continuous time joint price and inventory models. This observation is that when demand is modeled as a function of price, the in-transit inventory is no longer a constant equal to the demand over the lead-time as in the non-pricing models. This means that neglecting to explicitly include the in-transit inventory term in the cost expressions implies that either: 1) the lead-time is equal to zero or 2) that the purchaser pays for the inventory upon delivery. Clearly this is not always the case. For example, firms in Mexico often purchase raw materials from the United States and other countries and the processing time in customs results in extended and unavoidable lead-times. In general, global supply chains tend to have longer delivery times and international trade agreements often require up-front payments.

## 2 Competitive technical intelligence

The term 'competitive intelligence' refers to information about the external business environment that can affect the company's competitive position, specifically it's information that goes beyond just finding to include specific recommendations for responding to observations, analysis or conclusions Ashton and Klavans [5]. Competitive technical intelligence accomplishes the following three goals:

- Knowledge of technological events that in the future can improve or deteriorate the organization's performance.
- Identification of new processes/products that can improve the business.
- Knowledge of scientific and technological trends related to competitive environment, which identifies innovative opportunities Porter et al [31].

The proper identification of new processes that generate an added value, permit companies understand their environment and determine the changes that allow them to avoid future problems. If these problems are analyzed at the correct time, the relationships with clients and product providers will improve given that their requirements will be met according to the agreements established at the beginning. These agreements can only be established by constantly analyzing the environment through the competitive technical intelligence methodology. The environment can be analyzed using a systematic surveillance and analysis that

include diverse collection and screening efforts, such as scanning (broad surveying of external environment), monitoring (routine, focused tracking of specific topics of interest) and scouting (collecting and screening information on particular technologies, experts or organizations) Rodriguez and Lopez [36].

From the mid-1990s there has been a resurgence of research, literature, symposia, training and consulting in competitive technical intelligence Ashton and Stacey [4], Cartwright et al [7], Fuld [14], Gilad [15], McGonagle and Vella [25], Prescott and Gibbons [32]. Different companies like Procter & Gamble, Motorola, Johnson & Johnson and many others have efficiently managed the design and implementation of these intelligence systems, thus generating successful strategic plans in their business units Rodriguez, et al [35]. Even though these companies have been successful when implementing these systems, various developing countries, principally in Latin America, contain restrictions for the correct implementation Price [33]. The definition of opportunities and threats for innovation in products and/or processes hasn't been completely effective Alcorta and Perez [3], Etzkowitz [13], Varsakelis [43]. These companies should take into consideration the lead-times that exist in their actual transportation of goods to design a distribution system that accommodates to the restrictions of its environment and continue offering their products to their customers accomplishing location and time agreements. Latin-American transportation systems need to be fully comprehended by the companies since their products will use this system and should constantly monitor its changes to adapt accordingly. A difference of lead-time in the customs department will directly affect the delivery time, which will not meet the customer's demands. Commonly, companies solve their problems in the short run, while investment in technology and methodologies to manage it are deficient Rodriguez et al [35]. The formulation of a model that analyzes the changes in this transportation system will make companies offer the correct price and delivery estimate to their clients given the their actual restrictions of the environment.

### **3 Research in logistics**

Joint pricing and inventory problems were very likely first mentioned in print by Whitin [45], who proposed a link between pricing and inventory control but did not mention lead-time. Later researchers followed his lead and studied a variety of related problems. Kotler [20] showed that there exists an interaction between marketing policies and the economic order quantity. He first determined the optimal selling price that provides maximum revenue for a given demand function and then determined the economic order quantity considering the selling price and demand as fixed parameters. Kunreuther and Richard [21] develop two inventory models based on economic order quantity (EOQ) and economic production quantity (EPQ) models for determining the pricing and lot sizing policies for the case of the linear demand function. A general inventory model in which demand is a function of a sales price that depends on pricing policies and the unit cost in presented by Ladany and Sternlieb [22]. They show that determining an economic order quantity considering the sales price and demand as a function of purchase cost results in an increase in the net profit. Marketing policies and the possible presence of damaged items are incorporated into an EOQ model by Subramanyam and Kumaraswamy [40]. They consider the effect of price elasticity and advertising on the demand for the products and find that the expression for computing the lot size does not depend on the percentage of defective items. An inventory model based on the EPQ that considers the effect of price elasticity, the frequency of advertising, and lot size is presented by McTavish and Goyal [26]. Urban [42] develops an inventory model based on the EPQ model that considers learning effects and the possibility of defective goods in the fabrication process. It is used to determine the lot size, price mark-up, and advertisement expenditure simultaneously when the demand for the goods is a deterministic function of the selling price.

Several researchers have worked on joint pricing and inventory problems from a supplier's point of view. For example, Monahan [27] analyzes the effect of a price discount offered by a supplier to its unique buyer with the main objective of increasing the supplier's profit. A model for determining simultaneously the price and lot size for the supplier-buyer problem from the supplier's point of view considering a scheme of quantity discounts is presented by Rosenblatt and

Lee [37]. They show that the optimal order quantity for a supplier is an integer multiple of the buyer's lot size. Abad [1,2] solved the problem of joint price and lot size determination faced by a retailer when purchasing an item for which the supplier offers an incremental and an all-unit quantity discount scheme considering the linear and constant elasticity demand functions.

Lee [23] presented a geometric programming approach to determine a profit-maximizing price and order quantity for a retailer. He considered the demand as a nonlinear function of selling price with a constant elasticity. Lee and Kim [24] examined the effects of integrating production and marketing decisions for a short to medium planning horizon with a focus on the solution methodology. Kim and Lee [19] study fixed and variable capacity models for the joint setting of a product's selling price and lot size for a profit maximizing organization considering constant but sales price-dependent demands over a planning horizon. Most recently, an EPQ inventory model that determines the production lot size, marketing expenditure and product's selling price is developed by Sadjadi et al. [38] and an algorithm for simultaneous determination of the sales price and lot size in a make-to-order contract production environment from the supplier's perspective is developed by Banerjee [6].

Lead-time has not been completely overlooked in the inventory and pricing literature. In particular, it has been studied from the perspective of a supplier who must determine a price and a lead-time to offer to its customers. Several examples of this line of research can be found in the literature. Hatoum and Chang [17] present a model for a make-to-order environment that determines the optimal lead-time and price that the firm quotes to its customers in order to control flow time through the shop. Easton and Moodie [11] study a similar problem with contingent orders. In their model, a customer considers a quoted lead-time and price and decides whether or not to place the order. This introduces uncertainty into the lead-time. ElHafsi [12] presents a model for lead-time and price quotation in congested manufacturing facilities with machines subject to random failures and repairs. The paper by Chang and Chang [9] presents a model in which the supplier can control lead-time at a cost and has the option to buy raw materials or components with price-quantity discounts. The objective is to minimize costs subject to resource constraints. More recently, Webster [44] studies a dynamic pricing and lead-time determination problem in which customer valuation of lead-time and price change periodically and unpredictably over time. Ray and Jewkes [34] study an operating model in which the firm may reduce lead-time at a cost and strives to maximize profits in an environment in which the mean demand rate and the sales price depend on the lead-time. Pan et al. [30] present an optimal reorder point inventory model that considers that the supplier can modify its lead-time at a cost and offers discounts on backordered items. Demand is modelled with a normal distribution and with a general distribution. Pan and Hsiao [29] present a very similar model. It appears that due to variations in publication lead-times, the previous paper [29] is actually a later work. A very recent work by Charnsirisakskul et al. [10] considers a problem in which the supplier can set prices to influence demand, accept or reject orders, and set lead-times for accepted orders. Recently, Smith, Martínez-Flores and Cárdenas-Barrón [39] examined the benefits of joint price and order quantity optimisation as compared with a sequential decision process in which the price is determined first, followed by the determination of the order quantity. Numerical studies are performed that provide insight into how often it is advantageous to optimise jointly and how much benefit can be obtained. In general it is found that in many cases joint optimisation is of negligible value although it can be very beneficial in specific cases. Recently, there has been a great deal of research conducted on determining appropriate lead-times as well as the impact of reduction of the lead-time. For example, Keskinocak and Tayur [18] provided a recent review of establishing individual lead-times for the customers. Ray and Jewkes [34] considered establishing constant lead-times for all customers and Ouyang et al [28] considered the effect of reduction of the lead-time and Suri [41] considers the quick response initiatives in order to reduce the lead-time. Chan et al. [8] presented a survey and classification of coordination of pricing and inventory decisions. Despite the considerable attention given to the lead-time from the supplier's point of view, the effect of lead-time from the buyer's point of view is absent from the literature.

## 4 Proposed model

We study the effect of the lead-time using an average profit formulation problem. We consider three types of demand functions: exponential, constant elasticity, and linear. The exponential function is given by (1):

$$D(p) = M \cdot e^{\frac{-p}{k}} \quad (1)$$

where  $M$  is a demand scaling constant that can be interpreted as the highest possible level of demand. It is realized with a price equal to zero. The parameter  $k$  is a price scaling constant. The constant elasticity function is given by (2):

$$D(p) = M \cdot p^{-\alpha} \quad (2)$$

where  $M$  is a demand scaling constant and  $\alpha$  is the demand elasticity. Notice that  $M$  cannot be interpreted as a maximum demand in this case. The linear function is given by (3):

$$D(p) = M - bp \quad (3)$$

where  $M$  is the highest possible level of demand, realized with a price equal to zero and  $b$  is a price proportionality constant. These three demand functions are the most commonly used in previous works.

The average price model is based on the model described by Whitin [45], which builds on the classical EOQ model introduced, by Harris [16]. We extend the model by considering the possibility of a non-zero lead-time. In the classical non-pricing EOQ model, the in-transit inventory is a constant given by lead-time multiplied by demand being careful to use constant units. Since it is a constant, it is irrelevant in the optimization of the problem and thus is left out even when the lead-time is non-zero. However, in general it may not be left out when price is optimized jointly with inventory since the demand is a function of price, one of the decision variables. We thus arrive at the following average profit function:

$$TP(p, Q) = pD(p) - cD(p) - \frac{D(p)}{Q}S - \frac{hcQ}{2} - LciD(p) \quad (4)$$

where the notation is defined as:

$p$ : sales price, a decision variable

$Q$ : lot size, a decision variable

$c$ : variable unit cost

$S$ : setup or ordering cost  
 $h$ : on site holding cost as a percentage of variable cost  
 $L$ : lead-time  
 $i$ : in-transit holding cost as a percentage of variable cost

This shows that including the in-transit inventory cost in the cost function is mathematically equivalent to having to pay for  $Li D(p)$  more units than are delivered and eventually sold. The sales revenue (first term) depends on the true demand, as does the ordering cost (third term). A scenario in which this situation may arise is when the supplier ships lots with  $1/(1 + Li)$  fraction of defective items. The purchaser is this forced to increase the purchase quantity. (4) can be rewritten as:

$$TP(p, Q) = pD(p) - c_2 D(p) - \frac{D(p)}{Q} S - \frac{hc_1 Q}{2} \quad (5)$$

Now a third unit cost can be computed as the weighted average of  $c_1$  and  $c_2$  as follows:

$$c_3 = \frac{c_1 h Q + c_2 2D(p)}{h Q + 2D(p)} \quad (6)$$

This allows (5) to be rewritten as:

$$TP(p, Q) = pD(p) - c_3 D(p) - \frac{D(p)}{Q} S - \frac{hc_3 Q}{2} \quad (7)$$

Which show that including the in-transit inventory cost is also mathematically equivalent to increasing the unit purchase cost ( $c$ ) of a zero lead time item. The increase is given by:

$$c_3 - c = c \frac{2LiD(p)}{hQ + 2D(p)} \quad (8)$$

These expressions can be of great value to a practitioner evaluating international suppliers when the purchasing firm is implementing price optimization.

When (1), (2), and (3) are substituted into (4) we obtain three models corresponding to the three types of demand functions. With (1) and (4), we obtain:

$$TP(p, Q) = Mpe^{\frac{-p}{k}} - Mce^{\frac{-p}{k}} - \frac{Me^{\frac{-p}{k}}}{Q} S - \frac{hcQ}{2} - Lci e^{\frac{-p}{k}} \quad (9)$$

By taking first derivative and setting then equal to zero we obtain the first order conditions for the optimal price and lot size:

$$p^* = k + \frac{S}{Q} + c(1 + Li) \quad (10)$$

$$Q^* = \sqrt{\frac{2Me^{\frac{-p}{k}} S}{hc}} \quad (11)$$

Likewise, with (2) and (4), we obtain:

$$TP(p, Q) = Mp^{1-\alpha} - Mcp^{1-\alpha} - \frac{Mp^{1-\alpha}}{Q} S - \frac{hcQ}{2} - LciMp^{1-\alpha} \quad (12)$$

with the corresponding optimal price and lot size equations:

$$p^* = \frac{\alpha \left( c + \frac{S}{Q} + Lci \right)}{\alpha - 1} \quad (13)$$

$$Q^* = \sqrt{\frac{2Mp^{-\alpha} S}{hc}} \quad (14)$$

Finally, with (3) and (4), the model is the following:

$$TP(p, Q) = p(M - bp) - c(M - bp) - (M - bp) \frac{S}{Q} - \frac{hcQ}{2} - Lci(M - bp) \quad (15)$$

with corresponding price and lot size equations:

$$p^* = \frac{\frac{M}{b} + c + \frac{S}{Q} + Lci}{2} \quad (16)$$

$$Q^* = \sqrt{\frac{2S(M - bp)}{hc}} \quad (17)$$

For practical purposes, the MS Excel solver was found to be quite adequate for solving these. In cases when the profit is found to be negative, a better feasible solution is simply not to produce the item.

## 5 Numerical experiments

The numerical experiments we performed can be classified into two groups. The first type involves solving a number of randomly generated problems to observe how the optimal solution is affected by an increase in the lead-time. The second type involves determining the cost reduction that would be needed to maintain a constant sales price when the lead-time is increased.

### 5.1 First group

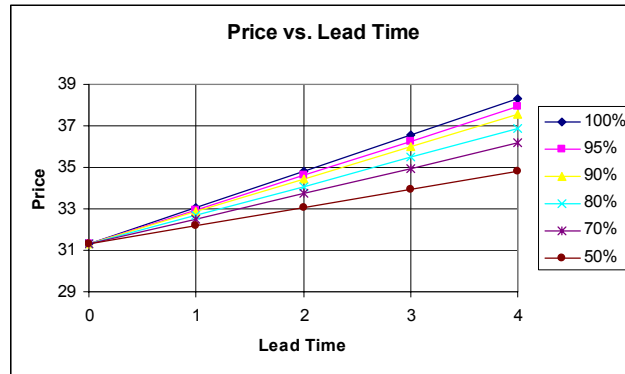
For the first group of experiments, 30 random problem instances were generated for each form of demand function. The parameter values were generated from uniform distributions with ranges as shown in *Table 1* for the exponential, constant elasticity, and linear demand functions.

*Table 1: Parameter values for demand functions*

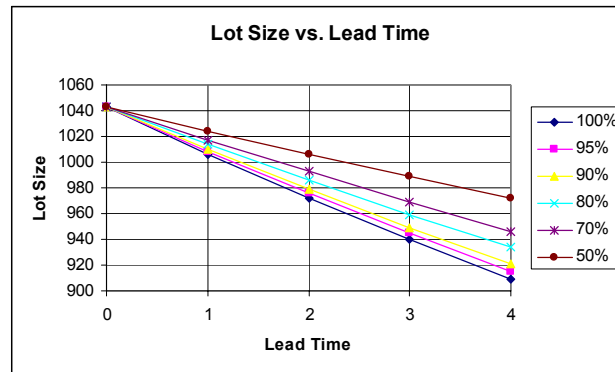
	Exponential demand		Constant elasticity demand		Linear demand	
	MIN	MAX	MIN	MAX	MIN	MAX
<b>S</b>	10	130	10	130	10	130
<b>h</b>	0.1	0.4	0.1	0.4	0.1	0.4
<b>c</b>	5	10	5	10	5	10
<b>M</b>	1,000	100,000	50,000	100,000	1,000	100,000
<b>k</b>	5	40	-	-	-	-
<b>α</b>	-	-	1.2	2.9	-	-
<b>b</b>	-	-	-	-	5	40
<b>L</b>	0	4	0	4	0	4



The results with each type of demand function are not directly comparable since they each behave differently. Once the problems were generated, they were solver to optimality. The results were summarized by averaging the results over all problem instances and the average values were plotted vs. the lead-time. In addition to varying the lead-time, we varied the proportion of financial opportunity cost in  $h$  in the range of 100% to 50%. For example, when the data series is labeled as 80% and  $h = 0.1$ , the value of  $I = 0.08$ , implying that the operating cost is 0.02 of the total inventory holding cost. *Figure 1* shows the average price behavior vs. the lead-time and proportion of financial opportunity cost for the exponential demand function. *Figure 2* shows the behavior of the lot size vs. the lead time and proportion of financial opportunity cost for the same function and *Figure 3* shows the corresponding graph for the average profit. For the constant elasticity function, the corresponding graphs are shown in *Figures 4, 5, and 6*. *Figures 7, 8, and 9* show the same for the linear demand function.



*Figure 1: Price vs. lead-time using the exponential function*



*Figure 2: Lot size vs. lead-time using the exponential function*

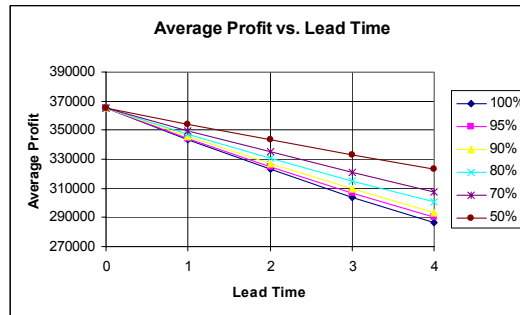


Figure 3: Average profit vs. lead-time using the exponential function



Figure 4: Price vs. lead-time using the constant elasticity function

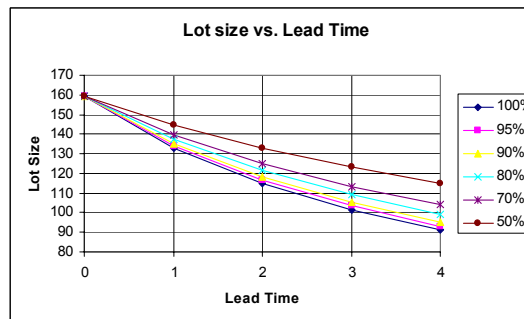


Figure 5: Lot size vs. lead-time using the constant elasticity function

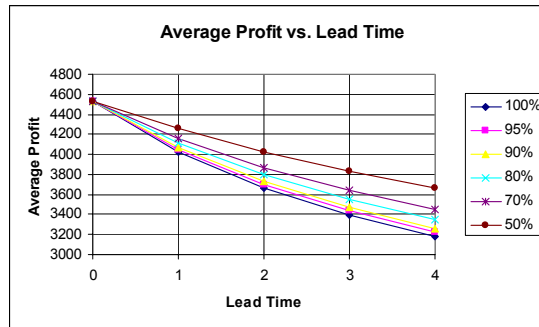


Figure 6: Average profit vs. lead-time using the constant elasticity function



Figure 7: Price vs. lead-time using the linear function

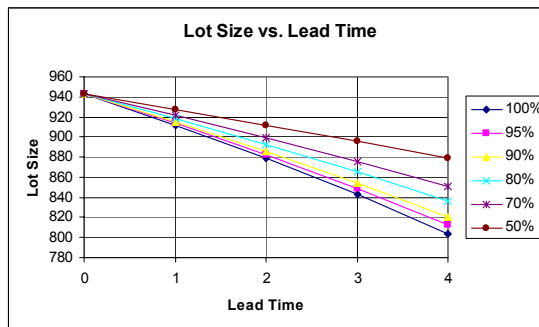


Figure 8: Lot size vs. lead-time using the linear function

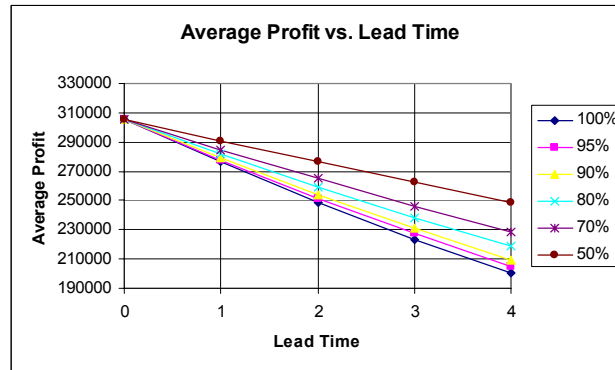


Figure 9: Average profit vs. lead-time using the linear function

## 5.2 Second group

The second experiments explored the effect of lead-time under the following scenario. Suppose a buyer has been buying from a local vendor with a zero lead-time. Under these conditions, an optimal price has been established, which is currently offered to the customers of the buyer. Then suppose the buyer decides to switch to an overseas vendor that offers a significant discount on the variable unit cost, but has longer lead-time and a higher ordering cost. In these experiments the variable unit cost is determined that would allow the buyer to maintain its average profit and continue to offer the pre-established sales price to its customers despite the increase in lead-time and ordering cost. This scenario has business implications for many firms that are currently seeking global sourcing opportunities, but may not have taken into account the effect of lead-time in a pricing context.

The following was done for each form of demand function:

- Generate 3 random parameter sets from uniform distributions as shown in *Table 1*. For the exponential function, the values of  $S$ ,  $h$ ,  $c$ ,  $M$ , and  $k$  were generated. For the elasticity function, the values of  $S$ ,  $h$ ,  $c$ ,  $M$ , and  $\alpha$  were generated. For the linear function, the values of  $S$ ,  $h$ ,  $c$ ,  $M$ , and  $b$  were generated. It was attempted to keep the parameter values as alike as possible among the three demand functions.
- For each parameter set generated in the previous step, create a problem instance by:
  - o Varying the proportion opportunity cost among the values of 50%, 70%, 80%, 90%, and 95%
  - o Varying the lead-time among the values 0, 2, and 4
  - o Varying the increase in ordering cost among the values of 0%, 5%, 10%, 50%, and 100%
- Solve the problems with zero lead-time and 0% increase in ordering cost to optimality to find the target sales price and target average profit. This is done using value of  $c$  generated in the first step.
- For all other variations of each problem, solve for the value of  $c$  that permits the average profit and sales price to remain constant.

*Table 2* shows the parameter values generated in Step 1 for the exponential, constant elasticity, and linear functions.

Table 2: Parameter sets for demand functions

	Exponential demand			Constant elasticity demand			Linear demand		
	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3
$S$	20.12	38.37	76.79	20.12	38.37	76.79	20.12	38.37	76.79
$h$	0.284	0.120	0.247	0.284	0.120	0.247	0.284	0.120	0.247
$c$	8.75	8.19	6.19	8.75	8.19	6.19	8.75	8.19	6.19
$M$	8,184.7	23,118.3	79,792.4	72,729.1	79,683.5	61,576.9	8,184.7	23,118.3	79,792.4
$k$	27.33	11.13	17.41	-	-	-	-	-	-
$\alpha$	-	-	-	2.42	1.68	2.85	-	-	-
$b$	-	-	-	-	-	-	165.96	982.92	2505.40

The results are summarized in the following graphs. To limit the length of the paper, we include only the graphs for 95% and 50% proportion of opportunity cost. *Figure 10* and *Figure 11* show the behavior of  $c$  (averaged over the three parameter sets generated) with increases in lead-time and ordering cost for the exponential demand function. *Figure 12* and *Figure 13* show the same for the constant elasticity function. Likewise the results for the linear function are shown in *Figure 14* and *Figure 15*.

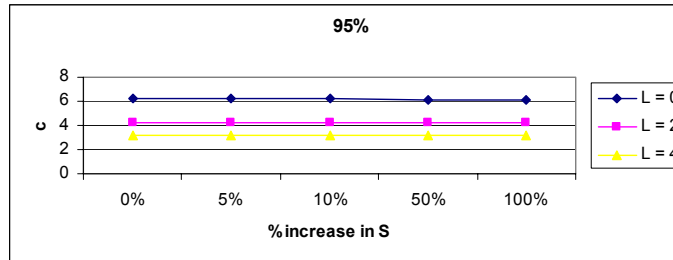


Figure 10: Values of purchase cost with 95% financial opportunity cost for the exponential function

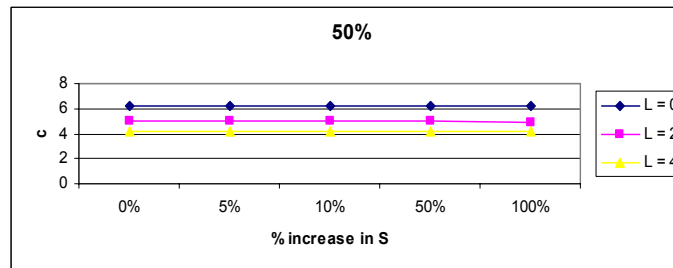


Figure 11: Values of purchase cost with 50% financial opportunity cost for the exponential function

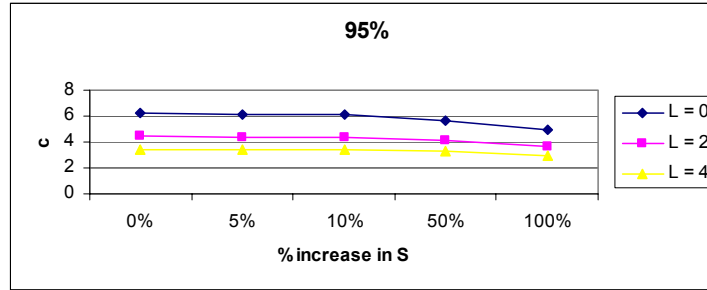


Figure 12: Values of purchase cost with 95% financial opportunity cost for the constant elasticity function

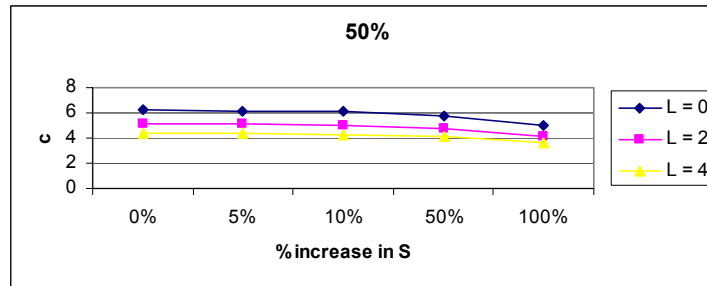


Figure 13: Values of purchase cost with 50% financial opportunity cost for the constant elasticity function

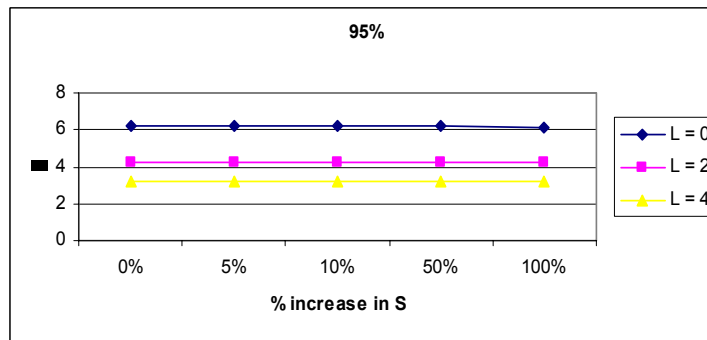


Figure 14: Values of purchase cost with 95% financial opportunity cost for the linear function

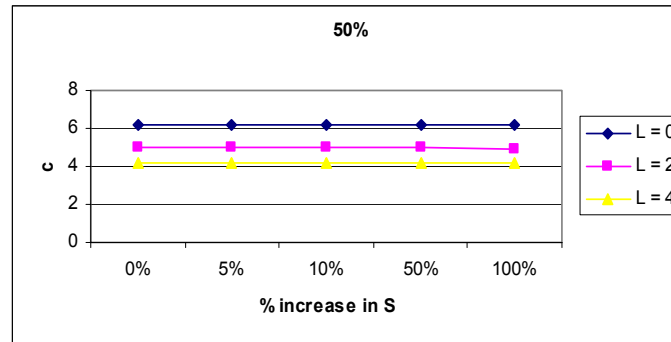


Figure 15: Values of purchase cost with 50% financial opportunity cost for the linear function

## 6 Discussion of the results

### 6.1 First group of experiments

The first group of experiments shows that when the lead-time is increased and all else is held constant, the optimal solution suggests higher prices and smaller lot sizes. In addition, the average profit tends to decrease. The effect on price, lot size, and profit becomes more pronounced the higher the proportion of financial opportunity cost. No large qualitative differences were found among the three forms of demand function. The main differences that can be observed is that the exponential function produces the most linear average effect graphs while some nonlinearity can be perceived in the constant elasticity and linear demand function graphs. One more observation is that the model is insensitive to the proportion of financial opportunity cost when the lead-time is equal to zero.

The implications for firms that wish to implement global sourcing were that, clearly, something must compensate the increase in lead-time. This is most often a reduction in the variable purchase cost. The second group of experiments sheds light on how great a reduction in purchase cost must be obtained to make the sourcing from a longer lead-time vendor attractive.

### 6.1 Second group of experiments

The second group of experiments uses the optimization models to determine the variable purchase cost that must be obtained from a longer lead-time vendor if the firm is to maintain a target profit level and a constant sales price. The general behavior observed for all three forms of demand function is that the purchase cost is not very sensitive to increases in ordering cost and is much more sensitive to increase in the lead-time. As in the first group of experiments, the effect is more pronounced when financial opportunity cost is a greater proportion of the inventory holding cost. No large quantity differences were found among the three forms of the demand functions. The main differences were found among the three forms of the demand functions. The main difference that can be observed is the non-linear behavior of the graphs in the case of the constant elasticity function. As in the first group of experiments, the model is insensitive to the proportion of financial opportunity cost when the lead-time is equal to zero.

The results are useful for firms that are considering global sourcing. The firm may use the model to obtain a first cut estimate that must be obtained from a longer lead-time vendor to make the venture worthwhile.

## 7 Conclusions

The main contributions of this paper are:

- Competitive technical intelligence should be used by companies to effectively monitor the changing environment and successfully adapt its transportation system.
- To point out that lead-time is relevant in joint pricing and inventory problems although this is not the case in the non-pricing case.
- To reveal the general behavior of the optimal solution to continuous time joint pricing and inventory problems as lead-times and ordering costs increase.

Latin-American transportation systems are substantially different from the ones in developed countries and a proper analysis should be made to offer its products according to the agreements established at the beginning with its clients. Competitive technical intelligence allows companies to use a defined methodology to monitor its environment and adapt according to the changes that may affect the company in the future. With respect to the transportation problem, this methodology provides a consistent analysis of the different activities and processes that affect lead-times and consequently the delivery process. The use of this methodology will allow the identification of other future problems that should be taken into account when establishing the commercial agreement.

In relation to the logistics model, we present the results of a set of numerical experiments that show that increases in lead-time result in solutions with higher prices, smaller lot sizes and decreases profits. A second set of numerical experiments shows that the required purchase cost discount is not very sensitive to increases in the ordering cost and much more sensitive to changes in the lead-time. Firms seeking to implement global sourcing can benefit from the insights provided by the model studied in this paper. A manager negotiating terms with a vendor could use the model to perform a sensitivity analysis to determine what is most important to negotiate (price, lead-time, ordering cost). As recommendations for further research, the problem could be modeled using a discontinued cash flow model that would more accurately represent the effect of financial opportunity costs. Versions of the model with stochastic demand and/or lead-times model may be formulated and solved to see if additional insights can be derived. As a final recommendation, the model could be embedded in a larger model to jointly determine price, lot size, and lead-time from a number of options with different costs.

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