INCREASING ON TIME DELIVERIES OF TEA BASED PRODUCTS BY USING TYPE-2 SERVICE LEVEL AND ANALYZING IMPACTS OF INFORMATION SHARING IN FOOD SECTOR

by

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Dedicated to

my father

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ABSTRACT

INCREASING ON TIME DELIVERIES OF TEA BASED PRODUCTS BY USING TYPE-2 SERVICE LEVEL AND ANALYZING IMPACTS OF INFORMATION SHARING IN FOOD SECTOR

The aim of this thesis is two fold, the first one is to develop an inventory control strategy for the most valuable products of a food company to improve customer service by using type-2 service level. The second is to show impact of information sharing on the magnitudes of cost saving and inventory reduction with a two level supply chain that consists one retailer and one manufacturer with autocorrelated external demand occur at the retailer.

In the first part, a target service level is set and the demand distributions are analyzed for the single product to determine decision rule parameters. The three distributions normal, exponential and Laplace are studied and decision rule parameters are determined for both desired target service level and current situation. Improvements which are provided by our inventory control model in terms of annual shortage, holding and setup costs are displayed.

In the information sharing part, we develop a model of two level supply chains and analyze the benefits of information sharing to the chain between manufacturer and customer. Information sharing could alone provide significant inventory reduction and cost saving to the manufacturer. However, retailer can also have advantages such as use of vendor managed program to reduce the its overhead and processing costs or lead time reduction to reduce the retailer’s inventory cost, while it negotiates arrangements with the manufacturer before sharing sales information. Moreover, we show the impact of the replenishment lead time and shortage cost on information sharing by implementing the sensitivity analysis.

ÖZET

GIDA SEKTÖRÜNDE ÇAY BAZLI ÜRÜNLERİN ZAMANINDA TESLİM ORANLARININ DOLDURMA ORANI METODUNU KULLANARAK ARTTIRILMASI VE BİLGİ PAYLAŞIMININ ETKİLERİNİN ANALİZ EDİLMESİ

Bu çalışmanın amacı iki aşamalıdır, birincisi bir gıda firmasınının en değerli ürünlerinin müşteri hizmet düzeyini arttırmak için *doldurma oranı metodunu* kullanarak bir envanter control stratejisi oluşturmaktır. İkincisi ise, parekendecide oluşan iki seviyeli tedarik zinciri modelinde bilgi paylaşımının tasarruf ve envanter azaltmaya olan etkisinin gösterilmesi.

Birinci bölümde, herbir ürün için hedef hizmet düzeyi belirlendi ve talep dağılımları incelenerek karar parametreleri saptandı. Normal, exponential ve Laplace talep dağılımları için çalışmalar yapıldı ve hem mevcut durum hem de hedeflenen hizmet düzeyi için karar parametreleri belirlendi. Tavsiye edilen envanter control modelinin yıllık eksik stok, elde envanter tutma ve kurulum maliyetlerine sağladığı iyileştirmeler gösterildi.

Bilgi paylaşımı kısmında ise, iki seviyeli bir tedarik zinciri modeli kurduk ve üretici ve parakendeci arasında bilgi paylaşımının zincire kazandırdığı faydaları analiz ettik. Bilgi paylaşımı tek başına üretici için dikkat çekici tasarruf ve envanter azalması sağlayabilir. Fakat, parakendeci de bilgi paylaşımı öncesi üreticiden tedarikçi tönetimli envanter programı kullanmasını isteyerek işletme ve sabit maliyetleri düşürme, ya da üretici ile teslim süresi azaltma anlaşması yaparak stok tutma maliyetlerini düşürme gibi fırsatlara sahiptir. Ayrıca, teslim süresinin ve eksik stok kalma maliyetinin bilgi paylaşımına olan etkisini duyarlılık analizleri yaparak gösterdik.

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LIST OF SYMBOLS /ABBREVATIONS

A^2	Test statistic of Anderson-Darling Goodness of Fit Test
c	Order cost per item
C_t'	Manufacturer's expected holding and shortage cost
d	Average weekly demand
D	Mean rate of demand per year
D_t	The autocorrelated demand process at the retailer
F_t'	The true distribution when there is no information sharing
h	Unit holding cost per year
H	Unit inventory holding cost at the manufacturer
H_0	Null hypothesis
I	Annual interest rate
I'	Average inventory without information sharing
K	Setup cost per cycle
$\hat{K}$	Parameter of manufacturer order-up- to level without information sharing
l	Replenishment lead time from manufacturer to the retailer
L	Replenishment lead time from external supplier to manufacturer
$L(z)$	Standardized loss function
m_t	Conditional expectation of the total demand
M_t	Mean of total shipment quantity without information sharing
M_t'	Mean of total shipment quantity with information sharing
$n(R)$	The number of shortages
O_i	Observed frequency
p	Maximum production rate in a week
P	Shortage cost per unit of unsatisfied demand
Q	Lot-size
R	Reproduction point
s	Reorder point
S	Reorder quantity

S_t	Retailer's order-up-to level
T_t	Manufacturer's order-up-to level
v	Variance parameter when there is information sharing
v_t	Conditional variance of the total demand
V	Variance parameter when there is no information sharing
Y_t	Retailer's order quantity
z	Safety factor

α	Probability of no stock-out during replenishment lead time
β	Fraction of demand satisfied directly from shelf
β_t	The total shipment quantity over manufacturer's lead time
ΔI	The percentage of average inventory saving
ε_t	Error terms
$\phi(t)$	Standard normal density function
θ	Variance parameter in Laplace distribution
λ	Demand rate
μ	Mean of external demand occur at the retailer
ρ	Autocorrelation coefficient
σ	Standard deviation of weekly demand

AR(1)	Autoregressive process of the first order
CDF	Cumulative Density Function
EOQ	Economic Order Quantity
GOF	Goodness of Fit Test
KA	Key Account
SCM	Supply Chain Management
SKU	Stock Keeping Unit
SPQ	Service Production Quantity
YTL	Yeni Türk Lirası

1. INTRODUCTION

Intensive global competition, faster product development, increasingly flexible manufacturing systems, an unprecedented number and variety of products are characteristics of today's global economy. Making supply meet demand in such an uncertain world is becoming a more and more challenging task for supply chain management (Yan and Woo, 2004). It is obvious that companies offering superior customer service remain competitive and profitable. The service level can be measured by the availability of goods, therefore inventory plays a vital role for maintaining high customer service level. The major functions of inventory can be described as: (1) to support and provide necessary physical inputs for manufacturing, and (2) to protect companies against uncertainties that arise from discrepancy between demand and production, machine deterioration, and human errors among others (Zeng, 1997). Specifically for finished goods, lead time demand process is considered as a major reason of uncertainty and variability. However, carrying inventory is extremely costly and it should be managed very carefully and efficiently. A wide variety of inventory control models exist in the literature. For the determination of the optimal decision parameters, some equations have to be solved. Sometimes numerical integrations and approximations are used to solve these equations.

In global markets, most of the companies have also realized that there is a direct connection between the performance of supply chains and availability of timely information, namely information sharing. There is no doubt that information sharing allows a supply chain to proceed more efficiently, and hence results in higher overall supply chain profit. In fact, many supply chain related problems can be attributed to lack of information sharing between supply chain members. One of the important facts in supply chain management, called the bullwhip effect, shows that demand variability is magnified as it is further upstream in the supply chain. The bullwhip effect is a significant issue in supply chains for several reasons. First, the variability of the demand process increases, each supply chain member is forced to carry excessively high inventories in order to fulfill the orders. Next, in spite of high stock levels through the supply chain network, the lack of synchronization between demand and supply process could lead to stock out at certain times. Finally, bullwhip effect increases the operating cost, too. Therefore, it should be decreased. By sharing information, each of the supply chain members can make predictions more accurately based on external demand. Information sharing among the supply chain partners has positive impacts on supply chain visibility and order process variability.

In this thesis we focus on inventory control strategy of Gıdasa A.Ş., and we attempt to bring its poor service level up by using two different strategies. First, we use fill rate, namely type-2 service level, which is defined as the percentage of demand satisfied directly from inventory during a replenishment lead time. Second, the benefits of information sharing have been considered with a two-tier supply chain that consists of one retailer and one manufacturer where external demand of end consumer is a simple autocorrelated AR(1) process.

Gıdasa A.Ş. is one of the biggest companies in food, oil, and beverage sector in Turkey. Firstly, it acquired "Piyale" which is one of the well-known pasta brands in Turkey. In addition to this, Gıdasa exists in the beverage sector with brand names "Saka" in water sector and "Deren" in tea sector. The production is executed with ultimate technology in three different plants one of which is in Adana, and two of which are located in Sakarya. About 45 different stock keeping units (SKU) of water, sparkling water, and ice tea-based products are distributed to domestic and foreign customers from warehouses located in Adana, İzmir, Konya, and İstanbul. Now, the company is in the first place among water exporter companies in Turkey. On the other hand, it has about 150 tea-based SKUs that are distributed from warehouses in Hendek plant. In this study, we only consider tea-based products, because company have problems with inventory control of tea-based products. The due dates cannot be met particularly for tea-based product orders placed by Key Accounts (Migros, Carrefour etc.). Since Key Accounts (KA) constitute the biggest portion of annual income and provide greater feedback about delivery time to the company, the managers consider the KAs the most important customer. In the first part of this thesis, we attempt to make decisions about how many stocks to hold and how much to produce each time in order to increase the low service level. To this end, a predetermined level of service is selected and parameters are computed. We compare the current situation and the target level of service level in terms of inventory level and expected cost. Expected costs in the current situation and desired situation are computed by an approximation by using a type-2 service level constraint. We claim that the overall annual expected cost consisting of the annual inventory carrying cost, annual setup cost, and annual shortage cost of a single item will decrease. The company is striving to achieve the specified fill rate for its most valuable tea-based products by using a better reproduction point *R*. We find that reproduction point *R* should be increased and the company should hold more inventories to improve the service level. Hence, the expected number of shortages and annual shortage cost diminish sharply. Besides carrying more inventories, planning managers should consider manufacturing more frequently with lower batches for a single item. Unfortunately, this means that for a higher customer service the company should be ready to pay more setup cost. However, the overall cost will be decreasing.

Secondly, we analyze the benefits of information sharing in the supply chain with respect to the current situation. Here, excess demand is backlogged. Our analysis reveals that information sharing alone provides approximately five per cent inventory reduction and cost savings. In addition to this, our computations suggest that the underlying external demand process and the lead times both from manufacturer to retailer and external supplier to manufacturer have a significant effect on the magnitude of cost savings and inventory reductions associated with information sharing. In particular, the company should make predictions to determine the true shortage cost value, since the penalty cost has an enormous impact on the overall cost. In other words, when the penalty cost increases, the overall cost increases significantly. Moreover, the manufacturer should be careful about the lead times. Reduction in lead time from manufacturer to the retailer reduces manufacturer's inventory levels and the overall cost. Information sharing provides relatively small cost savings to the manufacturer when lead time from external supplier to the manufacturer is small, but relatively large cost savings to the manufacturer with increasing lead time from external supplier to the manufacturer.

The thesis is organized as follows: The next section is literature survey of the service level constraint and information sharing. In the third section the approximation model for the predetermined service level is presented and numerical findings are given. The fourth section presents a model of a two-tier supply chain and examines that model with information sharing. Moreover, the benefits of information sharing and impact of the underlying parameters such as the shortage cost and lead times are analyzed. The final section includes the conclusions and future research possibilities.

2. LITERATURE REVIEW

Since the thesis consists of two different parts, i.e., increasing the service level and benefits of information sharing, it will be useful to provide some background information separately.

2.1. Inventory Control Literature

Inventories are produced, used (e.g., as raw materials, supplies, spare parts, and so forth), and distributed by every organization. Moreover, inventories represent a major investment from the perspective of both an individual firm and entire national economy. In addition, a significant cost is incurred in the planning, scheduling, control, and actual (procurement or production) activities (Silver and Peterson, 1985). The literature on inventory control discusses different models in different demand situations and the parameters of these models such as reorder level and service level are also different. However, the difference between inventory control models starts with demand process that is input to a supply chain, which is either known or random. Nahmias (1989) mentions that the fundamental problem of inventory management can be succinctly described by the following questions: (i) when should an order be placed and (ii) how much should be ordered. The complexity of the resulting model depends upon the assumptions about the various parameters of the system. The form of the cost functions and the assumptions about physical characteristics of the system also play an important role in determining the complexity of the resulting model. All stochastic demand models assume that the average demand rate is constant. They are generally both more realistic and more complex than the deterministic models. Thus, most of the literature and real life case studies are based on stochastic demand models. One can study the deterministic demand process to learn about the basic trade-offs encountered in inventory management and relatively good approximations can be obtained depending on the degree of demand uncertainty. Browne and Zipkin (1991) are concerned with the (R,Q) inventory model, where demand accumulates continuously, but the demand rate of each item is determined by an underlying stochastic process. Similarly, Tarim and Kingsman (2003) address the multi-period single item inventory lot-sizing problem with stochastic demand under the “static-dynamic uncertainty”. There has been an increasing recognition, as illustrated by Wemmerlow (1989), that future lot-sizing studies need to be undertaken on stochastic and dynamic environments that have at least a modicum of resemblance to reality. Inevitably, the forecast errors have to be taken into account when planning the future lot sizes (Tarim and Kinsman, 2003). Similar concerns have been expressed by Silver (1978): “One should not necessarily use a deterministic lot sizing rule when significant uncertainty exist in demand. A more appropriate strategy might be some form of probabilistic modeling.” Silver (1978) suggests a heuristic procedure for stochastic demand lot sizing problem.

Research on stochastic inventory models started in 1940s, although the first published materials appeared in the early 1950s, e.g., Dvorestsky, Kiefer, and Wolfowitz (1952).

Uncertainty in the demand process often causes firms to hold more inventories to save shortages. Nahmias (1989) states that uncertainty in external demand is the most important thing in the inventory control. For example, a retailer stocks different items so that it can be responsive to consumer preferences. If customer requests an item that is not available immediately, it is likely that the customer will go elsewhere. Worse, the customer may never return. Safety stock is the amount of inventory kept hand, on the average, to allow the uncertainty of demand and the uncertainty of supply in the short run. Safety stocks are not needed when the future rate of demand and the length of time it takes to get complete delivery of an order are known with certainty. The level of safety stock is controllable in the sense that this investment is directly related to the level of desired customer service (that is, how often customer demand is met from stock). If demand is unusually large, emergency actions are required to avoid a stock out situation. On the other hand, if the actual demand is lower than the anticipated one, the replenishment arrives earlier than needed resulting in excess inventory. Managers possess differing attitudes towards balancing of these two types of risk. There are five possible methods of modeling these attitudes to arrive at appropriate decision rules:

- Safety stocks established using of a safety factor
- Safety stocks based on shortage cost

- Safety stocks based on the effects of disservice on the future demand
- Safety stocks based on aggregate considerations
- Safety stocks based on service considerations**.**

Chang and Niland (1967), Herron (1983), and Oral *et al.* (1972) point out that the safety stock of an item is established to keep the sum of the expected shortage and carrying costs as low as possible. Peters and Waterman (1982) reported that "excellent" companies almost universally use the idea that "modeling the effects of shortages is to explicitly make future demand a function of the service now provided" and implement extremely high levels of service.

2.1.1. Lot Size Reorder Point

When the demand rate is approximately constant, we could easily use the basic economic order quantity (*EOQ*). In this model the only independent decision variable is Q. In lot-sizing technique, when the level of on hand inventory hits a specified point R, an order is placed or a batch of Q units is produced. The value of reorder point R is determined from Q, demand rate λ, lead time l. Inventory position rather than the net stock is used to trigger an order. The inventory position, which includes the on-order stock, takes proper account of the materials requested but not yet received from the supplier. In contrast, if net stock was used for ordering purposes, we might unnecessarily place another order today even though a large shipment was due tomorrow. The following assumptions are done in a lot-sizing model:

1. The system is continuous review.
2. Demand is stochastic and stationary.
3. There is a fixed positive lead time l for placing an order.
4. Setup cost K per order

   Holding cost h for a product held in stock per unit time.

   Order cost c per item.

   Shortage cost p per unit of unsatisfied demand.

Replenishment lead time demand continuous random variable *D* is represented with probability density function $f(x)$ and cumulative distribution function $F(x)$. As mentioned above, batch size *Q* and the reorder point *R* are the decision variables unlike the economic order quantity model. The implemented policy is as follows: A fixed quantity *Q* is ordered or produced whenever the inventory position drops to the reorder (reproduction) point *R*.

Nahmias defines the expected cost function denoted by $G(Q,R)$

$$G(Q,R) = h\left(\frac{Q}{2} + R - l\lambda\right) + \frac{K\lambda}{Q} + \frac{P\lambda n(R)}{Q} \tag{2.1}$$

Where $n(R)$ denotes the expected number of shortages.

This is a simple system, particularly in two-bin form, for the stock clerk to understand. A fixed order/production quantity also has advantages in terms of less likelihood of error and predictability of production requirements on the part of the supplier. One disadvantage of a lot-sizing (*R,Q*) model is that in its unmodified form it may not be able to effectively cope with the situation where individual transactions are of appreciable magnitude; in particular, if the transaction that triggers the replenishment of an (*R,Q*) system is large enough, then the replenishment batch *Q* will not even raise the inventory position above the reorder point. Of course, in such a situation one could instead order/produce an integer multiple of *Q* where the integer was large enough to raise the inventory position above *R* (Silver and Peterson, 1998).

The study of lot-sizing began with Wagner and Whitin (1958), and there is now sizeable literature on this area extending the basic model to consider capacity constraints, multiple items, multiple stages etc. However, most previous works on lot sizing have been directed towards the deterministic case. De Bodt *et al.* (1984), Potts and Van Wassenhove (1992), Kuik *et al.* (1994) and Kimms (1997) work on lot-sizing techniques.

Browne and Zipkin (1991) concern with the re-order point/order quantity (*R*,*Q*) inventory model, where demand accumulates continuously, but the demand rate at each instant specified by an underlying stochastic process. The primary result is the demonstration of an insensitivity property, which characterizes the limiting behavior of the model. This property drastically simplifies the computation of the performance measures of the system. Whitin (1975) discusses a lot size reorder point system with stock-out cost criterion. Similarly, Galliher, Morse and Simond (1959) and Hadley and Whitin (1963) work on continuous lot sizing with some different assumptions. Zipkin (1986) states that all the components of the standard average cost function are convex in (R,Q). To compute an optimal policy within the lot sizing – reorder point class, therefore, one need only submit this cost function to any standard non-linear program solver.

The situation for discrete demand is markedly different. The first such algorithm was presented in Zipkin (1987) class notes; this procedure is based on an approach developed by Sahin (1982). Federgruen and Zheng (1988) have since substantially refined and clarified the algorithm.

Tarim and Kingsman (2003) use the (s,S) policy while they propose a mixed integer programming formulation to solve the stochastic dynamic lot sizing problem to optimality under the "static-dynamic uncertainty". The (s,S) policy states that replenishment is made whenever the inventory position drops to the order point s. The best (s,S) system can be shown to have total cost of replenishment, carrying inventory, and shortage no larger than those of the best (R,Q) model. Scarf (1960) and later Iglehart (1963) provide the optimality of (s,S), and Veinott and Wagner (1965) consider methods for computing optimal (s,S) polices.

Hordijk and Schouten (1986) prove the existence of an optimal (s,S) policy when there is both continuous demand and a demand according to a jump process. The optimal solution the problem is the (s,S) model with different values for each period in the time varying demand situation. Where the demand level changes slowly, it is usually satisfactory to use a steady state analysis with constant S and s values updated once in a year. However, this is appropriate if the average demand can change significantly from period to period. This presents a non-stationary problem where the two control parameter change from period to period.

2.2. Service Levels

Zeng and Hayya (1998) state that regardless of the type of the firm, the management effectiveness regarding inventory decisions centers on three areas: Cost, service level and inventory turnover ratio, as shown in Figure 2.1. The total relevant cost involves ordering and holding expenses; the service level is used to control the amount of inventory needed for satisfying customers' demand; and the inventory turnover ratio is a measure of effectiveness of inventories are being used. Lead time demand is the major reason for holding inventory and should have a significant impact on inventory decisions.

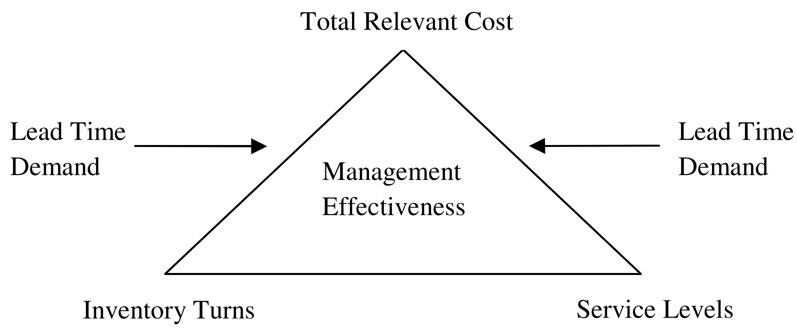


Figure 2.1. A triangle of management effectiveness regarding inventory decisions.

Recognizing the severe difficulties associated with costing shortages, a major approach is to introduce a control parameter known as *service level*. This becomes a constraint in establishing the safety stock of an item; for example, one might minimize the carrying cost of an item subject to satisfying, routinely from stock, a predetermined percentage of all demands. In fact, often in practice, an inventory manager, when queried, may say that the company policy is to provide a certain level of service and yet not be able to articulate exactly what is meant by service (Silver and Peterson, 1985).

Two service level measures are frequently employed in establishing safety stock. type-1 Service level is the probability of no stock-out during replenishment lead time, which is denoted by α. Type-2 Service level is the fraction of demand satisfied directly from shelf (also called fill rate), which is denoted by β. While there exist a number of control systems, we consider in this work an (R,Q) inventory model. As mentioned above, this system operates as follows: Whenever the inventory position drops to reorder point R, a constant production batch of Q unit is placed. Zeng and Hayya (1998) mention that this system provides simplicity, optimality for most situations, and it acts as a building block for many other complicated control policies. If reproduction point and batch size are considered as continuous variables, the formulas for α and β are given as:

$$\alpha = F(R) = \int_{0}^{R} f(x)d(x) \tag{2.2}$$

$$\beta = 1 - n(R)/Q \tag{2.3}$$

where $n(R)$ is the expected number of shortages, expressed as:

$$n(R) = \int_{R}^{\infty} (x-R)f(x)dx \tag{2.4}$$

$f(x)$ is density function of lead time demand and $F(x)$ is the cumulative distribution function of lead time demand. Here, a question arises: Are the two measures the same? Nahmias addresses that it is easier to determine the best operating policy satisfying a type-1 service level; this policy will not accurately approximate a type-2 service objective and should not be used in place of it.

What most managers mean by service level is the fill rate. In this study, we also use fill rate for the approximation of current situation and target level. Here, we describe details of firm's decision rule to determine the size of safety stock and reproduction point.

In literature, there are many studies presenting fill rate as service level constraint. As we mentioned before, Strijbosch and Moors (1998) study on periodic review fully periodic review fully back ordered order-up level system with stationary gamma distributed demand, constant lead time. One of the assumptions is that service level is fill rate. For the case that, demand parameters are known:

(i) Calculate exact safety factors, depending on three model parameter.
(ii) Present simple expressions that give nearly exact safety factors.

Tarim and Kingsman (2003) consider backordered cost with an assumption that the net inventory must not be negative. The paper presents a mixed integer programming formulation that determines both in a single giving the optimal solution for the "static dynamic uncertainty" strategy. The total expected inventory holding, ordering and direct item cost during the planning horizon are minimized under the constraint that the closing inventory in each time period will not be negative is set to at least a certain value. Vargas (1999) studies that for a model formulation with backorder costs and stationary unit production cost the exact solution can be found with the help of a shortest-path algorithm. For the same problem but with non-stationary unit production cost, Sox (1997) formulates a nonlinear mixed integer program and proposes a dynamic programming algorithm.

Many authors suggest heuristic approaches, for example, Silver *et al*. (1998) stress this point occasions. A clear example of such heuristic is presented by Ehrhardt (1979) – revised by Ehrhardt and Moiser (1984). Shore (1986) derives explicit approximate solutions for some common inventory models based on general approximations for the fractiles and the loss integral of a random variable. Platt *et al.* (1997) also stress the importance of a closed- form solution; they present “atheoretic heuristics” for the order quantity/reorder point (*Q,R*) model with the fill rate criterion and normally distributed demand.

The studies about service level mentioned above generally use a backordering assumption. Many other papers suggest approximation methodologies with a lost sales constraint. When excess demand is lost; the customer goes elsewhere to satisfy his need. This situation is most common at the retail–consumer link. For example, in big shopping centers, a person is unlikely to backorder a demand for any single item because he has various alternatives to obtain the item. In our study, we consider a service measure the where the average number of shortages per unit time and fraction of demand that is lost.

The normal distribution provides a good empirical fit the observed data, the impact of using other distributions is usually quite small, in particular, when one recognizes the other inaccuracies such as estimates of parameters of the distribution, estimates of cost factors expressed by Silver and Peterson (1998). They also comment specifically on three other distributions namely the Gamma, the Poisson, and the Laplace. As discussed by Burgin (1975), the Gamma has considerable intuitive appeal for representing the distribution of lead time demand. The distribution is not tractable as the normal; thus considerable effort should be devoted to developing approximations and tables. Burgin and Norman (1976), Johnston (1980), Taylor and Oke (1976) and Van der Ven (1981) are examples of studies using gamma distribution.

The Laplace distribution was first proposed by Presutti and Trepp (1970). Nahmias (1989)_states that a continuous distribution, which has been suggested for more variance in the tails than the normal. It has been called the pseudo-exponential distribution, as it is mathematically an exponential distribution with symmetric mirror image. He also addresses optimal (*Q,R*) policies can be found without an iterative solution. Therefore, it is because it could be a good alternative to the poisson distribution for low-demand items.

Zeng and Hayya (1998) consider exponential distribution for analyzing the performance of two popular service levels on the effectiveness in inventory control. He also uses the normal, the special weibull, and the gamma. The exponential distribution possesses appealing properties that make analysis straightforward and provide easy-to interpret results.

In this thesis, while analyzing the demand data we consider three continuous distributions: Normal, exponential and Laplace distributions.

2.3. Information Sharing

The literature on information sharing in the business press is proliferating. In this part, important insights can be obtained from analysis of the separate elements of the subject. We therefore shortly review the literature demand processes, replenishment policy and the benefits of information sharing that are related to our present study.

The end customer demand process has been modeled as either a stationary or non-stationary process. Most of the papers including Johnson and Thomson (1975), Aviv (2003), and So and Zeng (2003) have assumed the demand as a stationary process and have modeled it as an autoregressive Moving Average (ARMA) type of process of the first order. Lee *et al.* (2000a) deal with positively correlated demand in which the variance of the replenishment order at the retailer is larger than that of retail sales, and shows that the degree of variance amplification increases with an increase in the replenishment lead time. Aviv (2003) considers the demand model in which a vector autoregressive time series has been described as a linear state space form, and uses an adaptive replenishment policy. Alwan Layth *et al.* (2003) study the effect of the different forecasting models on serial supply chain with AR(1) demand. Comparison of a two level supply chain with deterministic as well as varying lead time for the AR(1) demand process have been studied by So and Zeng (2003) and the authors prove that in the case of varying lead-time, the variance in the order quantity is more in comparison to that of the deterministic lead time case.

For the non-stationary demand process, one of the most referred papers is by Graves (1999) wherein he considers the demand process as autoregressive integrated moving average (ARIMA), and shows that the net inventory in case of the non-stationary demand is more than that for the case of independent and identically distributed demand.

Agrawal *et al.* (2007) consider the impact of information sharing and lead time on the bullwhip effect and the on-hand inventory. In their model, they consider the end customer demand to be an autoregressive process of the first order, i.e., AR(1) and develop a forecasting model that a mean square error (MSE) optimal forecasting scheme is employed for the assumed AR(1) demand process.

The work of Lee *et al.* (2000b) considers a simple two level supply chain in which the demand process at the retailer is a simple autocorrelated AR(1) process. For a given AR(1) demand process, they analyze the retailer's order quantity. Then, by treating the retailer's order quantity as demand process for the manufacturer, they analyze the manufacturer's order quantity with and without information sharing. The aim of the paper is to examine the impact of the autocorrelation coefficient and lead time on the benefit of information sharing. The other inventory models that assumed AR(1) demand process include Kahn (1987) and Miller (1986).

In our current study, we used the demand process for a single product which is autocorrelated. When the underlying demand process is autocorrelated, the manufacturer can benefit from obtaining information about the demand from the retailer because it would enable more accurate forecast of future orders placed by the retailers.

Order-up-to policy minimizes the total discounted inventory carrying and shortage cost over the infinite horizon (Heyman and Sobel, 1984). Most of the papers assume periodic review order-up-to inventory replenishment policy. We also assume that our company and the retailers ordering decisions would adopt the order-up-to policy. This is a key trade off faced by the actor in a supply chain. In order to capture both aspects mentioned above, the paper develops a generalized order-up-to policy that includes a proportional controller in order to be able to alter its dynamic response.

The order-up-to policy used in studies can be considered as an adaptive policy because the order-up-to level changes from period to period. This policy also termed as myopic policy, it focuses on minimization of inventory related costs of the next single period only. Some other important study related myopic policy (Agrawal *et al*., 2007). Veinot (1965) does pioneering work in the area of myopic inventory policies for single period production/inventory problems. Ignall and Veinot (1969) consider different order-up-to policy for multi period production/inventory problems.

Uncertainties in a production distribution chain are usually buffered by inventories. To formulate an effective inventory control policy, uncertainties in the system need to be identified (Yu *et al*., 2001). This paper also addresses that in a supply chain, every member of the chain needs to make a forecast of its downstream site's product demand for its own production planning, inventory control and material requirement planning. Usually, the demand forecasting includes some uncertain terms, which can be described as demand variability. An important phenomenon observed in supply chain practices is that the variability of an upstream member's demand is greater than that of a downstream member. This effect called "bullwhip effect" was found by logistics executives at Procter & Gamble. It is largely caused by variability of ordering. To reduce the variability of ordering, information sharing in the supply chain network should be increased. Increasing vertical information sharing using Electronic Data Interchange (EDI) technology can enhance shipment performance of suppliers and greatly improve the performance of the supply chain system (Srinivasan *et al*., 1994)

Two seminal papers on the bullwhip effect are Lee *et al*. (1997a, b) which define an amplification effect as the phenomenon where orders to the suppliers tend to have a larger variance than the sales to the buyer, namely demand distortion. According to literature, this distortion propagates upstream in the amplified form, namely variance amplification. A quantitative measure of the bullwhip effect was proposed by the authors as the ratio of variance of order quantity at the echelon under consideration to the variance of demand of end customer. They identified five root causes for the amplification effect in supply chains as: (i) demand forecast updating; (ii) lead time; (iii) batch ordering; (iv) supply shortages and (v) price variations (Agrawal *et al*., 2007).

Examining how the sharing of demand information by the retailer reduces the variance of the order quantity at the upstream level when demand at the retailer level is autocorrelated over time has been studied Lee *et al*. (2000). This paper also analyzes the effects of lead times and demand process parameters such as autocorrelation coefficient on the value. This paper concludes that information sharing results inventory reduction and cost saving for the manufacture, especially when the demand is highly and positively correlated or highly variable, or when the lead time from the manufacturer to the retailer is long. For the case when autocorrelation coefficient is at zero, information sharing does not lead to inventory reduction and cost saving for the manufacturer.

Li *et al*. (2001) consider four common types of information sharing strategies for a supply chain of a single product: (i) order information sharing where every stage of the supply chain only knows the orders from its immediate downstream stage, (ii) demand information sharing where every stage has full information about consumer demand, (iii) inventory information sharing where each stage shares its inventory levels and demand information with its immediate upstream stage, and (iv) shipment information sharing where every stage shares its shipment data with its immediate upstream stage. The aim of authors is to study the effects of information sharing strategies on supply chain performance. The numerical results indicate that information sharing improves supply chain performance of overall inventory cost and fill rate when demand variability is low. In addition to this, different information sharing strategies affect different performance measures differently and may worsen some performance metrics when demand variability is high. Authors find that a hybrid information sharing strategy, which uses the demand information sharing policy in the distribution network while using the inventory information sharing policy in the supplier network, is a better strategy to improve the overall performance of a supply chain of customizable products when the variability of demand mix is high.

Yu *et al*. (2001) attempt to illustrate the benefits of supply chain partnerships with information sharing. Based on a two stage decentralized supply chain comprising a retailer and a manufacturer, modeling study and analysis have been performed to investigate supply chain member's optimal inventory policies. The partnerships between the retailer and the manufacturer are defined in terms of three information sharing levels. From the comparison results of inventory reductions and cost savings of the two members, it is deduced that Pareto improvement is achieved in respect of the entire supply chain performance. Specifically, both the retailer and the manufacturer can obtain performance improvement in terms of inventory level and cost with increasing level of information sharing. Seidmann and Sundararajan (1998) treat the level of information sharing not based on its exact content, but rather, based on the impact it has on the parties that contract to share the information. They identified four different levels of information sharing: ordering information, operational information, strategic information, and strategic and competitive information. They investigated how competition and contracting affect the nature of value sharing at each of these levels.

Chu and Lee (2005) consider a two-member supply chain that manufactures and sells newsboy-type products and comprises a downstream retailer and an upstream vendor. In this supply chain, the vendor is responsible for making stock-level decisions and holding the inventory, and the retailer is better informed about market demand. In each period, the retailer receives a signal about market demand before the actual demand is realized, and must decide whether to reveal the information to the vendor, at a cost, before the vendor starts production. This model differs from those that have been developed in previous research in one major aspect. They do not take information sharing in a supply chain for granted. Although information sharing may be beneficial to the supply chain as a whole, the better-informed party will have no incentive to share the information with the uninformed party if there is no benefit for them in doing so. The retailer bears the cost of the information sharing alone, and the passing of information from the retailer to the manufacturer is undertaken voluntarily and truthfully. The only benefit that the retailer may obtain from sharing the information is a possible increase in payoff due to the better stock level decisions that would be made by the manufacturer as a result of the information. However, such a benefit must be at least greater in value than the cost of sharing the information to justify the action. Hence, the decision of whether or not to reveal the information to the manufacturer is made strategically by the retailer.

The purpose of Cachon and Fisher (2000) show analytically how the manufacturer can benefit from using information about retailer's inventory levels when the retailers use a batch ordering policy. The purpose of this paper is to measure the value of information sharing and comparing this value to two other sources of supply chain improvement: reducing lead times and increasing delivery frequency by reducing shipment batch size. The paper states in numerical experiments with a wide range of parameter values they find that information sharing reduces supply chain costs by 2.2 per cent lower on average with the full information policy that does than with the traditional information policy, and the maximum difference is 12.1 per cent.

The reported benefits of information sharing vary considerable. Liljenberg (1996) finds that better allocation lowers supply chain costs by zero per cent to 3.9 per cent. Chen (1998) finds that supply chain costs are lowered up to nine per cent and on average by 1.8 per cent. Aviv and Federgruen (1998) report benefits of zero per cent–five per cent. In contrast, Lee *et al*. (2000) find that information sharing lowered supply chain cost by about 23 per cent highest demand nonstationarity.

Gavirni *et al*. (1999) find that information sharing is most valuable when capacity is not restrictive; information s valuable only if the system has flexibility to respond to the information. They report that sharing the retailer's demand data reduced the supplier's cost by one per cent–35 per cent (Those data are taken from the scenarios with the highest supplier capacity). The impact on the supply chain's cost would be lower because information sharing in their model has no impact on the retailer's costs.

The cost of expediting shortage from the manufacturer to the retailer may be shared by both the manufacturer and the retailer. In this thesis, we make a assumption that the cost borne solely by the manufacturer so as to isolate the benefits of information sharing to the our company. A similar assumption was made by most other researchers, such as Gavirni *et al*. (1999) and Bourland *et al*. (1996). If this assumption relaxed, then the information sharing could bring benefits to both manufacturer and the retailer, but this requires much more complex modeling of the relationship between the manufacturer and the retailer. Thus, we only compute the inventory reduction and cost saving for the manufacturer with respect to information sharing.

We also assume that shortages are backlogged. Kahn (1987) considers serial correlation in demand, and the backlogging of excess demand. The two are clearly related, since backlogs impart some serial correlation to the total demand faced by the firm. A large positive shock to demand in one period, for example, is carried over into the next period's total demand by means of backlog. The two sources are conceptually different, though, so it is useful to consider them separately. Backlogs are negligible or nonexistent in many industries that have significant serial correlation in demand.

3. PROBLEM DEFINITION AND TYPE-2 SERVICE LEVEL APPROXIMATION

In this chapter, the problem is defined first, and a type-2 service level approximation is then applied to suggest an inventory control strategy which minimizes the overall cost of the company.

3.1. Problem Definition

A brief explanation of the company and the problem are given in the introduction part. Supply chain managers realize that the company has a poor service level by the feedbacks from the customers. Gıdasa A.Ş. cannot perfectly fulfill the orders placed by the customers. Since shortages directly affect the quality of service, some of the orders are cancelled by the customer, so there are lost sales. This means that company has lower revenue than he can obtain. Moreover, the company may face another serious problem which is losing the customer. A high rate of unfilled demand will tire customers out and, since there is great competitive in retail market and customer can fulfill that order from another supplier easily. The major customer service level used by managers in the firm's supply chain directory is case fill rate, which is defined as cases of finished products shipped as a percentage of cases ordered. The company is attempting to achieve a target level of service measure for its most valuable products through efficient demand forecast and inventory control methods.

The most valuable customers of the company considered by the top management are Key Accounts namely Migros, Carrefour etc. KAs provide the biggest portion of overall orders and give greater feedback about the deliveries to the company. In addition, we only consider tea-based products because they are seen as the major problem experienced with KAs. The demand for this kind of stock keeping units is less predictable since the seasonal effect is very high. The current service level is undesirable for the company. The aim of this study is to suggest an inventory control model to scale-up the customer service level to 96 per cent which is the final target level. This target level is determined by the company managers' comments.

The reasons of the low service level can be summarized as,

(i) demand fluctuations: Mostly driven by business cycles and seasonality

(ii) volume discounts: Discounts induces distributer to order in large quantities

(iii) promotional activity: Tea Based market is very retail-driven sales environment, and on any given day one of a major retail chains might alter what they are promoting in the next term.

(iv) no maximum order quantity: Customers can order in what quantity they like.

(v) increasing product range: This is one of the biggest problem for poor service level. As the product range grows, uncertainty and volatility increase. As a result, the company looses production flexibility.

(vi) salesforce remuneration: Salesforce pushes products to meet monthly or quarterly targets and end of canvass period.

(vii) poor communication: Sales figures are distorted as they pass along the supply chain. Only the retailers know true demand coming from consumers. The underlying demand certain but it is distorted by the supply chain.

3.2. Base Model

In this section, we specify the terminology and the assumptions which are used to model a lot-sizing service level model approximation with a predetermined constant service constraint. The terminologies are derived from the literature review and all assumptions are harmonious with Nahmias (1989) book.

3.2.1. Modeling Assumptions

We make the following assumptions:

1. The system is continuous review. That is demands are recorded as they occur, and the stock level is known at all times.

2. Unsatisfied demand is lost.
3. All tea-based products are carried by a cargo company from the factory warehouse to KAs' depots. The delivery time is constant, that is one day. Thus, the orders are dispatched from factory one day before the certain due date. Since this process has worked well for a long time and there are no complaints by KAs, the following assumptions are done: The carrier works well in harmony with the company. Hence, if all the products are ready one day before the due date in the warehouse, that order is assumed to be fulfilled on time. Thus, the risks that might be born during transportation are neglected.

Holding Cost: Annual unit inventory holding cost includes cost of money, loss (damage, pilferage etc.), and handling administration insurance.

Shortage Cost: Annual stock out cost per unit unsatisfied demand including profit loss and long term losses.

Setup Cost: The obvious cost that it takes to setup the machines to start making a new product.

Lead Time: Response time of the firm to the retailer's orders. It is assumed to be a fixed positive time.

3.2.2. Service Level Model

Customer service has been considered one of the most important factors for a firm's survival and growth. In inventory control, providing a superior level of customer service becomes more important and difficult when suppliers' lead time and the demand process is variable. Since, the availability of goods directly affects the quality of service, quite often a company needs to invest in safety stock when making inventory decisions. However, the high cost of holding safety stock and the objective of achieving a desired level of service present a dilemma for the managers that cannot be dealt with easily (Zeng, 2000).

Here, we consider a single item, single stage (R,Q) inventory control system, where R is the reproduction point and Q is the fixed production quantity. The type-2 service level, also known as the fill rate, is an inventory model which measures the proportion of demands that are met from stock. It can be defined as:

Fill rate = 1 –(expected number of stock outs per cycle / total number of units demanded per cycle). Hence we can write the following expression

$$n(R) = EPQ(1-\beta) \tag{3.1}$$

where *EPQ* is the economic production quantity and $n(R)$ is the expected number of shortages in a cycle.

This expression can be used for all kinds of demand distributions. In the literature, even though the normal distribution takes the lion share, there also exist models with other distributions. After analyzing the demand, we realized that stock keeping units have different distributions such as normal, exponential, and Laplace. Now, we discuss the type-2 service level for these three different demand distributions.

The general notation used in the approximation model:

Capacity *(p)* : Maximum production amount in one week

Demand/week *(d)* : Average weekly demand placed from KAs

Sigma *(σ)* : Standard deviation of weekly demand distribution

Demand/ Year *(D)* : Mean rate of demand per year placed from KAs

Holding Cost *(h)* : Unit holding cost per year

Setup Cost *(K)* : Setup cost per cycle

Penalty Cost *(P)* : Stock-out cost per unit of lost sales

EPQ : Economic production quantity

SPQ : Service production quantity

Before defining service level methodology, first, we mention about a base model namely economic production quantity. Since Gıdasa A.Ş. is a production company, the inventory accumulates as internal orders. Economic production quantity model (*EPQ*) is an extension of the economic order quantity model. The difference is that the *EPQ* model assumes orders are received incrementally during the production process. The function of this model is to balance the inventory holding cost and the average fixed production cost. Thus, an economic production quantity model was used for a base inventory management method.

$$Q = \sqrt{\frac{2KD}{h\left(1-\frac{d}{p}\right)}} \tag{3.2}$$

<u>3.2.2.1 Fill Rate with Normal Demand.</u> Optimal (R,Q) lot-sizing policies subject to type-2 service level with a normal demand process can be performed with the following formulas. Penalty cost can be driven as follows, where $F(X)$ is cumulative probability of normal distribution demand.

$$P = Qh / \left((1-F(R))D\right) \tag{3.3}$$

Derivation of this formula is detailed in (Nahmias, p. 296). Under fill rate constraint, the penalty cost is eliminated. Therefore P can be substituted in the lot size formula:

$$Q = \frac{n(R)}{1-F(R)} + \sqrt{\frac{2KD}{h\left(1-\frac{d}{p}\right)} + \left(\frac{n(R)}{1-F(R)}\right)^2} \tag{3.4}$$

Equation (3.4) is called service production quantity formula SPQ. This equation is simultaneously solved with equation (3.1). Number of shortages can be computed by using standardized loss function $L(z)$ when the demand is distributed normally. The standardized loss function is defined:

$$L(z) = \int_z^\infty (t-z)\phi(t)dt \tag{3.5}$$

where $\phi(t)$ denotes the standard normal density. In this thesis we use the following formulas to determine $L(z)$:

$$L(z)=\int_{z}^{\infty} t\phi dt - z\left(1-\phi(z)\right)=\phi(z)-z\left(1-\phi(z)\right) \tag{3.6}$$

Equation (3.5) is derived from the definition of the cumulative distribution function, and Equation (3.6) is a consequence of a well-known property of the normal distribution.

$$L(z)=n(R)/\sigma = Q(1-\beta)/\sigma \tag{3.7}$$

By using Equations (3.6) and (3.7), z parameter is obtained. Then, reproduction point can be defined as

$$R=\sigma z+d \tag{3.8}$$

The solution procedure is started by defining $Q_0 = EPQ$. Then, $n(R)$ and $L(z)$ are calculated by using (3.1) and (3.7). In the next step, by using normal distributions table define z, is defined and calculate R is calculated by using (3.8). The second iteration starts with calculation of *SPQ* and goes on. The process terminates when two successive values of Q and R are close enough.

When the proportion of *setup cost / holding cost per unit* (*K/h*) is very high, the model suggests larger lot size *(Q)*. Thus, $L(z)$ grows rapidly. This yields a negative z value. Moreover, the negative z value can cause a negative reproduction point. In that case, reproduction point is fixed at value zero, with an assumption that the net inventory must not be negative. Generally, this situation occurs while there is very low customer service level. The major reason is that as $(1-\beta)$ increases, the expected number of shortages becomes larger. The annual costs are calculated as follow.

The annual holding cost $= h\left[\frac{Q}{2}+R-d\right]$ (3.9)

The annual setup cost $= KD/Q$ (3.10)

The annual stock out cost $= PDn(R)/Q$ (3.11)

In this study, in order to compare overall inventory cost of the target level with the approximate current situation's cost, we assign a penalty cost per unit (*P*). Hence, the annual shortage can be determined with fill rate constraint.

3.2.2.2 Fill Rate with Exponential Demand. Since the normal is an infinite distribution, when the mean is small it is possible that a substantial portion of density curve extends into the negative half line. This could give poor results for safety stock calculations. Another choice for modeling slow moving items is the exponential distribution which is a continuous distribution and defined on the positive half line only.

The expected number of shortages can be expressed as:

$$n(R) = E\left(\max\left((D-R),0\right)\right) = \int_R^\infty (x-R) f(x) dx \tag{3.12}$$

The demand distribution is exponentially distributed with the density function $f(x) = \lambda e^{-\lambda x}$ and cumulative distribution function $F(x) = 1 - e^{-\lambda x}$ with exponential rate λ .

Thus, the number of shortages for is formulated as

$$n(R) = \int_R^\infty (x-R)\lambda e^{-\lambda x} dx \tag{3.13}$$

The integration of Equation (3.13) is quite easy:

$$n(R) = \frac{1}{\lambda} e^{-\lambda R} = EPQ(1-\beta) \tag{3.14}$$

By solving (3.14) and cumulative density function of exponential distribution simultaneously, reproduction point can be defined as follows

$$R = \left[-\ln\left(\lambda n(R)\right)\right] / \lambda \tag{3.15}$$

$$Q = \frac{n(R)}{1-F(R)} + \sqrt{\frac{2KD}{h\left(1-\frac{d}{p}\right)} + \left(\frac{n(R)}{1-F(R)}\right)^2} \tag{3.16}$$

This models works quite easy. Again, the calculation is started with $Q_0 = EPQ$. Then $n(R)$ is computed by (3.14) and, reproduction point is found by using (3.15). The process continues with determination of *SPQ* and $n(R)$ in an iterative way. Until Q and R values are close enough to their previous values.

In an exponential demand process, batch size Q is independent of the customer service level. This is because $n(R)/[1-F(R)]$ ratio is constant and equals to $1/\lambda$ independent of R with positive reproduction point. Similar to normal demand, when the proportion of *setup cost / holding cost per unit* (*K/h*) is so high, the method states larger lot size Q. Hence, R can drop to negative. Because of the rule that that reproduction point cannot be negative, we set it to zero when it drops to negative.

3.2.2.3. Fill Rate with Laplace Demand Process The Laplace distribution has been called the pseudo–exponential distribution, as it is mathematically an exponential distribution with a symmetric mirror image around mean. It has more variance in tails than the normal distribution. Its pdf is

$$f(x) = 1/2\theta \exp\left(-|x-\mu|\right)/\theta \qquad \text{for} \qquad -\infty < x < \infty$$

It can be easily shown that the mean of the Laplace distribution is μ. The variance is $2\theta^2$. Presutti and Trepp (1970) noticed that it significantly simplifies the calculation of optimal policy for the *(R,Q)* model. The complementary cumulative distribution $1-F(R)$ and the loss integral $n(R)$ are given by

$$1-F(R) = 0.5\exp\left(-[(R-\mu)/Q]\right) \tag{3.17}$$

$$n(R) = 0.5\theta\exp\left(-[(R-\mu)/Q]\right) \tag{3.18}$$

Thus, reproduction point can be determined by

$$R = -\theta \ln\left(2\left(1 - F(R)\right)\right) + \mu \tag{3.19}$$

The ratio $n(R)/\left[1 - F(R)\right] = \theta$ is a constant value like in exponential distribution, which is independent of *R*. The service production quantity representation for lot size *Q* that does not include penalty cost per unit, is given by

$$Q = \frac{n(R)}{1 - F(R)} + \sqrt{\frac{2KD}{h\left(1 - \frac{d}{p}\right)} + \left(\frac{n(R)}{1 - F(R)}\right)^2} \tag{3.20}$$

$$Q = \theta + \sqrt{\frac{2KD}{h\left(1 - \frac{d}{p}\right)} + \left(\theta\right)^2} \tag{3.21}$$

Lot-size is not dependent reorder point. Notice that, the optimal lot size and reproduction point can be calculated in one-step. First, lot size *Q* is calculated by (3.21). Then, compute the reproduction point *R* is computed by Equation (3.19).

3.3. Collection of Data

3.3.1. Data Collection Procedure

The data collection procedure is summarized as

a) The 2006 annual revenue of the company is provided. This set of data includes the sales amount of each SKU in YTL of both “water” and “tea” divisions. We consider values for the tea based products that consists of approximately 150 different stock keeping units.

b) The weekly demand rates by KAs for a single product between January 2006 and May 2007 are obtained.

c) In order to standardize the calculations, “case” is defined as a unit.

d) The number of orders in which there is stock-out is obtained from the system. Then, the proportion of orders in which there is no shortage is determined.

e) The total number of unfilled cases is recorded in the system. The average day of shortages are calculated from the data for each single product.

f) The Response time is the reorder lead time. Generally, KAs give the orders weekly. This information is not recorded in the computer system. We determine the lead time after interviewing with customer representatives, logistic department etc. Moreover, the production planning is handled in weekly periods. Thus, in this study we assume lead time as a fixed and one week.

g) Unit cost, unit weight, and unit profits of each single product are obtained from the system.

Table 3.1. Unit cost, unit weight, and unit profits of products

PRODUCTS	Cost of Product YTL/kg	Unit Weight (kg)	Unit Cost (YTL)	Unit Profit (YTL)
POURED 1000gr * 9	4.60	9.00	41.40	3.73
THIN GLASS 1000gr *9	4.18	9.00	37.62	3.37
TEA BAG 6*100	14.89	1.20	17.87	3.60
TEA POT BAG 6*100	9.01	1.92	17.30	2.57
TEA POT BAG 12*48	9.82	1.84	18.10	2.23
EARL GREY TEA POT BAG 6*100	10.21	1.92	19.60	3.04
FORM TEA 12*20	17.08	0.48	8.20	2.98
SPECIAL FOR WOMEN 12*20	21.00	0.48	10.08	2.88
EARL GREY TEA POT BAG 12*48	10.46	1.84	19.28	2.75
FORM WITH LINSEED	23.11	0.36	8.32	2.54

3.3.1.1. Determination of the Unit Holding Cost. Inventory holding cost includes cost of money, loss (damage, pilferage etc), and handling administration insurance. Annual interest rate is assumed to be I = 0.2. Furthermore, the company has paid rent for extra storage places to protect “tea-based product”.

Table 3.2. Extra storage cost per unit

PRODUCTS	# Cases in a Pallet	Cost (YTL/m^2)	Storage Cost (YTL/Case)
POURED 1000gr * 9	56 Cases	46.7	0.807
THIN GLASS 1000gr *9	56 Cases	46.7	0.807
TEA BAG 6*100	104 Cases	86.7	0.435
TEA POT BAG 6*100	120 Cases	100.0	0.377
TEA POT BAG 12*48	120 Cases	100.0	0.377
EARL GREY TEA POT BAG 6*100	120 Cases	100.0	0.377
FORM TEA 12*20	192 Cases	160.0	0.236
SPECIAL FOR WOMEN 12*20	192 Cases	160.0	0.236
EARL GREY TEA POT BAG 12*48	121 Cases	100.8	0.374
FORM WITH LINSEED	192 Cases	160.0	0.236

Approximately 15,500 YTL/month is being paid for 5,000 m^2 storage area that is 37.6 YTL per m^2 per year. Extra cost for per SKU is derived in the Table 3.2. First column shows the number of cases stowed in a pallet. The other columns display the storage cost per m^2 and unit storage, respectively. Therefore, an extra cost is added to the inventory holding cost. Hence, we calculate annual unit inventory carrying cost by the formula

$$h = Ic + \textit{Extra Warehouse rent per case} \qquad (3.22)$$

where c and I are unit cost of a single product and annual interest rate, respectively.

<u>3.3.1.2 Determination of the Unit Penalty Cost.</u> The percentage of lost sales over all shortages is computed from recorded data in the computer system. By the help of SAP system, we obtain the number of lost sales, which are the returned orders *due to late delivery and the orders that do not leave the factory because of not meeting a certain due date*. Unit profit per case is obtained from the. The penalty cost per unit is calculated as

$$P = \textit{Profit per case} + \textit{long term losses per case} \qquad (3.23)$$

In this thesis we assume long term losses are equal to zero and one unit profit per cases. To show the impact of penalty cost, we calculate the annual stock-out cost for two cases when the value of long term losses equals to zero and equals one unit profit.

3.3.1.2 Determination of Setup Cost per Cycle. The obvious cost is the time that it takes to setup the machines to start making a new product. There is some question as to whether the productive time lost during a setup is part of the cost or not. However, in this study, we assumed that it is not a part of the setup cost.

$$K = \textit{Setup time} * \textit{Production capacity of machine} * c \qquad (3.24)$$

3.3.2. Determining the Products and Current Service Levels

First, the revenue of the company in 2006 is analyzed. Since, the SAP system is introduced to utilize in 2005, the most reliable data can be obtained in 2006 from the system. Also, according to this data 10 of tea-based products are determined to be studied on. These are the most valuable tea-based products of the company that have approximately 50 per cent of the overall revenue. Hence, it is reasonable to work with these stock keeping units to represent the overall inventory system.

At the end of this section, we give a comparison with overall cost in current situation (that is approximated by using the fill rate) and overall cost in target customer service situation. Thus, the current customer service level should be measured. Here, to measure the customer service of the company for a single item, two types of service are considered, namely type-1 and type-2, respectively.

Type-1 Service Level (α): Probability of no stock out during replenishment lead time.

$$\alpha = F(R) = \int_{R}^{\infty} f(x)dx \qquad (3.25)$$

where $f(x)$ denotes the density function of demand distribution. To compute the service level with type-1 constraint, we find first the fraction of orders in which there is stock-out. Then, the complementary of this value equals to the type-1 customer service level.

Type-2 Service Level (β): Fraction of demand satisfied directly from the stock is found by $1 - n(R)/Q$ where $n(R)$ and Q denote the number of shortages and order size, respectively as mentioned in section 3.2.2. The total number of units that resulted in shortages is found from data recorded in the system. Hence, the proportion of total shortages over the total demand is the type-2 service level of the company. The current customer service levels by the company are given in Table 3.3.

Table 3.3. Service levels subject to type-1 and type-2 service

PRODUCTS	TYPE 1 Level of Service (%)	TYPE 2 Level of Service (%)
POURED 1000gr * 9	88	81
THIN GLASS 1000gr *9	92	93
TEA BAG 6*100	86	80
TEA POT BAG 6*100	90	89
TEA POT BAG 12*48	91	94
EARL GREY TEA POT BAG 6*100	82	84
FORM TEA 12*20	83	85
SPECIAL FOR WOMEN 12*20	87	90
EARL GREY TEA POT BAG 12*48	80	83
FORM WITH LINSEED	74	78

There is a significant difference between two types of service levels. Generally, type-1 measures the customer service lower than the type-2 service level. Because, type-1 service level considers no stock-out per replenishment period. Thus, most managers believe that the fill rate gives a better view of the problem.

In this study, we use only the type-2 service level while defining the problem and suggesting an approximation method. In the literature, most studies use the fill rate as part of the inventory decision making. In addition to this, some other reasons for employing the fill rate are

(i) If an order is certainly going to be delivered late, it is not sent from the factory to the customer. The products wait in the factory warehouse. Hence, the cases belong the unsent orders can be input for the next orders.

(ii) Rejected orders by KAs return to factory warehouse, thus, these stocks can be used for the next orders.

3.4. Determination of the Demand Distribution

In literature, the demand distribution can be obtained in at least two ways. One way is to observe a set of real data from firm's records and use a probability distribution to fit those data. The other is accomplished by convolution of the respective distributions of the demand and lead time obtained from real data (Zeng, 2000). Here, we apply the former method. After determining weekly demand for each single product, probability distribution of each SKU should be decided. After the analyzing demand data, we realize that in addition to the normal distribution, some stock keeping units' have distributions such as exponential, Laplace and gamma. In this thesis, we do not consider gamma distribution due to its calculation difficulties.

3.4.1. Analyzing the Data and Significance Tests

In order to fit the best demand distribution, we use *Easy Fit* which is a data analysis and simulation software allowing fitting probability distributions to sample data, select the best model, and apply the analysis results to make business decisions. The obtained

Table 3.4. Fitted distributions and statistics

PRODUCTS	**Distribution**	**Parameters**	
		Mean	**Std** (σ)
POURED 1000gr * 9	Normal	2482	1214
TEA BAG 6*100	Gamma	388	352
TEA POT BAG 6*100	Normal	292	110
TEA POT BAG 12*48	Normal	321	191
EARL GREY TEA POT BAG 6*100	Normal	153	80
FORM TEA 12*20	Normal	112	73
FORM WITH LINSEED	Laplace	129	103
		λ	
SPECIAL FOR WOMEN 12*20	Exponential	0.0077	
EARL GREY TEA POT BAG 12*48	Exponential	0.00687	
THIN GLASS 1000gr *9	Exponential	0.000202	

By analyzing the real data, the demand processes are fitted to the appropriate distributions. The software states the distributions from the best fitted to the worst one. We choose the available distribution model by taking into account both significance test and calculation difficulties. This means that the distribution fitted in the first rank by the software is not always chosen as the appropriate model, directly. Normal, exponential and Laplace distribution models are preferred on the condition that they pass from the goodness of fit tests with a 0.05 significance level. Moreover, with easy fit we could carry out Kolmogorov–Smirnov; Anderson Darling; Chi-Squared tests to determine which form of the distribution best reflects the demand pattern.

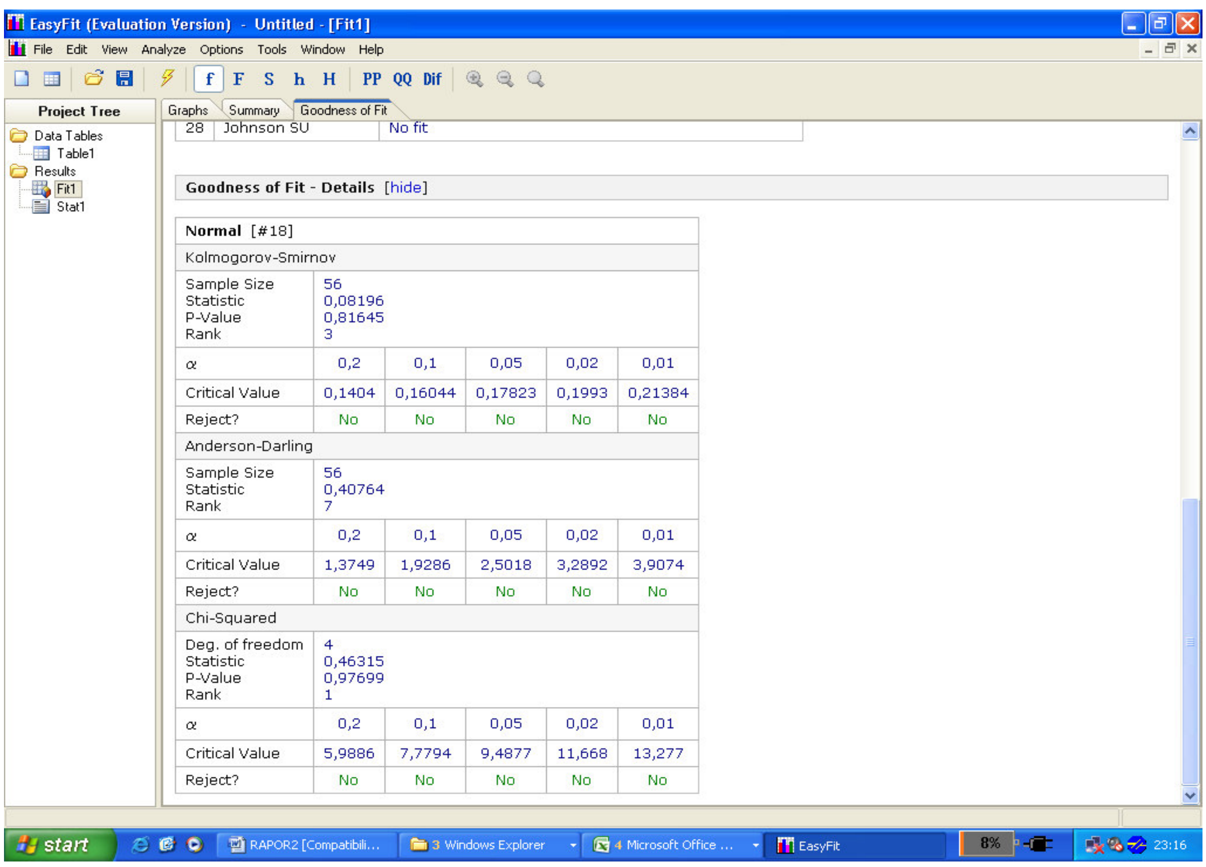


Figure 3.1. Output of goodness of-fit-test

Figure 3.1. displays the three famous goodness-of-fit-test (GOF) methods, and their statistics and outputs carried out by the software. In order to determine the significance, a hypothesis test is implemented at different significance levels where test statistics are

computed by the software. The software output also demonstrates the rank of the fitted distribution.

According to the specific features of selected goodness-of-fit-tests, we decide whether the fitted distribution is appropriate for the demand pattern or not. The decision rule is that if the critical value is bigger than the test statistic, null hypothesis is rejected. Hence, the data follow specified distribution.

3.4.1.1 Kolmogorov – Smirnov Test This test is used to decide if a sample comes from a hypothesized continuous distribution. The empirical CDF is denoted by

$$F_n(x) = \frac{1}{n}\left[Numberofobservations \leq x\right] \tag{3.26}$$

The Kolmogorov-Smirnov statistic *(D)* is based on the largest vertical difference between the theoretical and the empirical cumulative distribution function.

$$D = \max_{0 \leq x \leq 1}\left[F(x_i) - \frac{i-1}{n}, \frac{i}{n} - F(x_i)\right] \tag{3.27}$$

H_0 : The data follow the specified distribution

H_1 : The data do not follow specified distribution

The null hypothesis regarding the distributional form is rejected at the chosen significance level α if the test statistic D is greater than the critical value obtained from a table.

3.4.1.2 Anderson–Darling Test The Anderson-Darling procedure is a general test to compare the fit of an observed cumulative distribution function to an expected cumulative distribution function.

$$A^2 = -n - \frac{1}{n}\sum_{1}^{n}(2i-1)\left[\ln F(x_i) \ln F(x_{n-i+1})\right] \tag{3.28}$$

The null hypothesis regarding the distributional form is rejected at the chosen significance level α if the test statistic A^2 is greater than the critical value obtained from table.

<u>3.4.1.3 Chi–Square Test</u> This test is applied to binned data, so the value of the test statistic depends on how the data is binned. This goodness of fit test is available for continuous sample data only. Although there is no optimal choice for the number of bins (*k*), there are several formulas which can be used to calculate this number based on the sample size (*N*). For instance, in our study, we employ the formula by using Easy Fit $k = 1 + \log_2 N$

The data can be grouped into intervals of equal probability. The Chi-Squared statistic is defined as

$$x^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)}{E_i} \tag{3.29}$$

where O_i denotes the observed frequency for bin *i*, and O_i is the expected frequency for bin *i* calculated by

$$E_i = F(x_2) - F(x_1) \tag{3.30}$$

where *F* denotes the CDF of the probability distribution being tested, and x_1 and x_2 are the limits for bin *i*.

H_0: The data follow specified distribution

The null hypothesis is rejected at the chosen significance level α, if the test statistic is greater than the critical value defined as $\chi^2_{1-a,k-1}$ that is meaning the Chi-Squared inverse CDF with *k*-1 degrees of freedom and a significance level of α. Though the number of degrees of freedom can be calculated as *k*-*c*-1 (where *c* is the number of estimated parameters), in this study, Easy Fit calculates it as *k*-1 since this kind of test is less likely to reject the fit in error. Table below displays the summary of test statistics, and decision criteria for each single product which is obtained from the software.

Table 3.5. Summary of test statistics for $\alpha = 0.1$ and $\alpha = 0.05$

		α = 0.1			α = 0.05		
PRODUCT		**Kolmogorov Smirnov**	**Anderson Darling**	**Chi-Squared**	**Kolmogorov Smirnov**	**Anderson Darling**	**Chi-Squared**
POURED 1000gr * 9	Test statistic	0.08196	0.40764	0.46315	0.08196	0.40764	0.46315
	Critical Value	0.16044	1.9286	7.7794	0.17823	2.5018	9.4877
	Null Hypothesis Reject?	No	No	No	No	No	No
THIN GLASS 1000gr *9	Test statistic	0.09974	1.0324	5.8702	0.09974	1.0324	5.8702
	Critical Value	0.15144	1.9286	9.2364	0.16823	2.5018	11.07
	Null Hypothesis Reject?	No	No	No	No	No	No
TEA BAG 6*100	Test statistic	0.06487	0.3785	2.5798	0.07896	0.42329	2.8729
	Critical Value	0.15144	1.9286	9.2364	0.16823	2.5018	11.07
	Null Hypothesis Reject?	No	No	No	No	No	No
POT BAG 6*100	Test statistic	0.08806	0.49293	3.0034	0.08806	0.49293	3.0034
	Critical Value	0.15144	1.9286	9.2364	0.16823	2.5018	11.07
	Null Hypothesis Reject?	No	No	No	No	No	No
TEA POT BAG 12*48	Test statistic	0.11347	0.69242	0.65843	0.11347	0.69242	0.65843
	Critical Value	0.15385	1.9286	7.7794	0.17091	2.5018	9.4877
	Null Hypothesis Reject?	No	No	No	No	No	No
EARL GREY TEA POT BAG - 6*100	Test statistic	0.04888	0.20144	0.64063	0.04888	0.20144	0.64063
	Critical Value	0.15263	1.9286	9.2364	0.16956	2.5018	11.07
	Null Hypothesis Reject?	No	No	No	No	No	No
FORM TEA 12*20	Test statistic	0.09215	0.83647	2.0168	0.09215	0.83647	2.0168
	Critical Value	0.15027	1.9286	9.2364	0.16693	2.5018	11.07
	Null Hypothesis Reject?	No	No	No	No	No	No
SPECIAL FOR WOMEN 12*20	Test statistic	0.10752	0.80987	3.1382	0.10752	0.80987	3.1382
	Critical Value	0.15144	1.9286	9.2364	0.16823	2.5018	11.07
	Null Hypothesis Reject?	No	No	No	No	No	No
EARL GREY TEA POT BAG- 12*48	Test statistic	0.04302	0.10343	1.0742	0.04302	0.10343	1.0742
	Critical Value	0.15144	1.9286	9.2364	0.16823	2.5018	11.07
	Null Hypothesis Reject?	No	No	No	No	No	No
FORM WITH LINSEED	Test statistic	0.11956	1.6487	4.3292	0.11956	1.6487	4.3292
	Critical Value	0.14381	1.9286	9.2364	0.15975	2.5018	11.07
	Null Hypothesis Reject?	No	No	No	No	No	No

3.5. Computational Results

In this section, we introduce the numerical results of our computational experiments performed by using a type-2 service level approximation for the current customer level and target level. In addition, we present our comments on the results.

3.5.1. Approximation with Type-2 Constraint

We use the methodology that is mentioned in section 3.2.2 for each single product regarding their demand pattern. First, we attempt to define the decision rule for the current situation. It was crucial because we need to determine the annual shortage cost, annual inventory holding cost and setup cost in a cycle. However, the only data that we have are the demand patterns and service measures of a single product. Thus, we use the approximation subject to the fill rate constraint to determine the decision rule parameters reproduction point and batch size quantity.

Service level is defined as a substitute for a stock out cost. The purpose of type-2 service level is that people cannot determine the exact value for the stock out cost. However, in this thesis, we assign a unit penalty cost after the determination of decision rule parameters of inventory control policy to compute the annual overall cost. This method is applied both for the current level and the predetermined target level; hence, the effectiveness of suggested inventory control method can be perceived and compared numerically.

Here, we make a general discussion about numerical results. Intuitively, we would expect that the required safety stock (reproduction point) would increase if service level β increased and production batch size Q decreased. This behavior could be explained as that from Equation (3.7), a better customer service leads to decrease in standardized loss function $L(z)$. Hence, a decrease in $L(z)$ implies an increase in z, so higher safety stock required by Equation (3.8), that is, exactly the desired behavior. Thus, a higher annual holding cost and, a higher setup cost desirable. Our numerical results support the discussion above; furthermore, discussions are unsurprisingly valid not only for normal demand process but also for exponential demand and Laplace demand since results are not dependent on distribution.

Below, the computational results for each of nine single SKUs are summarized by two tables one is input parameters and the other is decision rule parameters. The second row of second table displays the *lot-size* for type-2 service level for the current level approximation and target level. The third row exhibits reproduction point of each cycle. The other rows show annual holding cost, annual setup cost and annual shortage cost.

1. Poured 1000gr * 9

The Tables 3.6. and 3.7. show the summary of parameters that we use in our calculations and the cost comparison of target level and approximate current level, respectively.

Table 3.6. Summary of parameters of Poured 1000gr*9

Production rate/week	P	14,616
Demand/week	d	2,482
Demand/year	D	129,064
Holding cost/unit	H	9.09 YTL
Setup cost/cycle	K	1,800 YTL
Standard deviation	σ	1,214

The demand process of "Poured 1000gr*9" is normally distributed with mean 2,482 and standard deviation 1,214. This product has the highest sale volume among the all SKUs that is approximately 130,000 cases in a year. We can realize that the setup cost in a cycle is very high compared to unit holding cost. This can be explained as that the production rate is very high so unproduced products during the machine setup time is considerable.

Table 3.7. Comparison of target level and current level of Poured 1000gr*9

		$P = 2.98$			$P = 5.96$		
		Approximate Current Service Level	**Target Service Level**	**Current vs. Target (%)**	**Approximate Current Service Level**	**Target Service Level**	**Current vs. Target (%)**
Service level	β	β = 0.81	β = 0.96		β = 0.81	β = 0.96	
Lot size	Q	9,500	8,720		9,500	8,720	
Reproduction point	R	0	2,786		0	2,786	
Holding cost/year	$h[Q/2+R-d]$	20,608 YTL	42,375 YTL	106	20,608 YTL	42,375 YTL	106
Setup cost/year	KD/Q	24,467 YTL	26,656 YTL	9	24,467 YTL	26,656 YTL	9
Stock-out/year	$PDn(R)/Q$	73,076 YTL	7,692 YTL	-89	146,152 YTL	15,384 YTL	-89
TOTAL COST		118,151 YTL	76,724 YTL	-35	191,227 YTL	84,415 YTL	-56

In section 3.3.1.2 we mentioned about determination of unit penalty cost. It is assumed to be unit profit lost plus long term losses. In this study, we calculate the annual stock-out cost for two cases, when value of long term losses equals zero and equals one unit profit. The profit of "Poured 1000gr*9" is 3.73 YTL per case. Therefore, annual stock-out cost is calculated for P = 2.98 YTL and P = 5.96 YTL. The target service level suggests that company should carry more inventories. The annual holding cost of target level is more than two times of current situation. Furthermore, annual setup cost is slightly increasing with a better service level. While these costs increase, the annual shortage cost decreases. Our numerical experiments show annual overall cost reduction is 35 per cent while P = 2.98 and 56 per cent while P = 5.96, that are approximately 42,000 YTL and 107,000 YTL respectively.

Table 3.8. Comparison of model and real data of Poured 1000gr*9 for the current situation

	Model	**Real data**	**Diff. (%)**
Average inventory level (case)	2,750	2,390	13
Total number of lost sales (case)	23,130	24,512	-5

For the current situation our inventory control model approximates the average inventory level 2,750 cases. However, the real data reflects that the average inventory level is 2,390 cases. The difference results from low customer service level. We set reproduction point at zero while it goes to negative, so that we are overestimating the true value of average inventory level.

2. Thin Glass 1000gr *9

Table 3.9. Summary of parameters of "Thin glass 1000gr *9"

Capacity	*P*	14,616
Demand/week	*d*	495
Demand/year	*D*	25,740
Holding cost/unit	*H*	7.52 YTL
Setup cost/cycle	*K*	1,636.47 YTL
	λ	0.000202

The overall demand per year of this type of product is less than "Poured 1000gr*9". However, it is still one of the most popular types of product. The demand process is distributed exponentially therefore standard deviation of demand rate approximately equals to the mean.

Table 3.10. Comparison of target level and current level of "Thin glass1000gr *9"

		$P = 3.37$			$P = 6.74$		
		Approximate Current Service Level	**Target Service Level**	**Current vs. Target (%)**	**Approximate Current Service Level**	**Target Service Level**	**Current vs. Target (%)**
Service level	β	$\beta = 0.92$	$\beta = 0.96$		$\beta = 0.92$	$\beta = 0.96$	
Lot size	*Q*	3,935	3,935		3,935	3,935	
Reproduction point	*R*	224	567		224	567	
Holding cost/year	$h[Q/2+R-d]$	13,665 YTL	15,347 YTL	12	13,665 YTL	15,347 YTL	12
Setup cost/year	KD/Q	10,704 YTL	10,704 YTL	0	10,704 YTL	10,704 YTL	0
Stock-out/year	$PDn(R)/Q$	6,940 YTL	3,470 YTL	-50	13,879 YTL	6,940 YTL	-51
TOTAL COST		31,309 YTL	29,421YTL	-7	38,248 YTL	32,991 YTL	-13

Unit profit of this SKU is 3.37 YTL. Although the current customer service for "Thin Glass 1000gr*9" is not very low, our inventory model offers seven per cent overall cost reduction when P = 3.37 and 13 per cent when P = 6.74. Since the lot size Q is independent with customer service level for the exponential demand pattern, setup cost does not change with increasing service level.

Table 3.11. Comparison of model and real data of Thin Glass 1000gr*9 for the current situation

	Model	Real data	Diff. (%)
Average inventory level (case)	1,815	1,779	2
Total number of lost sales (case)	1,769	1,817	-3

Our average inventory and total lost sale approximation is reasonably accurate. The real data and approximated values are very close.

3. Tea Pot Bag 6*100

Table 3.12. Summary of parameters of "Tea Pot Bag 6*100"

Production rate/week	P	5,880
Demand/week	d	292
Demand/year	D	15,184
Holding cost/unit	H	3.00 YTL
Setup cost/cycle	K	188.16 YTL
Standard deviation	σ	110

The production rate of "Tea Pot Bag 6*100" is less than the other types of products exactly due to the machine features. This capacity constraint also reduces the setup cost per cycle that is 188 YTL per cycle. The demand process is normally distributed with a low standard deviation which is less than half of the mean.

The table below states that our model suggests a 24 per cent cost reduction while offering seven per cent customer service improvement when penalty cost equals to the unit profit. If the company wants to achieve these benefits for a single product, it should pay 800 YTL more for holding "Tea Pot Bag 6*100" inventories.

Table 3.13. Comparison of target level and current level of "Tea Pot Bag 6*100"

		$P = 2.57$			$P = 5.14$		
		Approximate Current Service Level	**Target Service Level**	**Current vs. Target (%)**	**Approximate Current Service Level**	**Target Service Level**	**Current vs. Target (%)**
Service level	β	$\beta = 0.89$	$\beta = 0.96$		$\beta = 0.89$	$\beta = 0.96$	
Lot size	Q	1,547	1,526		1,547	1,526	
Reproduction point	R	0	268		0	268	
Holding cost/year	$h[Q/2+R-d]$	1,342 YTL	2,112 YTL	57	1,342 YTL	2,112 YTL	57
Setup cost/year	KD/Q	1,781 YTL	1,873 YTL	5	1,781 YTL	1,873 YTL	5
Stock-out/year	$PDn(R)/Q$	3.114 YTL	780 YTL	-74	6,228 YTL	1,561 YTL	-74
TOTAL COST		6,237 YTL	4,765 YTL	-24	9,351 YTL	5,546 YTL	-40

Table 3.14. Comparison of model and real data of Tea Pot Bag 6*100 the current situation

	Model	**Real data**	**Diff. (%)**
Average inventory level (case)	724	672	7
Total number of lost sales (case)	1,090	1147	-5

The real data show that our computations are quite accurate and thus are useful for overall cost approximations.

4. Earl Grey Tea Pot Bag 6*100

Table 3.15. Summary of parameters of "Earl Grey Tea Pot Bag 6*100"

Production rate/week	P	5,880
Demand/week	d	143
Demand/year	D	7,436
Holding cost/unit	H	4.30 YTL
Setup cost/cycle	K	343.06 YTL
Standard deviation	σ	73

The raw material of this type of product is slightly more expensive than the other tea-based products. Thus, its unit holding cost is 1.3 YTL higher than that the unit holding cost of "Tea Pot Bag 6*100". This SKU is one of the slow moving products among these 8 products whose annual demand is approximately 7,500 cases.

Table 3.16. Comparison of target level and current level of "Earl Grey Tea Pot Bag 6*100"

		$P = 3.04$			$P = 6.08$		
		Approximate Current Service Level	**Target Service Level**	**Current vs. Target (%)**	**Approximate Current Service Level**	**Target Service Level**	**Current vs. Target (%)**
Service level	β	$\beta = 0.84$	$\beta = 0.96$		$\beta = 0.84$	$\beta = 0.96$	
Lot size	Q	1,296	1,156		1,296	1,156	
Reproduction point	R	0	158		0	158	
Holding cost/year	$h[Q/2+R-d]$	2,170 YTL	2,547 YTL	17	2,170 YTL	2,547 YTL	17
Setup cost/year	KD/Q	1,969 YTL	2,206 YTL	12	1,969 YTL	2,206 YTL	12
Stock-out/year	$PDn(R)/Q$	3,617 YTL	452 YTL	-87	7,234 YTL	904 YTL	-86
TOTAL COST		7,755 YTL	5,205 YTL	-32	11,372 YTL	5,658 YTL	-50

Table 3.16. reflects that the customer service level is very poor for the "Earl Grey Tea Pot Bag 6*100". This can be explained as that since the raw materials of this SKU are imported from different countries, replenishment lead time of the external supplier is relatively longer. Therefore, increasing shortage risk is for the raw materials results shortages for the finished products. Offering a 17 per cent increase in inventory carrying

cost and 12 per cent increase in annual setup cost will be a significant effect to reduce annual shortage cost. The company saves 2,500 YTL and 5,500 of overall cost while unit penalty cost is 3.04 YTL and 6.08 respectively.

Table 3.17. Comparison of model and real data of Tea Pot Bag 6*100 the current situation

	Model	Real data	Diff. (%)
Average inventory level (case)	505	480	5
Total number of lost sales (case)	1190	1230	-3

5. Form Tea 12*20

Table 3.18. Summary of parameters of "Form Tea 12*20"

Production rate/week	P	14 616
Demand/week	d	109
Demand/year	D	5 668
Holding cost/unit	H	1.88 YTL
Setup cost/cycle	K	352.53 YTL
Standard deviation	σ	76

Table 3.19. Comparison of target level and current level of "Form Tea 12*20"

		$P = 2.98$			$P = 5.96$		
		Approximate Current Service Level	**Target Service Level**	**Current vs. Target (%)**	**Approximate Current Service Level**	**Target Service Level**	**Current vs. Target (%)**
Service level	β	$\beta = 0.85$	$\beta = 0.96$		$\beta = 0.85$	$\beta = 0.96$	
Lot size	Q	1,702	1 578		1,702	1 578	
Reproduction point	R	0	104		0	104	
Holding cost/year	$h[Q/2+R-d]$	1,391 YTL	1,471 YTL	6	1,391 YTL	1,471 YTL	6
Setup cost/year	KD/Q	1,174 YTL	1,267 YTL	8	1,174 YTL	1,267 YTL	8
Stock-out/year	$PDn(R)/Q$	2,534 YTL	676 YTL	-73	5,067 YTL	1,351 YTL	-73
TOTAL COST		5,099 YTL	3,413 YTL	-33	7,633 YTL	4,089 YTL	-46

Form tea is one of the functional teas whose demand process is normally distributed with mean 109 and standard deviation 76. The fraction of the lost sales over the total shortage demand is 15 per cent, and the unit shortage cost is 2.98 YTL. Approximated current supply chain cost is about 5,100 YTL per year when penalty cost is 2.98. This amount is anticipated to decrease to 3,413 YTL by using a type-2 service level approximation. In addition, when unit penalty cost equals to 5.96 YTL, our inventory control model suggests 46 per cent overall cost reduction.

Table 3.20. Comparison of model and real data of Form Tea 12*20 the current situation

	Model	**Real data**	**Diff. (%)**
Average inventory level (case)	741	701	5.5
Total number of lost sales (case)	850	897	-6

The real data show that our computations are quite accurate and thus are useful for overall cost approximations.

6. Special for Women 12*20

Table 3.21. Summary of parameters of "Special for Women 12*20"

Capacity	P	14,616
Demand/week	d	127
Demand/year	D	6,604
Holding cost/unit	H	2.25 YTL
Setup cost/cycle	K	584.64 YTL
	λ	0.0077

"Special for Women" has highly variable exponential demand with mean 127 per week and standard deviation 136. Unit shortage cost and unit inventory carrying cost 2.59 and 2.25, respectively.

Table 3.22. Comparison of target level and current level of “Special for Women 12*20”

		P = 2.88			P = 5.76		
		Approximate Current Service Level	**Target Service Level**	**Current vs. Target (%)**	**Approximate Current Service Level**	**Target Service Level**	**Current vs. Target (%)**
Service level	β	β = 0.90	β = 0.96		β = 0.90	β = 0.96	
Lot size	Q	2,077	1,991		2,077	1,991	
Reproduction point	R	0	147		0	147	
Holding cost/year	$h[Q/2+R-d]$	2,052 YTL	2,288 YTL	11	2,052 YTL	2,288 YTL	11
Setup cost/year	KD/Q	1,859 YTL	1,939 YTL	4	1,859 YTL	1,939 YTL	4
Stock-out/year	$PDn(R)/Q$	1,902 YTL	761 YTL	-60	3,804 YTL	1,522 YTL	-61
TOTAL COST		5,843 YTL	4,988 YTL	-14	7,715 YTL	5,749	-25

The suggested inventory control system provides 1,000 YTL and 2,000 YTL cost reduction for different unit penalty cost and six per cent of better customer service. As mentioned above in exponential distribution production lot size would be independent of service level. However, for “Special for Women 12*20”, service level β = 0.90 suggests a negative reproduction point R, but we fix it at zero value. Therefore, production lot size Q differs with different service levels.

Table 3.23. Comparison of model and real data of Special for Women 12*20 for the current situation

	Model	**Real data**	**Diff. (%)**
Average inventory level (case)	911	866	5
Total number of lost sales (case)	660	690	-4

The real data show that our computations are quite accurate and thus are useful for overall cost approximations.

7. Earl Grey Tea Pot Bag 12*48

Table 3.24. Summary of parameters of "Earl Grey Tea Pot Bag 12*48"

Capacity	*P*	5,880
Demand/week	*d*	146
Demand/year	*D*	7,592
Holding cost/unit	*H*	4.16 YTL
Setup cost/cycle	*K*	336.81 YTL
	λ	0.00687

The demand process is exponentially distributed with equal mean and variance. The production rate is 5,880 cases in a week.

Table 3.25. Comparison of target level and current level of "Earl Grey Tea Pot Bag 12*48"

		$P = 2.75$			$P = 5.5$		
		Approximate Current Service Level	**Target Service Level**	**Current vs. Target (%)**	**Approximate Current Service Level**	**Target Service Level**	**Current vs. Target (%)**
Service level	β	$\beta = 0.83$	$\beta = 0.96$		$\beta = 0.83$	$\beta = 0.96$	
Lot size	Q	1,373	1,278		1,373	1,278	
Reproduction point	R	0	153		0	153	
Holding cost/year	$h[Q/2+R-d]$	2,254 YTL	2,790 YTL	24	2,254 YTL	2,790 YTL	24
Setup cost/year	KD/Q	1,863 YTL	2,001 YTL	7	1,863 YTL	2,001 YTL	7
Stock-out/year	$PDn(R)/Q$	3,549 YTL	835 YTL	-76	7,099 YTL	1,670 YTL	-76
TOTAL COST		7,666 YTL	5,526 YTL	-27	11,215 YTL	6,361 YTL	-43

Production lot size differs significantly with different service levels, According to suggested approximation, the company should be ready pay for 24 per cent higher inventory holding cost and seven per cent for setup cost. The overall cost saving increases with penalty cost. When penalty cost is 2.75 YTL the model saves 2,000 YTL and the penalty cost s 5.5 YTL the cost saving is 5,000 YTL.

Table 3.26. Comparison of model and real data of Earl Grey Tea Pot Bag 12*48 the current situation

	Model	**Real data**	**Diff. (%)**
Average inventory level (case)	541	504	6
Total number of lost sales (case)	1291	1310	-1.5

The model approximates the total number of lost sales quite accurate.

8. Form with Linseed

Table 3.27. Summary of parameters of "Form with Linseed"

Capacity	*P*	14,616
Demand/week	*d*	129
Demand/year	*D*	6.708
Holding cost/unit	*H*	1.90 YTL
Setup cost/cycle	*K*	482.54 YTL
Teta	θ	72

Table 3.28. Comparison of target level and current level of "Form with Linseed"

		$P = 2.54$			$P = 5.08$		
		Approximate Current Service Level	**Target Service Level**	**Current vs. Target (%)**	**Approximate Current Service Level**	**Target Service Level**	**Current vs. Target (%)**
Service level	β	$\beta = 0.78$	$\beta = 0.96$		$\beta = 0.78$	$\beta = 0.96$	
Lot size	Q	1 928	1 928		1 928	1 928	
Reproduction point	R	0	125		0	125	
Holding cost/year	$h[Q/2+R-d]$	1,587 YTL	1,832 YTL	15	1,587 YTL	1,832 YTL	15
Setup cost/year	KD/Q	1,679 YTL	1,679 YTL	0	1,679 YTL	1,679 YTL	0
Stock-out/year	$PDn(R)/Q$	3,748 YTL	341 YTL	-90	7,497 YTL	682 YTL	-90
TOTAL COST		7,014 YTL	3,851 YTL	-45	10,762 YTL	4,192 YTL	-61

The external customer demand process is distributed with Laplace distribution. Due to very poor service level in current situation, the overall cost decreases sharply with our inventory control model. The annual shortage cost decreases 90 per cent when unit penalty cost is 2.54 and 5.08 YTL. As in exponential distribution, the production lot size is independent in customer service level.

Table 3.29. Comparison of model and real data of Form with Linseed for the current situation

	Model	**Real data**	**Diff. (%)**
Average inventory level (case)	835	747	10
Total number of lost sales (case)	1476	1510	-2

The real data show that our computations are quite accurate and thus are useful for overall cost approximations.

In this part, we consider eight valuable tea-based products sold in Key Accounts. These products constitute about 45 per cent of the annual YTL volume of sales. Our numerical results show that the current overall cost of these top eight products is about 177,000 YTL and 284,000 YTL per year for two cases when unit penalty cost equals to one unit profit and two unit profits. However, in the target service level overall cost will be 133,000 YTL and 145,000 YTL per year. Besides this significant saving, our inventory control model guarantees 96 per cent customer service level.

4. INFORMATION SHARING

Supply chain management (SCM) is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, distributers and retailers, so that goods are produced, distributed and delivered at the right quantities, to the right places, and at the right time (Yan and Woo, 2004). In this part, we consider an important problem in SCM– the bullwhip effect and we suggest a solution procedure with increasing info sharing. The bullwhip effect essentially the phenomenon of demand variability resulted from the information distortion in a supply chain where companies upstream do not have information on the actual consumer demand (Lee *et al*., 2000). To reduce the bullwhip effect, forecasts, inventory policies, and to some extend lead-times should be controllable. Furthermore, the importance of information sharing of relevant information across various stages of the supply chain is being increasingly realized and has been found to reduce the overall bullwhip effect (Agrawal *et al*., 2007). The harmful effect of demand distortion can be reduced by increasing transparency of point of sales data through the supplier.

One of the tails of the supply chain network in Gıdasa A.Ş. is its selling channels that manage the manufactured products. The KAs give the weekly order receipt to the sales representatives' of the company. This information is recorded to the SAP system and can be reached by anyone who is responsible for fulfilling this order. The responsible parts are planning, logistic, production, purchasing and quality and so on. Then, if company have enough stock to fill order, then the order is met from the stock in a given due date. In addition, there is an upper level of Gıdasa that are source of raw materials. In this research, we assume, these suppliers provide whatever Gıdasa orders in a constant lead time. Such a supply chain network resembles a two-tier supply chain model.,

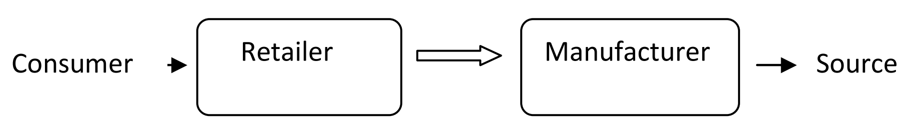


Figure 4.1. A two-level supply chain

The retailer comes to manufacturer and gives his order regularly to ensure a continuous selling based on its forecast of the end consumer's demand and its own inventory. The supplier fulfills the retailer's order, and the upper tier of supplier s supposed to be the very initial outside source of the product, and has responsible for meeting all raw material requirements (Yan and Woo, 2004). In this section, we analyze the benefit of information sharing to the supply chain network in terms of inventory reduction and cost saving to the manufacturer. We present the numerical results of the products under different scenarios whose demand processes can be expressed as AR(1) process.

External demand for single for a single item occurs at the retailer, where the underlying demand process faced by the retailer is a simple autocorrelated AR(1) process.

$$D_t = d + \rho D_{t-1} + \varepsilon_t \tag{4.1}$$

where

D_t = The AR(1) demand process at the retailer,

$d > 0$ = Constant term of AR(1) demand process,

$-1 < \rho < 1$ = Autocorrelation coefficient,

ε_t = Error term that is normally distributed with mean zero and variance σ^2.

Key Accounts placed an order every period to the manufacturer and the manufacturer attempts to meet order. Thus, both retailer and manufacturer's inventory level replenishes each period. In the same way outside supplier tries to fulfill the order placed from the manufacturer. Here, we consider a periodic review system in which each site reviews its inventory level and replenishes its inventory from the upstream site every period.

4.1. Assumptions

A1 Excess demand is backlogged. If the manufacturer does not have enough stock to fill order, then the manufacturer meets the shortfall by obtaining from an alternative source. Thus, an additional cost will be occurred for the manufacturer, because this additional cost will be higher than the unit manufacturing cost.

A2 We assume manufacturer responsible for all the penalty costs that occur due to the shortages and resupplying from an alternative source. Manufacturer guarantees supply the order to the retailers.

A3 When placing an order no fixed order cost is incurred.

A4 The retailer and the manufacturer use the order-up-policy, since such policy minimizes the total discounted holding and shortage cost

A5 Holding cost and penalty cost stationary over time.

A6 l is the constant replenishment lead time from manufacturer to retailer, and L is the constant replenishment lead time from external supplier to manufacturer.

4.2. Model

Our supply chain network consists of two tiers, one retailer and one manufacturer. The retailer places an order regularly and manufacturer attempts to fulfill that order. Retailer's order quantity will be considered as demand process for manufacturer. We analyze the manufacturer's order quantity with information sharing and without information sharing. Then, the impact of information sharing on manufacturer's average inventory reduction and cost saving in manufacturer's inventory carrying cost and shortage cost.

In order to analyze retailer ordering decision, we know about external demand comes from end consumers. The retailer decides his final orders by considering the signal from consumers, and also defines the order-up- to level S_t for each period. After demand D_t has been realized, the retailer observed the inventory level and places an order size Y_t. where

$$Y_t = D_t + (S_t - S_{t-1}) \tag{4.2}$$

As mentioned above the order-up-to level for the retailer's ordering decision is defined by using signal comes from end consumers D_t. An expression is derived for S_t that minimizes expected holding and shortage cost *n* period $t + l + 1$.

Let m_t the conditional expectation of the total demand during the lead time where :

$$m_t = E\left(\sum_{i=1}^{l+1} D_{t+i} \,|D_t\right) \tag{4.3}$$

$$m_t = \frac{d}{1-\rho}\left[(l+1) - \sum_{j=1}^{l+1} \rho^j\right] + \frac{\rho(1-\rho^{l+1})}{1-\rho} D_t \tag{4.4}$$

Let v_t the conditional variance of the total demand over the lead time where

$$v_t = \text{var} \sum_{i=1}^{l+1} D_{t+i} \,|D_t \tag{4.5}$$

$$v_t = v\sigma^2 \tag{4.6}$$

where

$$v = \sum_{i=1}^{l+1}\left[\sum_{i=0}^{j-1} \rho^j\right]^2 = \frac{1}{(1-\rho)^2}\sum_{j=1}^{l+1}(1-\rho^j)^2 \tag{4.7}$$

The total demand processes over lead time is a normally distributed demand. After derivations of parameters of S_t, the retailer's order-up-to level can be written as $S_t = m_t + k\sigma\sqrt{v}$ where k is $\phi^{-1}[P/(P+H)]$ for the standard normal distribution ϕ. P is unit shortage cost per time period at the manufacturer and H denotes the unit inventory holding cost at the manufacturer. Now, by using the equation (4.2) retailer order quantity can be expressed as

$$Y_t = D_t + \frac{\rho(1-\rho^{l-1})}{1-\rho}(D_t - D_{t-1}) \tag{4.8}$$

When $\rho = 0$ we can see that actual order is equals to the external demand comes from the consumers. In addition to this, order-up-to level does not depend on the external demand process. It is easy to see that when autocorrelation does not exist, bullwhip effect does not take a role in the retailer ordering process.

Manufacturer receives retailers order receipt Y_t and reacts to the order as soon as possible, and if manufacturer's stock level is enough to meet order, he sends the ordered party to the retailer. However, if manufacturer does not fulfill the order, he will use outsource to fill this order. Here, we assume that the unit product cost of outsourcing is greater than unit cost product while it is produced at our factory.

Fulfilling the retailer's order by the manufacturer causes requirement of new raw materials. At the end of the period t, the manufacturer gives an order to his external supplier to put forward his inventory position to an order-up-to level T_t. This order arrives to the manufacturer at the same time with the order that he ships to the retailer. Manufacturer's total order quantity is equal to the total orders placed by the retailer. The total shipment quantity over the manufacturer's lead time which is denoted by β_t:

$$\beta_t = \sum_{i=1}^{L+1} Y_{t+i} \tag{4.9}$$

By using (4.1) and (4.8) it can be observed that

$$Y_{t+1} = d + \rho Y_t + \frac{1-\rho^{l+2}}{1-\rho}\varepsilon_{t-1} - \frac{\rho(1-\rho^{l-1})}{1-\rho}\varepsilon_t \tag{4.10}$$

The total shipment quantity over the manufacturer's lead time for any given value of retailer's order quantity

$$\beta_t = \sum_{i=1}^{L+1} Y_{t+i} = \frac{d}{1-\rho}\left[(L+1) - \frac{\rho(1-\rho^{L+1})}{1-\rho}\right] + \frac{\rho(1-\rho^{L+1})}{1-\rho}Y_t + \frac{1-\rho^{l+2}}{1-\rho}\varepsilon_{t+L+1}$$

$$+\frac{1}{1-\rho}\sum_{i=1}^{L}(1-\rho^{L+l+3-i})\varepsilon_{t-i} - \frac{\rho(1-\rho^{L+1})(1-\rho^{l+1})}{(1-\rho)^2} \tag{4.11}$$

Manufacturer's ordering decision will be analyzed for while there is no information sharing and while there is information sharing. When there is no information sharing manufacturer can not realize about the error term of external demand process Y_t. Thus, parameters will be different.

4.2.1. Manufacturer Ordering Decision without Information Sharing

While there is no information sharing, the manufacturer gets only information about the retailer's order quantity Y_t. In this case the error term ε_t has been realized, but is unknown to the manufacturer when he determines his order-up-to level T_t. Thus β_t, manufacturer's total shipment quantity over manufacturers' lead time, is normally distributed with mean M_t and variance $V\sigma^2$.

where

$$M_t = \frac{d}{1-\rho}\left[(L+1) - \frac{\rho(1-\rho^{L+1})}{1-\rho}\right] + \frac{\rho(1-\rho^{L+1})}{1-\rho}Y_t \tag{4.12}$$

$$V = \frac{1}{(1-\rho)^2}\left[(1-\rho^{l+2})^2 + \sum_{i=1}^{L}(1-\rho^{L+l+3-i})^2 + \frac{\rho^2(1-\rho^{L+1})^2(1-\rho^{l+1})^2}{(1-\rho)^2}\right] \tag{4.13}$$

The variance of total shipment quantity of manufacturer does not depend on order placed by the retailer Y_t when there is no sales information sharing. It is obvious that the variance of β_t is increasing with increasing replenishment lead time from manufacturer to supplier (*l*), replenishment lead time from external supplier to manufacturer (*L*), auto correlation coefficient ρ. Here, the manufacturer's order-up-to level without information sharing T_t' depends on mean M_t and variance $V\sigma^2$.

$$T_t' = M_t + K\sigma\sqrt{V} \tag{4.14}$$

where $K = \phi^{-1}[P/(P+H)]$ for the standard normal distribution ϕ.

4.2.2. Manufacturer Ordering Decision with Information Sharing

While there is information sharing, in addition to retailer order quantity manufacturer realizes error term ε_t information. Thus, he determines the order-up-to level T_t according to this information. In this case, the manufacturer's total shipment quantity over manufactures' lead time β_t , is normally distributed with mean M_t' and variance $V'\sigma^2$.

$$M'_t = M_t - \frac{\rho(1-\rho^{L+1})(1-\rho^{l+1})}{(1-\rho)^2} \quad (4.15)$$

$$V' = \frac{1}{(1-\rho)^2}\left[(1-\rho^{l+2})^2 + \sum_{i=1}^{L}(1-\rho^{L+l+3-i})^2\right] \quad (4.16)$$

The variance of the manufacturer's total shipment over replenishment lead time does not depend on time and retailer order quantity. And, it is increasing with *l*, *L*, ρ . Information sharing would reduce the variance of the total shipment quantity over the manufacturer's lead time *L*. The order-up-to level of manufacturer is shown as

$$T_t' = M_t' + K\sigma\sqrt{V'} \quad (4.17)$$

4.3. Impacts of Information Sharing

Above the parameters are derived according to with information sharing and without information sharing. After determining retailer's and manufacturer's ordering decision with info sharing and without info sharing, we now show the benefits of information sharing for the manufacturer. Because, Gıdasa is manufacturer in our model we focus on the impact of information sharing to the manufacturer in terms of average inventory reduction and expected cost saving. The tea based stock keeping units (SKU) are considered and are analyzed whether they are proper to AR(1) process and our assumptions or not by performing Minitab. We see that three products are available to be analyzed out of eight products that we defined to be work on in this thesis. Their autocorrelation coefficient ρ varies from 0.82 to 0.86. We do the sensitivity analyze for the different shortage cost values *P*, lead time from external supplier to manufacturer *L*, and lead time from the manufacturer to the retailer.

We consider the benefit of the information sharing for the manufacturer inventory reduction and cost saving.

4.3.1. Average Inventory Reduction

An approximation will be used for the average on hand inventory, because it is difficult to obtain exact expressions for the average inventory levels when the underlying demand process is autocorrelated over time (Lee *et al.*, 2000). For any order-up-to level T_t system with retailer order process is the demand process at time *t*, $\beta_t = \sum_{i=1}^{L+1} Y_{t+i}$ is the total demand for the manufacturer, from the period *t*+1 to period *t*+*L*+1 the average on hand inventory can be expressed as

$$T_t - E(\sum_{i=1}^{L+1} Y_{t+i}) + \frac{E(Y_t)}{2} \tag{4.18}$$

Above expression is the common derivation done by Silver and Petersen. By using this approximation Lee (2000) derives an approximation the average inventory level for manufacturer both while there is sale information sharing and while there is no sale information sharing.

$$I = \frac{d}{2(1-\rho)} + K\sigma\sqrt{V} \tag{4.19}$$

where *I* is the average on hand inventory without information sharing,

$$I' = \frac{d}{2(1-\rho)} + K\sigma\sqrt{V'} \tag{4.20}$$

where *I'* denotes the average on hand inventory without information sharing.

The manufacturer's on hand inventory position reduces $I - I' = K\sigma\sqrt{V} - \sqrt{V'}$ by increasing information sharing. Highly variable demand processes are affected from the information sharing. The percentage of average inventory saving can be denoted by $\Delta I = (I - I')/I$

By solving the (4.19) and (4.20) simultaneously

$$\Delta I = \frac{1 - \sqrt{\dfrac{V}{V'}}}{\dfrac{d}{2KD(1-\rho)\sqrt{V}} + 1} \tag{4.21}$$

In the last part of this section, we discuss the impact of the different parameter levels on the inventory reduction with information sharing and without information sharing. We give the numerical results. However, here, it can be realized that when the demand distortion is high, the benefit of information sharing on inventory reduction will be greater. In addition to this, the greater autocorrelation causes, the bigger inventory reduction. The percentage inventory reduction corresponds to unit shortage cost and holding cost. When the proportion of penalty cost to holding cost is bigger, the impact of inventory reduction on information results in higher percentage.

4.3.2. Average Cost Saving

Standardized loss function is used to derive expression for manufacturer's expected inventory holding and shortage cost. When the demand is normally distributed, the expected number of shortages that occur in a period is computed by using the standardized loss function. The standardized loss function $L(x)$ is defined as $L(z) = \int_x^\infty (z - x)\phi(z)dz$ where $\phi(z)$ denotes the standardized normal density.

When there is information sharing the manufacturer knows about the total shipment quantity over lead time and knows about the error term ε_t. Here, manufacturer uses the optimal order-up-to level that minimizes the expected total inventory holding and shortage cost with respect to the true distribution F_t'. Since the total order β_t is normally distributed, C_t' can express the manufacturer's expected holding and shortage costs when there is information sharing.

$$C_t' = E_{\varepsilon_t}[P\int_{T}^{\infty}(x-T')dF_t'(x) + H\int_{-\infty}^{T'}(T'-x)dF_t'(x)] \tag{4.22}$$

$$C_t' = \sigma\sqrt{V'}[(H+P)L(K)+HK] \tag{4.23}$$

We can divide this expression into two parts. One part represents the expected inventory holding cost and the other is penalty cost caused by obtaining the shortages from an alternative source. Thus, inventory carrying cost can be expressed as $\sigma\sqrt{V'}[(H+P)L(K)]$ and shortage cost can be shown as $\sigma\sqrt{V'}HK$ when there is information sharing.

Second, consider the case with there is no information sharing. Manufacturer has no information about the error term ε_t. Manufacturer thinks that the order quantity Y_t is distributed with mean M_t and variance $V\sigma^2$. Hence, he uses the order-up-to level $T' = M_t + K\sigma\sqrt{V}$. The fact is not like that, the actual parameters of the total order over the lead time F_t' are mean M_t and variance $V\sigma^2$. In addition, $\hat{K}$ is chosen instead of *K*. In this case manufacturer's optimal order-to-up level will be $T' = M_t' + \hat{K}\sigma\sqrt{V'}$.

$$\hat{K} = \frac{M_t - M_t'}{\sigma\sqrt{V'}} + K\sqrt{\frac{V}{V'}} \tag{4.24}$$

Again, since the total order β_t is normally distributed, C_t can be expressed as the manufacturer's expected holding and shortage costs when there is no information sharing.

$$C_t = E_{\varepsilon_t}[P\int_{T_t'}^{\infty}(x-T_t')dF_t'(x) + H\int_{-\infty}^{T_t'}(T_t'-x)dF_t'(x)] \quad (4.25)$$

$$C_t = E_{\varepsilon_t}(\sigma\sqrt{V'}[(H+P)L(\widehat{K}) + H(\widehat{K})] \quad (4.26)$$

We also can divide this expression into two parts. One part represents the expected inventory holding cost and the other is penalty cost caused by obtaining the shortages from an alternative source. Thus, inventory carrying cost can be expressed $E_{\varepsilon_t}(\sigma\sqrt{V'}[(H+P)L(\widehat{K})]$ and shortage cost can be shown as $E_{\varepsilon_t}\sigma\sqrt{V'}H(\widehat{K})$ when there is no information sharing. Here, we can see that inventory holding cost and shortage cost increase when the total shipment quantity highly variable.

4.3.3. Determination of Shortage Cost

Shortage Cost (YTL/ Unit): Excess demand is backlogged. Thus, the unit penalty cost will differ from penalty cost which we have calculated with lost sales assumption in type-2 service level calculations. Here, if the manufacturer does not have enough stock to fill order, then the manufacturer will meet the shortfall by obtaining some units from an alternative source, with additional cost representing penalty cost. However, this additional cost should be greater than own-production cost. This is a reasonable assumption because if own-production cost is higher than the outsourcing cost, manufacturing this type of product in our plant will be senseless.

In the thesis, since it is difficult to obtain exact information about fulfilling shortages from an alternative source, we work with different unit penalty cost values. Then, we analyze the data with these values to see the impact of unit shortage cost in the information sharing. The expected result is that the level of benefits of information sharing for both inventory reduction and cost saving will increase with penalty cost.

4.4. Numerical Results

In order to see the impact of information sharing on the inventory reduction and cost saving numerically, first, we check the availability of demand distributions. Because, we make some assumptions for the demand at the retailer, that is modeled as AR(1). And the other assumption is that mentioned above β_t denotes the manufacturer's total shipment quantity over manufactures lead time, which is normally distributed with mean M_t and standard deviation $\sigma\sqrt{V}$. These assumptions do not work for some products' demand distribution. Thus, we neglect four SKU's demand distribution which are "Earl Grey 6*100", "Thin Glass 1000gr*9", "Form with Inseed" and "Special for Women" due to violation of normality assumption.

We should know about external demand for single for a single item occurs at the retailer D_t. We have the demand process information of the manufacturer in the SAP system and we also have the demand information of unsold products which are returned from the KAs. Thus, we reach the external demand process occurs at the KAs. Another crucial assumption reflects that external demand for a single SKU occur at the retailer is a simple autocorrelated AR(1) process. Autocorrelation tests are done by Minitab and according the significance test done by program, we decide to work on two SKU's which are "Poured 1000gr*9" and "Tea Pot Bag 6*100".

4.4.1. Poured 1000gr *9

"Poured 1000gr*9" is one of the most important SKU for Gıdasa A.Ş. because most of consumers prefer poured tea instead of tea bags. This SKU has a good stock turnover rate. Moreover, it's the most expensive tea based product of the company. Thus, company makes considerable money in "Poured 1000gr*9". The figure shows, time series of external demand for a single item occurs at the retailer. As we can see from the graph below, external sales are greater in fall months than in summer months. Hence, variation of the demand is very high. The numerical values of descriptive statistics are given in the third section. The highly variable demand requires high inventory levels in order to meet the orders. Although company tries to hold more stock through the supply chain, due to the highly variability could lead to complete stock out certain times and causes low customer service rate.

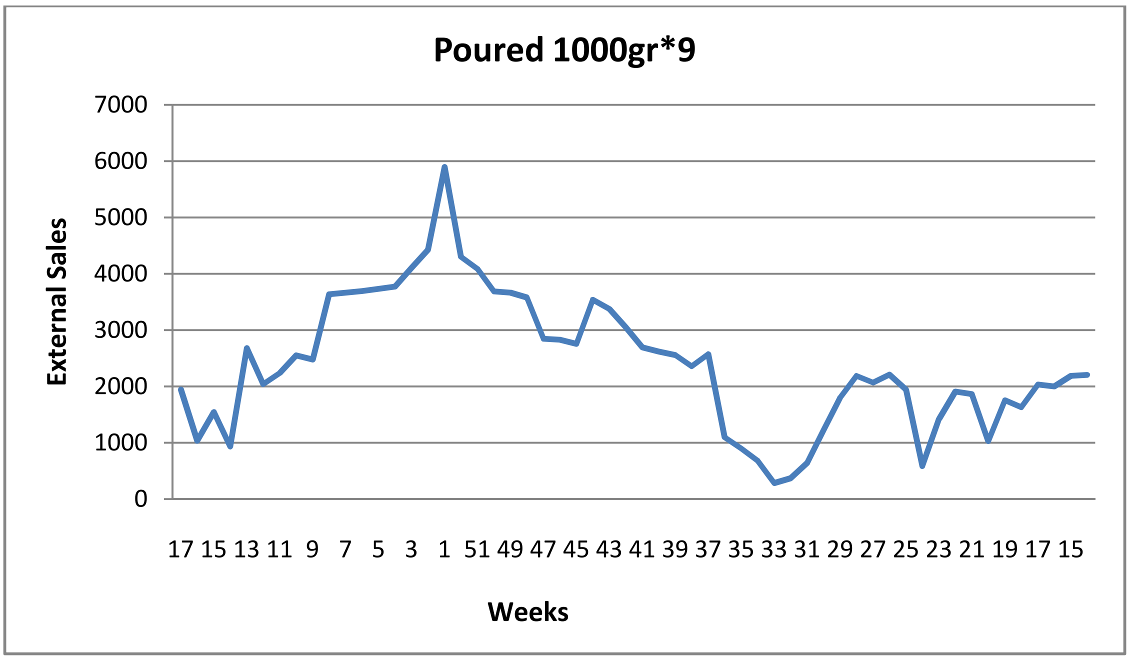


Figure 4.2. External weekly demand of "Poured 1000gr*9"

Most of the studies including Johnson and Thomson (1975), Lee at al. (1997b, 2000), and So and Zheng (2003) have assumed the demand as a stationary process and have modeled it as an autoregressive moving average type process of the first order. In order to analyze external demand data, we use Minitab. The time series analysis – Arima – AR(1) model is used. The software gives test statistics for the specified data automatically whether the model can be used or not. The Arima procedure fits the model with a certain number of parameters and tests for the significance of the parameters. The null and alternative hypothesis:

H_0 = Parameters are not different from zero

H_1 = Parameters are different from zero

Arima gives two statistics that we can use to conduct a test of significance of the parameters considered in the model that are the *T* statistic and the *p-value*. The *T* statistic is not very informative by itself, but can be used to determine the *p-value*. As a "rule of thumb", we consider *T* statistics that in absolute value are over two as indicating that the associated parameters are significantly different from zero. The *p-value* tells just how likely it is that we would obtain our estimate of the parameters if they were actually zero.

The p-value must be determined before performing the test. The value that we determine as significance level is called the *α*-level. If the *p-value* is less than *α*-level, then we reject H_0 and conclude that the associated parameter is different from zero. The expected result is smaller *p-value*.

We need check after fitting an Arima model is the correlation of the residuals (error term ε_t). Arima gives again two statistics that are used to conduct a test of correlation for the residuals which are the Ljung-Box Chi-Square statistic and the *p-value*. The chi-square statistic is used to determine if the residuals are correlated or not which is very informative by itself, but is used to determine the *p-value*. The *p-value* tells just how likely it is that we obtain autocorrelations if the residuals were actually uncorrelated. Again, the *p-value* must be decided before performing the test. The value that is chosen by us is called the a-level. If the *p-value* is greater than *α*-level, then you should not reject your null hypothesis that the residuals are uncorrelated. The smaller *p-value* tells us reject H_0, so residuals are correlated. Here, the expected result is uncorrelated error terms, so we need a greater *p-value*.

We choose a 0.01 significance level for both parameters and residuals. We have 56 weeks external sales data for "Poured 1000gr*9". The Minitab statistics are below;

ARIMA Model: Poured 1000gr*9

```
Estimates at each iteration

Iteration        SSE     Parameters
        0   63893352  0.100  2166.923
        1   48154664  0.250  1805.238
        2   35837040  0.400  1443.532
        3   26940465  0.550  1081.790
        4   21464914  0.700   719.984
        5   19410372  0.850   358.057
        6   19391403  0.864   320.556
        7   19391196  0.865   316.886
        8   19391194  0.865   316.509

Relative change in each estimate less than 0.0010


Final Estimates of Parameters

Type         Coef  SE Coef       T      P
AR   1     0.8651   0.0685   12.63  0.000
Constant  316.51     80.11    3.95  0.000
Mean      2345.4     593.7
```

```
Number of observations:  56
Residuals:    SS =  19360387 (backforecasts excluded)
              MS =  358526  DF = 54


Modified Box-Pierce (Ljung-Box) Chi-Square statistic

Lag            12      24      36      48
Chi-Square   14.0    37.6    51.7    64.7
DF             10      22      34      46
P-Value     0.172   0.020   0.026   0.036
```

For the sales data of “Poured 1000gr*9”, the T statistic is 12.63 for the AR(1) parameter and the associated *p-value* is 0.000. The T statistic for constant is 3.95 and the associated p-value is 0.000. The *p-value* of 0.000 indicates that there is a 0.0 per cent chance that we would have obtained our estimates of the parameter if the true parameter is zero. Moreover, the *T* statistic for degrees of freedom 54 and 0.01 significance level equals approximately 2.4. Since the *p-value* and *T* test statistic is smaller, we reject the null hypothesis. This means, the sales pattern of this SKU is significantly autocorrelated at 0.01 significant level.

For the external sales data of “Poured 1000gr*9”, the chi-square statistics of 14, 37.6, 51.7, and 64.7 give *p-values* of 0.172, 0.020, 0.026, and 0.036. Since the *p-values* are larger than the 0.01 significance level, do not reject the null hypothesis, thus the residuals appear to be uncorrelated. The parameters of the model are significantly different from zero and the residuals are uncorrelated, so we use this model in our calculations.

The replenishment lead time from the manufacturer to the retailer (l) is in constant period and here, we make calculations when l varies from one to five.

The replenishment lead time from the external supplier to the manufacturer denoted by L. “Poured 1000gr*9” is produced with mixture of many of different types of tea. Some of ingredients are being imported from different countries. Thus, lead time of external supplier L is longer than the manufacturer’s lead time. In this part, we make the calculations varies from three to 10. Retailer’s ordering decision is independent of the manufacturer’s replenishment lead time L, the retailer’s cost is not affected by the manufacturer’s replenishment lead time.

Penalty Cost (YTL/Unit): In the section 4.3.3 we mentioned how we determine the unit shortage cost. We assume the extra cost of obtaining one single unit from alternative source varies from 9 YTL which is unit inventory carrying cost to 30 YTL. (Approximate unit selling price is 71 YTL and approximate cost unit cost is 41 YTL)

Holding Cost (YTL/Unit): The unit holding cost is same as holding cost calculated in the former part. We use inventory holding cost 9 YTL/unit.

Summary of parameters are below.

Mean	μ	2,345 cases
AR(1) coefficient	ρ	0.8651
Constant	d	316
Error standard deviation	σ	598.77
Lead time for retailer	l	1–5 weeks
Lead time for manufacturer	L	3–9 weeks
Penalty cost for manufacturer	P	9–30 YTL/case
Holding cost for manufacturer	H	9.087YTL/case

In order to determine average inventory levels with information sharing and without information sharing, first we calculate V and V' by using (4.11) and (4.14) that are a multiplier of variance parameter. Increasing V tells us increasing the variability of the total shipment quantity over the manufacturer's lead time. As shown in the developed expressions above, the benefits of information sharing to the manufacturer can be captured by the term $\sqrt{V} - \sqrt{V'}$ .Therefore we can conclude that the benefit of information sharing is substantial when the error terms significantly large.

Since we could not determine an exact shortage cost we calculate the average on hand inventory, and shortage cost for parameters $H = 9.087$, $l = 1$, and $L = 5$. We vary P from nine to 30.

Table 4.1. Impact of penalty cost on average manufacturer's inventory level

	On-Hand Inventory without info Sharing	On-Hand Inventory with info Sharing	Percentage of Inventory Reduction from Info Sharing (%)
P = 9	1,227	1,217	0.81
P = 13	2,797	2,503	10.51
P = 17	4,001	3,491	12.75
P = 21	4,936	4,257	13.76
P = 25	5,696	4,880	14.33
P = 30	6,477	5,520	14.78

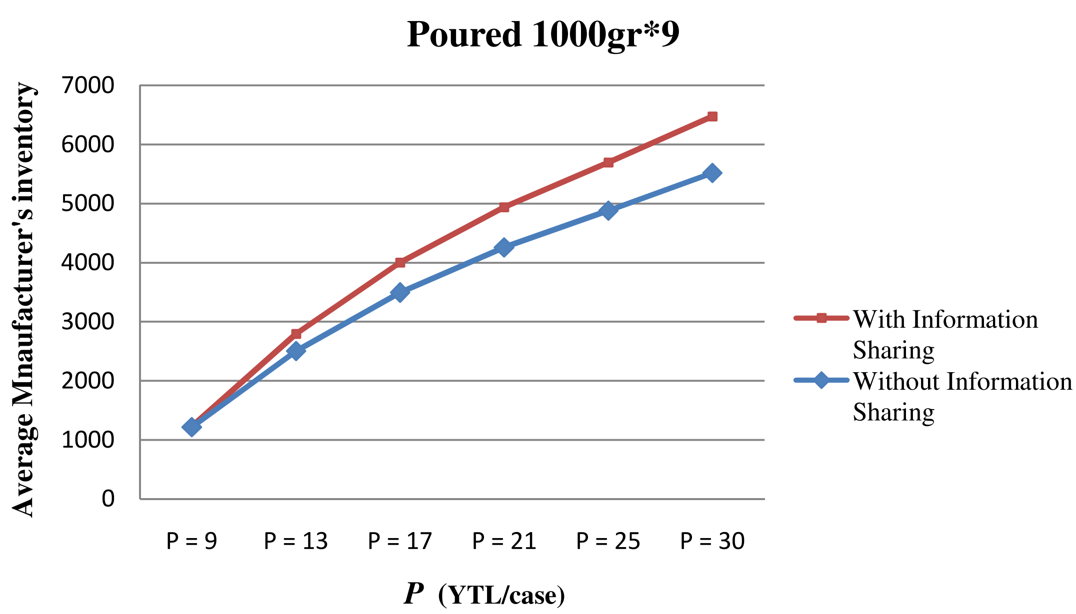


Figure 4.3. Impact of *P* on average on-hand inventory

Figure 4.2 shows that manufacturer's average inventory level with increasing unit shortage cost. As shortage cost increases, manufacturer carries more inventory to give better service to the retailer, thus there is a general increasing trend with increasing penalty cost. However, since variability decreases with information sharing, manufacturer holds fewer inventories when there is information sharing compared to without information sharing.

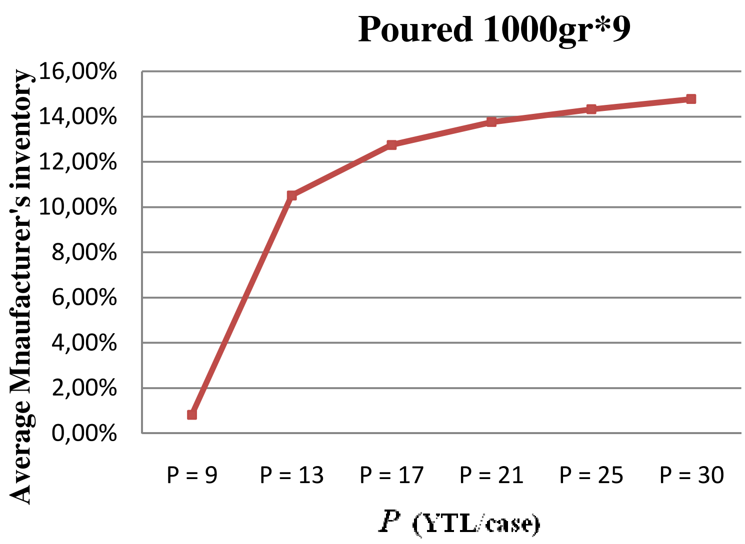
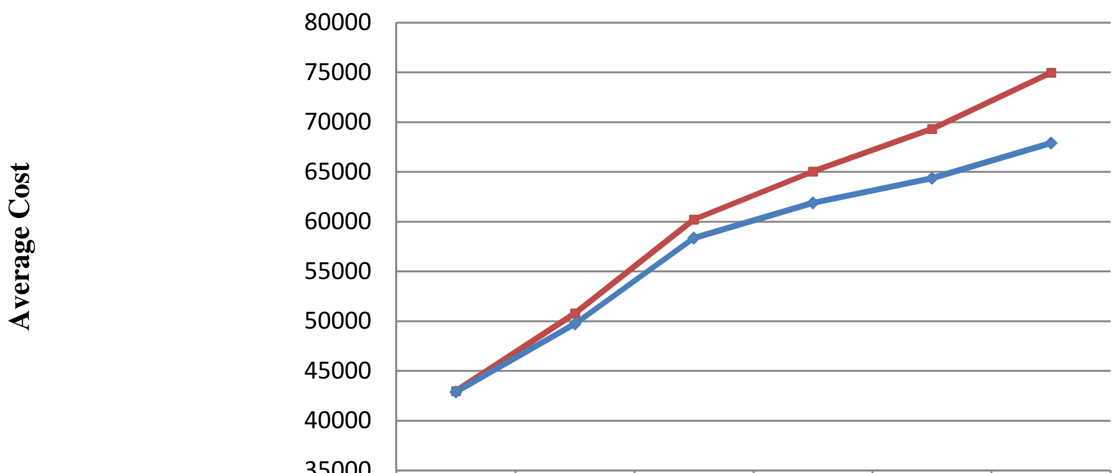


Figure 4.4. Impact of *P* on percentage of inventory reduction

The figure shows that percentage of inventory reduction increases with penalty cost. This can be expressed as that when the shortage cost *P* is high relative to holding cost *h* information sharing also results in higher percentage of inventory reduction. However, for higher values of penalty cost, percentage of inventory reduction is almost fixed.



	P = 9	P = 13	P = 17	P = 21	P = 25	P = 30
Without Information Sharing	42959	50794	60191	65019	69321	74968
With Information Sharing	42867	49707	58347	61893	64340	67902

Figure 4.5. Impact of *P* on average cost

As we can see from the Figure 4.5. the average cost has an increasing trend with increasing unit penalty cost. Furthermore, we realize from the figure the benefit of information sharing increases with unit shortage cost. The information sharing provides significant cost saving with 10 per cent when P = 30, while it is zero per cent when P = 9.

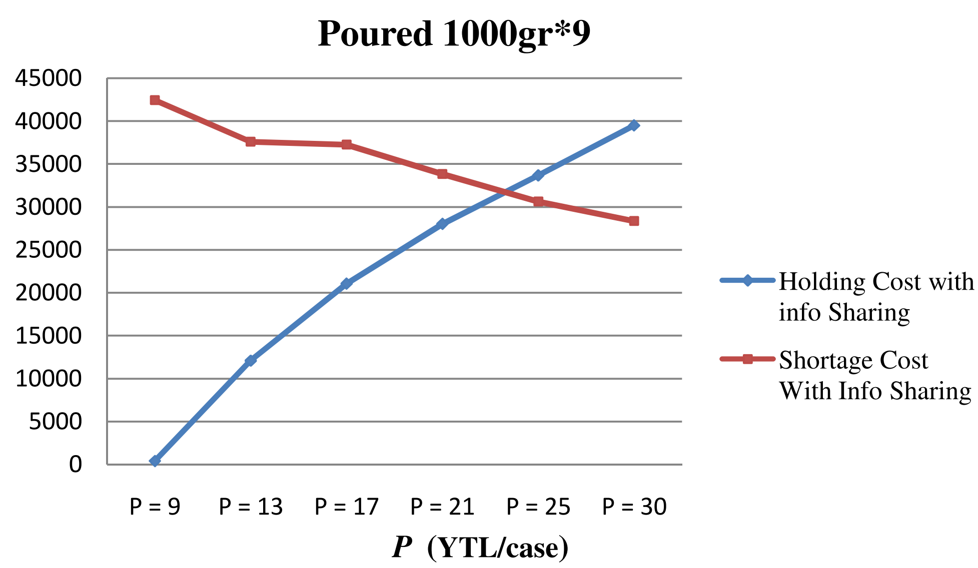


Figure 4.6. Holding cost vs. shortage cost with information sharing

From Figure 4.6. we know that the average cost increases with increasing shortage cost for both with info sharing and without info sharing. Here, we analyze the behavior of shortage cost and holding cost when there is information sharing. The figure states that with increasing penalty cost, in order to lower average shortage cost the company tends to hold more inventories. To illustrate; when P = 9, the company holds almost no inventory because obtaining from an alternative source is not very expensive. Furthermore, Figure 4.5 assists us while determining appropriate shortage cost when excess demand backlogged. We can conclude that the shortage cost between 21 and 25 is appropriate for the “Poured 1000gr*9”.

Table 4.2. Impact of lead time on average cost from the manufacturer to the retailer

	Average Cost with Info Sharing	Average Cost without Info Sharing	Percentage of Cost saving from Info Sharing (%)
l= 1	61,893	65,019	4.81
l= 2	68,534	75,369	9.07
l= 3	72,379	78,197	7.44
l= 4	77,492	83,847	7.58
l= 5	79,451	85,124	6.66

To illustrate the magnitude of impact of lead time from manufacturer to the retailer on cost saving associated with information sharing, the manufacturer company's cost parameters are specified as P = 21, and L = 5 while l varies from one to five. The percentage of cost saving is by five per cent to 7.5 per cent lead time from our company to KAs is assumed constant and one week.

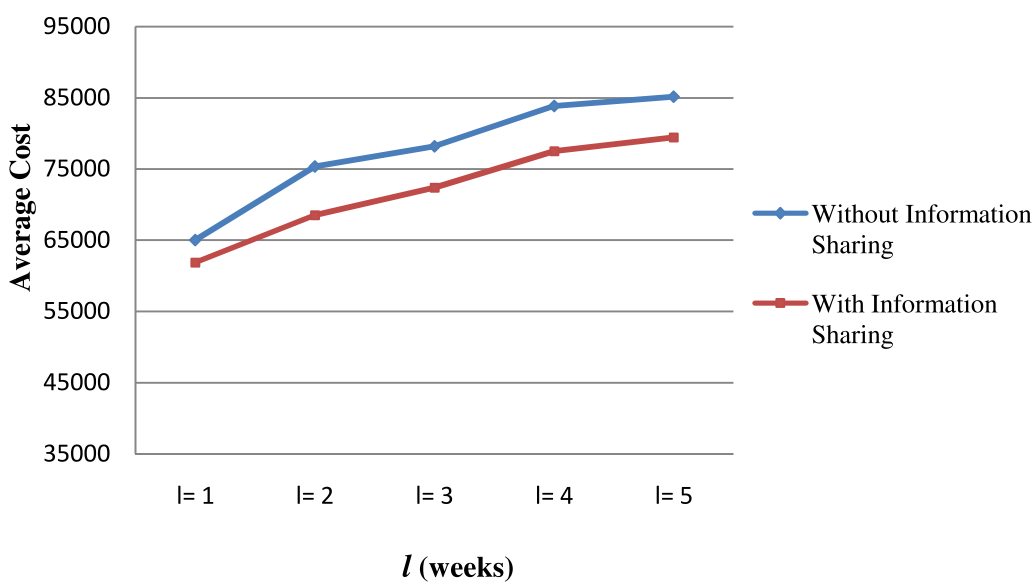


Figure 4.7. Impact of lead time on average cost from manufacturer to the retailer

Figure 4.7. seems to suggest that long lead time l hurts manufacturer average cost. Moreover, the figure also states that information sharing provides additional cost savings to the manufacturer; however this savings does not vary with respect to *l*. Furthermore, our results indicates that reducing *l* would reduce the manufacturer's average cost only slightly and intuitively therefore by itself is not enough of an incentive for the manufacturer to invest in lead time reduction. However, this may be a means to persuade the retailer to share demand information, which benefits the manufacturer. In other words, information sharing alone will benefit the manufacturer only and lead time reduction alone will benefit the retailer primarily. However both partners may obtain benefits when information sharing and lead time reduction implemented together.

Table 4.3. Impact of *L* on average cost that varies *L* = 3 to *L* = 9

	Average Cost with Info Sharing	Average Cost without Info Sharing	Percentage of Cost Saving from Info Sharing (%)
L= 3	43,908	45,983	4.51
L= 4	53,011	55,719	4.86
L= 5	61,893	65,019	4.81
L= 6	68,828	72,135	4.58
L= 7	75,607	78,950	4.23
L= 8	82,699	86,191	4.05
L= 9	88,597	92,158	3.86

To show the magnitude of impact of lead time from external supplier to the manufacturer on cost saving associated with information sharing, the manufacturer company's cost parameters are specified as P = 21, and l = 1 while L varies from three to nine. The percentage of cost saving does vary slightly that is four per cent to five per cent. Lead time from external suppliers to our company is approximately five-six weeks because most of the raw materials are imported from different countries.

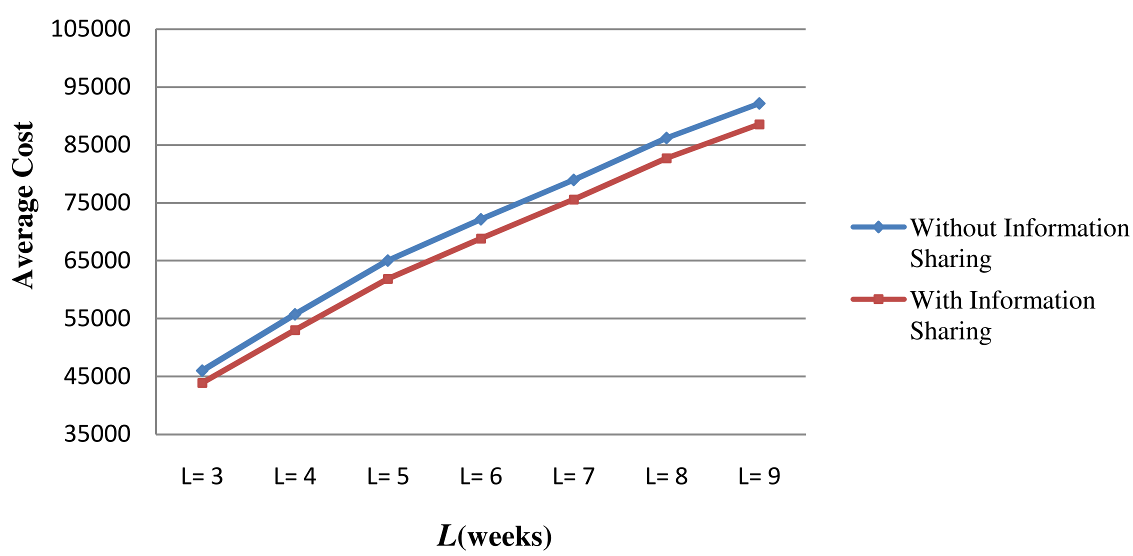


Figure 4.8. Impact of lead time from external supplier to the manufacturer

Information sharing may enable the manufacturer to obtain slightly larger cost savings when *L* is reasonable large. This implies that when lead time from supplier to the manufacturer large, the manufacturer can be more eager to obtain demand information from the retailer. The larger *L* results more additional inventory reduction with respect to information sharing.

4.4.2. Tea Pot Bag 6*100

Another stock keeping unit is "Tea Pot Bag 6*100" whose external demand process autocorrelated and normally distributed. The figure below displays the weekly demand data between 2006 January and 2007 May. From the figure, it can be realized that the highest demand occur at the KAs between 10th and 50nd weeks. We can easily point out that the demand variation is not high as that of "Poured 1000gr*9", so that the consumer service would be better than "Poured 1000gr*9" as expected.

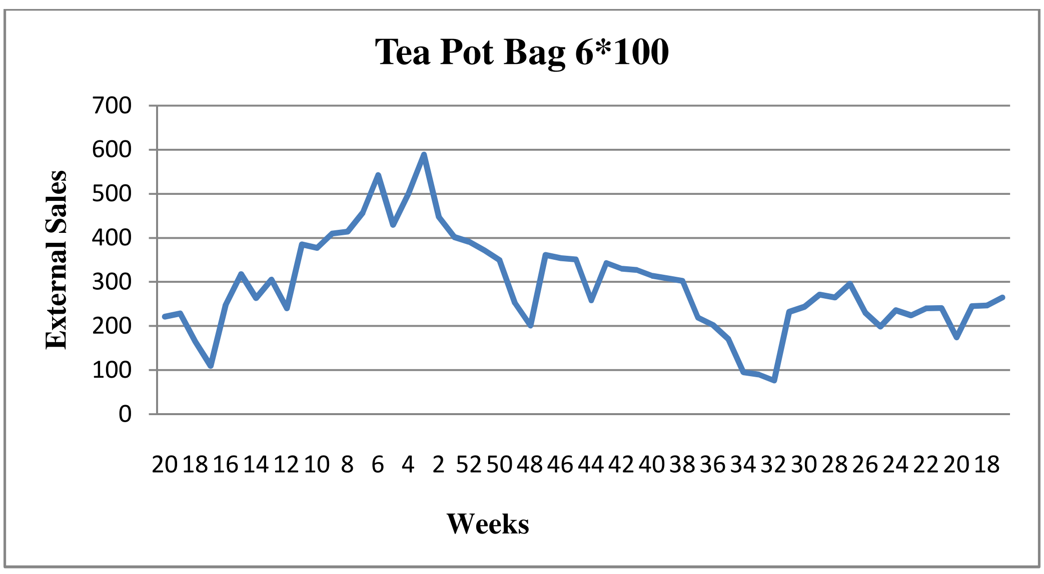


Figure 4.9. External demand for "Tea Pot Bag 6*100"

We analyze the demand process by using Minitab to determine the AR(1) process parameters and to fulfill the significance tests. The statistics are below

ARIMA Model: Tea Pot Bag 6*100

```
Estimates at each iteration

Iteration      SSE    Parameters
        0   608706   0.100   257.718
```

```
        1  479436  0.250  214.213
        2  379253  0.400  170.727
        3  308162  0.550  127.278
        4  266179  0.700   83.904
        5  253345  0.831   46.154
        6  253177  0.840   42.548
        7  253174  0.841   42.097
        8  253174  0.841   42.045

Relative change in each estimate less than 0.0010


Final Estimates of Parameters

Type         Coef  SE Coef      T      P
AR   1     0.8408   0.0796  10.57  0.000
Constant  42.045     8.352   5.03  0.000
Mean      264.15     52.47


Number of observations:  63
Residuals:    SS =  252797 (backforecasts excluded)
              MS =  4144  DF = 61


Modified Box-Pierce (Ljung-Box) Chi-Square statistic

Lag            12     24     36     48
Chi-Square    9.1   23.6   30.9   40.5
DF             10     22     34     46
P-Value     0.521  0.370  0.620  0.700
```

According the Minitab statistics mentioned above, the *t-value* is 10.57 for the AR(1) parameter ρ and the associated *p-value* is 0.000. Moreover, the *t-value* for constant term is 3.95 and the associated *p-value* is 0.000. The p-value of 0.000 indicates that there is a 0.0 per cent chance that we would have obtained our estimates of the parameter if the true parameter is zero. Moreover, the *T* test statistic for degrees of freedom 61 and for a 0.01 significance level equals approximately 2.5. The very small *p-value* implies that autocorrelation coefficient ρ and constant term can be judged as significantly different from zero at a 0.01 significance level.

The Ljung-Box statistics of 9.1, 23.6, 30.9, and 40.5 give p-values of 0.521, 0.370, 0.620, and 0.700. Since the *p-values* are larger than the 0.01 significance level, do not reject the null hypothesis, thus the residuals appear to be uncorrelated. The parameters of the model are significantly differs from zero and the residuals are uncorrelated. Therefore, we conclude that The AR(1) model appears to fit well so we use it in our analyzes.

The replenishment lead time from the manufacturer to the retailer (*l*) is in constant period and here, we make calculations when *l* varies from one to five. And, we make the calculations for lead time from supplier to the manufacturer while it varies from three to 10.

Summary of parameters are below for "Tea Pot Bag 6*100"

Mean	μ	264 cases
AR(1) coefficient	ρ	0.8408
Constant	d	42
Error standard deviation	σ	64
Lead time for retailer	l	1 – 5 weeks
Lead time for manufacturer	L	3 – 9 weeks
Penalty cost for manufacturer	P	3 – 13 YTL/case
Holding cost for manufacturer	H	3 YTL/case

We now show the results of our numerical experiment related with "Tea Pot Bag 6*100". Shortage cost has a significant impact on average cost saving associated with information sharing.

Table 4.4. Impact of shortage cost on cost saving with information sharing

	On-Hand Inventory with info Sharing	On-Hand Inventory without info Sharing	Percentage of Inventory Reduction from Info Sharing (%)
P=3	1,542	1,586	2.77
P=5	1,951	2,002	2.55
P=7	2,140	2,299	6.92
P=9	2,515	2,650	5.09
P=11	2,805	3,075	8.78
P=13	3,054	3,399	10.15

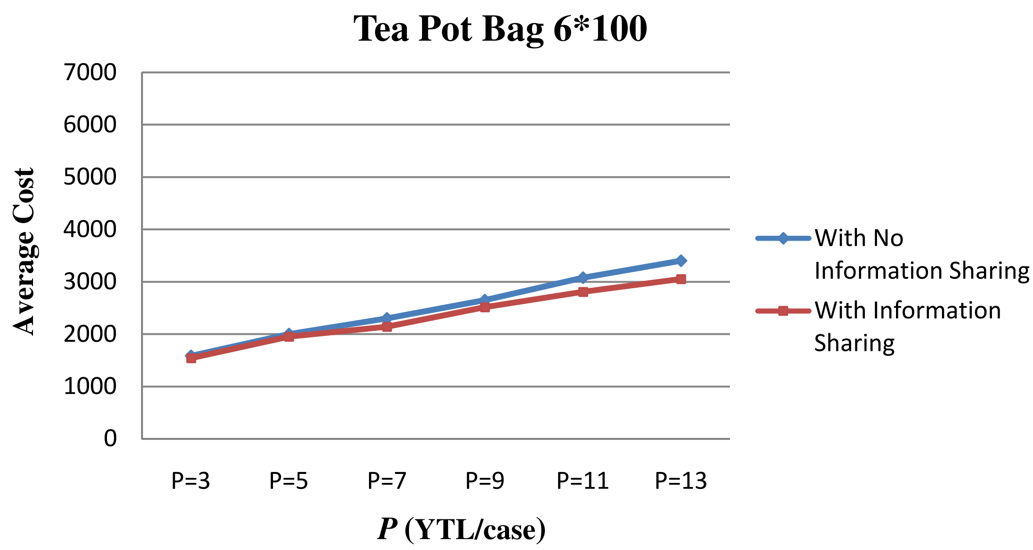


Figure 4.10. Impact of shortage cost on cost saving

The average cost has an increasing trend with increasing unit penalty cost. Furthermore, we can realize that the percentage of cost saving increases as penalty cost increases. According to calculations performed in the third part, the approximate average cost level of “Tea Pot Bag 6*100” is in the range 2800–3200 YTL. Thus, an appropriate shortage cost level can be determined between P = 9 and P =11. Furthermore, for this level of shortage cost, the benefit of information sharing is on cost saving is about seven per cent–eight percent of average cost.

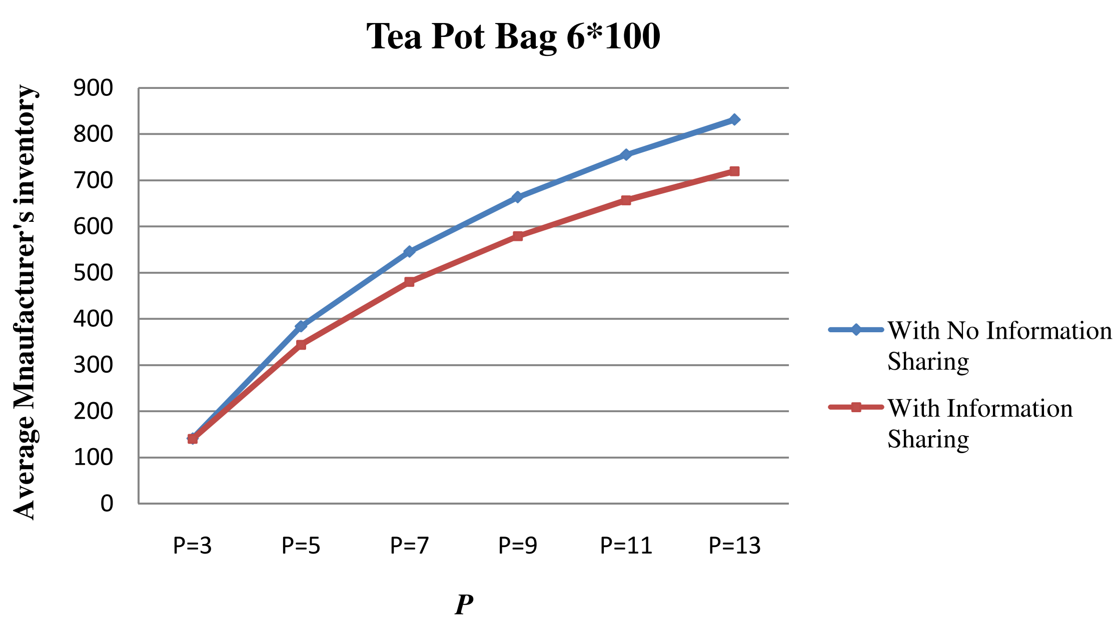


Figure 4.11. Impact of shortage cost on cost saving

5. CONCLUSION AND FUTURE RESEARCHES

The aim of this thesis is two fold; the first one is to develop an inventory control policy for the most valuable products of the company to improve customer service level by using type-2 service constraint. The second one is to show the impact of information sharing on the magnitudes of cost saving and inventory reduction with a two level supply chain that consists one retailer and one manufacturer with autocorrelated external demand processes. We also implement sensitivity analysis of the replenishment lead time and shortage cost.

In the first part, we set a target service level and analyze the demand distributions for a single product to determine decision rule parameters. The three different distributions -normal, exponential, and Laplace are studied and decision rule parameters are determined. Then, we consider a single stage (R,Q) inventory control model with type-2 service level constraint, where R is the reproduction point and Q is the fixed production quantity. The type-2 service level is an inventory model which measures the proportion of demands that are met from stock. This model is employed for both company's current service level and desired target service level. Then, we show the improvements which are provided by our inventory control model in terms of annual shortage, holding and set up costs. It is intuitively expected that the required reproduction point (safety stock) would increase if the service level (β) increased and production batch size Q decreased. A better customer service level leads to decrease in standardized loss function $L(z)$. Hence, a decrease in $L(z)$ results in an increase in safety factor z. The higher safety factor provides a higher safety stock. The numerical results reflect that since the number of shortages in a year is significantly high, company's approximate current overall supply chain cost is very high. Thus, our inventory model suggests company to hold more inventories to be lowered the number of shortages. Therefore, the annual penalty cost decreases sharply. At this point, there is an important remark to notice that if the customer service level is too low, a negative value of z is called by the formulation. However, very low safety factor value results in a negative value of reproduction point R. This is unreasonable for the decision rule parameters. In this study, we set a lower limit at zero of the reproduction point R. In this study to show the impact of penalty cost in inventory control, we calculate the annual stock-out cost for two cases, when value of long term losses equals zero and equals one unit profit. Based on our computations the suggested inventory policy provides a cost reduction varying from 51 per cent to 90 per cent of annual shortage cost. On the other hand, as desirable, since our model suggests holding more inventories to reduce the shortages, the annual inventory carrying cost increases by six percent to 106 per cent. However, for all stock keeping units that we studied on, the overall supply chain costs are lowered varying from seven percent to 41 per cent. The magnitude of cost reduction is not independent on *current costumer service level* for the corresponding product. The higher improvement rates are realized for the lower service levels. Furthermore, as well as the suggested inventory model provides a cost reduction in supply chain management, it also promises better customer service level for a single product.

In the fourth section, we develop a model of two level supply chain and we analyze the benefits of information sharing to the chain between Gıdasa A.Ş. and KA. Our numerical results indicate the information sharing could alone provide significant inventory reduction and cost saving to the manufacturer. However, the retailer can also have advantages such as use of the vendor managed inventory program to reduce the its overhead and processing cost, price reduction to reduce the retailer's variable cost, or lead time reduction to reduce the retailer's inventory cost, while it negotiates arrangements with the manufacturer before sharing sales information. We assume that our company and the retailers ordering decisions would adopt an order-up-to policy which minimizes the total discounted inventory carrying and shortage cost over the infinite horizon. In our model, excess demand is backlogged. We analyze two "tea-based products" whose demand processes are autocorrelated and normally distributed. Our numerical experiments suggest that the shortage cost and lead time have significant impact on inventory reduction and cost saving. When we set all parameters constant other than the unit shortage cost of the manufacturer, we show that the manufacturer obtains inventory reduction and cost saving from one per cent to 15 per cent and from zero per cent to nine per cent respectively. Since variability decreases with information sharing, the manufacturer needs to hold fewer inventories than when there is no information sharing. Therefore, inventory carrying cost is lowered with information sharing. Furthermore, reduction lead time from manufacturer to the retailer l would reduce the manufacturer's and retailer's inventory level. Our results indicates that reducing l would reduce the manufacturer's average cost slightly and intuitively; therefore, it is not an enough incentive, by itself, for the manufacturer to invest in lead time reduction. However, this may be a means to persuade the retailer to share demand information, which benefits the manufacturer. In other words, information sharing alone will only benefit the manufacturer and lead time reduction alone will benefit the retailer primarily. Finally, in order to show the impact of reduction of lead time from external demand to manufacturer *L*, we fix the all parameters other than *L*, while *L* varies from three to nine. In this situation, reduction of *L* suggests cost saving by three per cent to five per cent while there is information sharing.

For further researches, we first deal with the information sharing model. In our information model between our company and the KAs, we assume that the excess demand is backlogged. Exactly the same approach can be used by lost sales or by mixed strategy including backlogs and lost sales.

Next, in this thesis we focus on a single retailer. The same approach can be extended to analyze the benefit of information sharing with multiple retailers. This would be a very reasonable study because our company's distribution network is very large. The study can also be extended to show how the reduction of manufacturer's average inventory will change with the increasing number of retailers. The other further research can be interested in that some retailers are pushing for the manufacturer to participate in the Vendor Managed Program (VMI). Such a program would require the manufacturer to monitor the retailer's inventory and to schedule replenishment deliveries to the retailer. Thus, VMI program's relative benefits compared to information sharing can be investigated.

For the service level part, our model can be extended for the missing demand distributions such as gamma distribution.

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