DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

INVENTORY CONTROL FOR SLOW-MOVING ITEMS WITH APPLICATION TO REAL DATA

by

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INVENTORY CONTROL FOR SLOW-MOVING ITEMS WITH APPLICATION TO REAL DATA

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"INVENTORY CONTROL FOR SLOW-MOVING ITEMS WITH APPLICATION TO REAL DATA"** completed by **SEZİN TAMER** under supervision of **ASSIST. PROF. DR. UMAY UZUNOĞLU KOÇER** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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INVENTORY CONTROL FOR SLOW-MOVING ITEMS WITH APPLICATION TO REAL DATA

ABSTRACT

Inventory is material held in storage for later sale or use and it may consist of raw materials, in-process goods, and finished goods. Inventory control of goods is a common problem to all enterprises because for most firms, inventories account for a large percentage of working capital. The purpose of inventory management is to have the appropriate amounts of inventory at the right time, and at low cost.

Slow-moving stocks can be defined as the products whose average demand in the lead time is below ten units and which are expensive products. The demand of the slow-moving stocks has a discrete distribution whose values is mostly zero, so assessing good strategies for the management of these stocks is not easy. Because of being stochastic and lumpy demands, the forecasting of the lead time demand distribution is very difficult, which is essential to obtain the control parameters of most inventory policies.

In this study, principally, it is applied ABC classification to select important units for the enterprise and detection of the products about their being “slow-moving or not” is made by using real data. For defining the decision variables of the slow moving stocks, the methods for estimating the intermittent demand are needed and these forecasting techniques are implemented. In order to evaluate the sensitivity of the forecasting methods, the values of the total cost and the realized customer service levels are constructed. Then, the re-order points and the order quantity which satisfying the target customer service level of the firm was found. By using these values, optimal inventory policy was improved for the firm by being used continuous review inventory model.

Keywords: Inventory, stochastic inventory models, slow-moving items, intermittent demand, forecasting.

YAVAŞ DEVREDEN STOKLAR İÇİN ENVANTER KONTROLÜNÜN GERÇEK VERİLERE UYGULANMASI

ÖZ

Envanter, daha sonraki satış veya kullanım için stokta tutulan malzemedir. Envanter, hammaddeler, yarı mamuller ve mamullerden oluşabilir. Ürünlerin envanter kontrolü tüm işletmeler için yaygın bir problemdir. Çünkü, çoğu işletme için envanter, işletme sermayesinin büyük bir kısmını oluşturur. Envanter yönetiminin amacı, doğru zamanda, düşük maliyet ile uygun stok miktarına sahip olmaktır.

Yavaş devreden stoklar, tedarik süresindeki talebi on birimin altında ve pahalı olan ürünler olarak tanımlanır. Bu stokların talebi çoğu değeri sıfır olan kesikli dağılıma sahiptir, bu nedenle yavaş devreden stokların yönetimi için iyi stratejiler geliştirmek kolay değildir. Taleplerin olasılıklı ve düzensiz olması nedeni ile, tedarik süresindeki talep dağılımını tahmin etmek çok zordur ve çoğu envanter politikasının kontrol parametrelerini elde etmede önemlidir.

Bu çalışmada, öncelikle, gerçek veriler kullanılarak işletme için önemli olan ürünleri belirlemede, ABC analizi uygulanmıştır ve bu ürünlerin yavaş devreden olup olmadıklarının tespiti yapılmıştır. Yavaş devreden stokların karar değişkenlerini (tekrar sipariş verme noktası ve sipariş miktarı) tanımlamak için, kesikli talep tahmin yöntemlerine gereksinim duyulmuş ve bu tahmin yöntemleri uygulanmıştır. Tahmin yöntemlerinin duyarlılığını ölçmek için, toplam maliyet ve gerçekleşen müşteri servis düzeyleri karşılaştırılmıştır. Sonuç olarak, firmanın istenen müşteri servis düzeyini sağlayan, tekrar sipariş verme noktası ve sipariş miktarı bulunmuştur. Bu değerlere göre, sürekli gözden geçirme envanter modeli kullanılarak firma için optimal envanter politikası geliştirilmiştir.

Anahtar Kelimeler: Envanter, olasılıklı envanter modelleri, yavaş devreden ürünler, kesikli talep, tahmin.

CONTENTS

Page

CHAPTER ONE
INTRODUCTION

The inventory theory is concerned with the analysis of several types of decisions relating primarily to the problem of when to order and how much to order of a given item. Also, it is interested in obtaining inventory policies that are reasonable or optimal according to some appropriate measures of effectiveness.

There are many different types of inventory control models to solve these questions. Inventory models can be classified as deterministic and stochastic. In deterministic inventory models are assumed that the demand is known besides in stochastic inventory models are assumed that the demand is random. In real life, stochastic inventory models are generally used. There are some assumptions associated with the demand, the lead time, the shortage and the lost sales. The inventory models are detected according to the assumptions.

Slow-moving items are defined as inventories having a slower rate of turnover than the average turnover for the entire inventory. In other words, these items have mostly low-consumption rate. Slow-moving stocks are very inflexible with respect to overstocking. Overestimating the demand for these items can result in extra storage costs and losses due to the items becoming obsolete. It can be said that, slow-moving items are risky product group for the enterprise and these items are defined mostly in class A stock.

Forecasts play an important role in the planning process because they enable managers to anticipate the future so they can plan accordingly. Accurate forecasting of demand is important in inventory control, but the intermittent nature of demand makes forecasting especially difficult for slow-moving items. Accordingly inventory control of slow-moving items is difficult as well.

In this thesis, the aim is to build up a stochastic inventory policy in the condition where the demand is uncertain, irregular, and has discrete distribution. Firstly, in chapter two, inventory models are explained with the assumptions in detail. Some definitions about demand structure are discussed and the slow-moving stocks are explained in chapter three. Then, the forecasting methods for intermittent demand and lead time demand modeling methods are mentioned. Chapter four is composed of application with real data by using information given in previous chapters. ABC analysis is proposed in this chapter and, the A class items are determined, besides the structure of demands for selecting items is analyzed. Different demand forecasting techniques for intermittent demand are evaluated. Then, the control parameters that are the re-order point and optimal order quantity are calculated. Consequently, optimal policies that minimize the expected total cost are obtained for the related products that are manufactured in the enterprise. Finally chapter five includes the interpretations and comparisons of inventory policies obtained.

CHAPTER TWO
INVENTORY MODELS

The purpose of inventory theory is to determine the rules that organisation can use to minimize the costs associated with maintaining inventory and meeting customer demand on time. There are two important questions in inventory management: One of them is, how much an order should be, and the other one is, when an order should be placed. These questions are important because, while excess inventory leads to high holding costs, stockouts can have great impact on operations performance.

Inventory models are usually classified according to whether the demand for a period is known (deterministic demand) or is a random variable having a known probability distribution (nondeterministic or random demand). Another possible classification relates to the way the inventory is reviewed, either continuously or periodically. In continuous review, an order is placed as soon as the stock level falls below the prescribed reorder point. In periodic review, the inventory level is checked at discrete intervals, and ordering decisions are made only at these times even if the inventory level dips below the reorder point between the preceding and current review times (Hillier & Lieberman, 1995). All these models will be explained briefly in this chapter.

2.1 Deterministic Inventory Models

The basic assumption of these models is that the demand is assumed to occur at a known, constant rate. Besides, the lead time for each order is constant. Deterministic inventory models can be classified into four groups. These are explained briefly in following sections.

2.1.1 Economic Order Quantity Model

For the basic Economic Order Quantity (EOQ) model, lead time is zero for each order. No shortages are allowed. All demands must be met on time. There are generally four types of costs associated with inventory: Ordering and setup cost, unit purchasing cost, holding or carrying cost and stockout or shortage cost. The inventory models involve some or all of these costs. In the basic EOQ model, if an order of any size is placed, an ordering and setup cost K is incurred. The cost per unit year of holding inventory is h. The annual demand is represented D. The order quantity is represented by q and the value of q is determined that minimizes annual cost (call it q^*). TC(q) is the total annual cost incurred if q units are ordered each time the inventory level is zero. The annual total cost can be calculated as in (2.1).

$$TC(q) = annual\ cost\ of\ placing\ orders + annual\ purchasing\ cost + annual\ holding\ cost \tag{2.1}$$

Since each order is for q units, D/q orders per year will have to be placed so that the annual demand D units are met. Hence

$$\frac{Ordering\ cost}{Year} = \left(\frac{ordering\ cost}{order}\right)\left(\frac{orders}{year}\right) = \frac{KD}{q} \tag{2.2}$$

For all values of q, the per-unit purchasing cost is p. Since D units are purchased per year,

$$\frac{Purchasing\ cost}{Year} = \left(\frac{purchasing\ cost}{unit}\right)\left(\frac{unit\ purchased}{year}\right) = pD \tag{2.3}$$

Any interval of time that begins with the arrival of an order and ends the instant before the next order is received is called a cycle. The average inventory during any cycle is simply half of the maximum inventory level attained during the cycle. This result is valid in any inventory model which demand occurs at a constant rate and no shortages are allowed. In the basic EOQ model, the average inventory level during a cycle is q/2 units.

$$\frac{Holding\ \cos t}{Year} = \left(\frac{holding\ \cos t}{cycle}\right)\left(\frac{cycles}{year}\right) \tag{2.4}$$

Since the average inventory level during each cycle is q/2 and each cycle is of length q/D,

$$\frac{Holding\ \cos t}{Year} = \frac{q^2 h}{2D}\left(\frac{D}{q}\right) = \frac{hq}{2} \tag{2.5}$$

The annual total cost is obtained by adding ordering cost, purchasing cost, and holding cost.

$$TC(q) = \frac{KD}{q} + pD + \frac{hq}{2} \tag{2.6}$$

(Winston, 2004).

To find the value of q that minimizes TC(q), the first derivative of TC(q) with respect to q. This yields

$$TC^{'}(q) = -\frac{KD}{q^2} + \frac{h}{2} = 0 \tag{2.7}$$

The economic order quantity is found, and it is given by

$$q^* = \left(\frac{2KD}{h}\right)^{1/2} \tag{2.8}$$

(Winston, 2004).

Under the assumptions of the EOQ model, “how – much - to - order” decision is provided by the derived quantity q^*. When – to – order – rule: An order should be placed when the inventory position equals the demand during the lead time (Epen & Gould & Schmidt, 1989).

2.1.2 The Quantity Discount Models

In real life, suppliers often reduce the unit purchasing price for large orders; this situation is named of quantity discounts. If a supplier gives quantity discounts, the annual purchasing cost will depend on the order size. So, a new approach is needed to find the optimal order quantity. The quantity discount model is described in Winston (2004) as below.

If $q < b_1$, each items costs p_1.
If $b_1 \leq q < b_2$, each items costs p_2.
If $b_{k-2} \leq q < b_{k-1}$, each items costs p_{k-1}.
If $b_{k-1} \leq q < b_k = \infty$, each items costs p_k
$b_1, b_2, \ldots, b_{k-1}$ are called price break points. Since larger order quantities should be associated with lower prices, it is reached this result $p_k < p_{k-1} < \ldots < p_2 < p_1$.

The following definitions are needed.
$TC_i(q)$: total annual cost if each order is for q units at a price p_i.
EOQ_i : quantity that minimizes total annual cost if , for any order quantity, the purchasing cost of the item is p_i.
EOQ_i is admissible if $b_{i-1} \leq EOQ_i < b_i$ (Winston, 2004).

Firstly, for each discount category, EOQ_i is calculated using the EOQ formula based upon the unit cost associated with the discount category. Then, for those finding EOQ_i’s that are too small to qualify for the assumed discount price, adjust the order quantity upward to the nearest order quantity that will allow the product to be purchased at the assumed price. Consequently, for each of the order quantities, the total annual cost using the unit price from the appropriate discount category is computed as in (2.6). The order quantity yielding the minimum total annual cost is the optimal order quantity (Anderson & Sweeney & Williams, 1992).

2.1.3 The Continuous Rate EOQ Model

Many goods are produced internally rather than purchased from an outside supplier. This situation is unrealistic because each order does not arrive at the same time. That is the EOQ assumption is not valid in this model. This type of the EOQ model is named of the continuous rate EOQ model or economic production lot size model. If a firm meets demand by making its own products, the continuous rate model will be more realistic than the EOQ model (Winston, 2004). It is assumed that demand is deterministic and occurs at a constant rate. Also, since it is assumed that the production rate exceeds the demand rate, so shortages are not subjected.

The continuous rate EOQ model assumes that a firm can produce a good at a rate of units per time period. q is the number of units produced during each production run and K is the cost of setting up a production run.

Assuming that per-unit production costs are independent of run size, the value of q must be determined. Since demand occurs at a constant rate, it may write, average inventory level = ½(maximum inventory level).

The maximum inventory level occurs at time $\frac{q}{a}$. Since between zero and $\frac{q}{a}$, the inventory level is increasing at a rate of a – D units per year, the inventory level at time $\frac{q}{a}$ will be $\left(\frac{q}{a}\right)(a-D)$. Then

$$\frac{Holding\ \cos t}{Year} = h(average\ inventory)(1\ year) = \frac{h(a-D)q}{2a} \tag{2.9}$$

The annual holding cost for the continuous rate EOQ model is the same as that for a conventional EOQ model in which the unit holding cost is $\frac{h(a-D)}{a}$ and annual ordering cost.

$$\frac{Holding\ \cos t}{Year}+\frac{Ordering\ \cos t}{Year}=\frac{hq(a-D)}{2a}+\frac{KD}{q} \tag{2.10}$$

(Winston, 2004).

This equation shows that the problem of minimizing the sum of annual holding and ordering costs for the continuous rate model is equivalent to solving an EOQ model with holding cost $\frac{h(a-D)}{a}$, ordering cost K, and annual demand D. Consequently, this equation result is found.

$$Optimal\ run\ size=\left(\frac{2KD}{\frac{h(a-D)}{a}}\right)^{1/2}=\left(\frac{2KDa}{h(a-D)}\right)^{1/2}=EOQ\left(\frac{a}{a-D}\right)^{1/2} \tag{2.11}$$

(Winston, 2004).

2.1.4 The EOQ Model with Back Orders Allowed

In many real-life situations, demand is not met on time, shortages occur and costs are incurred. Let s be the cost of being short one unit for one year. It is assumed that all demand is backlogged and no sales are lost. The lead time for each order is zero. This type model is called the EOQ model with back orders allowed. Maximum shortage that occurs under an ordering policy is represented q – M. Since purchasing costs do not depend on q and M, it can be minimized annual costs by determining the values of q and M that minimize

$$\frac{Holding\ \cos t}{Year}+\frac{Shortage\ \cos t}{Year}+\frac{Order\ \cos t}{Year} \tag{2.12}$$

Let TC(q, M) be the total annual cost if the order policy uses parameters q and M. TC(q, M) is calculated as below

$$TC(q, M) = \frac{M^2 h}{2q} + \frac{(q - M)^2 s}{2q} + \frac{KD}{q} \tag{2.13}$$

(Winston, 2004).

The first derivative of TC(q, M) with respect to q and M, and is equaled to zero. Consequently, TC(q, M) is minimized for q^* and M^*:

$$q^* = \left[\frac{2KD(h+s)}{hs}\right]^{1/2} = EOQ\left(\frac{h+s}{s}\right)^{1/2} \tag{2.14}$$

$$M^* = \left[\frac{2KDs}{h(h+s)}\right]^{1/2} = EOQ\left(\frac{s}{h+s}\right)^{1/2} \tag{2.15}$$

Maximum shortage = q^* - M^*

(Winston, 2004).

2.2 Stochastic Inventory Models

Stochastic inventory models are those in which demand over a given time period is uncertain, or random. Lead time is nonzero and the demand during each lead time is random. When demand is assumed to be stochastic, inventory is managed according to two principles. These models will be explained in detail as follows.

2.2.1 Continuous Review Models

The continuous review models are used when lead time is nonzero and the demand during each lead time is random. These models are modification of the EOQ. An order may be placed at any time. A continuous review inventory policy, in which an order is placed a quantity q whenever inventory level reaches a reorder level r, is often called an (r, q) policy. If demands of size greater than one unit can occur at a point in time, then (r, q) model may not yield a policy that minimizes expected annual cost (Winston, 2004). In such situations, (s, S) policy can be used. To implement an (s, S) policy, an order is placed whenever the inventory level is less than or equal to s. The size of the order is sufficient to raise the inventory level to S (assuming zero lead time). Exact computation of the optimal (s, S) policy is difficult. The optimal (s, S) policy is approximately as follows. Set S – s equal to the economic order quantity q. Then set s equal to the reorder point r. Finally, it is obtained S = r + q.

Notation;

D: random variable representing annual demand with mean E(D), variance Var(D), and standard deviation σ_D

L: lead time for each order (assumed to be known with certainty)

c_B: cost incurred for each unit short

OHI(t): on-hand inventory at time t

B(t): number of outstanding back orders at time t

I(t): net inventory level at time t

r: reorder point

X: random variable representing demand during lead time

In (r, q) models assume that X is a continuous random variable having density function f(x), mean E(X), variance Var(X), and standard deviation σ_X. If the demand different points in time are independent, then it can be shown that the random lead time demand X satisfies

$$E(X) = L \cdot E(D) \tag{2.16}$$

$$Var(X) = L \cdot Var(D) \tag{2.17}$$

$$\sigma_X = \sigma_D \sqrt{L} \tag{2.18}$$

If D is normally distributed, then X will also be normally distributed.

Suppose that the lead time L to be a random variable with mean E(L), variance Var(L), and standard deviation σ_L. If the length of the lead time is independent of the demand per unit time during the lead time, then

$$E(X) = E(L)E(D) \tag{2.19}$$

$$Var(X) = E(L)Var(D) + E(D)^2 Var(L) \tag{2.20}$$

The purpose of continuous review models find that q and r to minimize the annual expected total cost (exclusive of purchasing cost). There are two cases:

- Back-ordered case
- Lost sales case

The situation in which all demand must eventually be met and no sales are lost is called the back-ordered case. The reorder point and order quantity that minimize annual expected cost are determined. Each unit is purchased for the same price, so purchasing costs are fixed.

TC(q, r) = expected annual cost (excluding purchasing cost) incurred if each order is for q units and is placed when the reorder point is r.

I(t) = OHI(t) – B(t)

Expected value of I(t) $\cong$ Expected value of OHI(t)

Expected annual holding cost = h(expected value of on-hand inventory level)

Here, it can be found that expected annual holding cost = h(expected value of I(t)). The expected value of I(t) equals the expected value of I(t) during a cycle and expected value of I(t) during a cycle can be written as below

$$\frac{1}{2}\begin{bmatrix}(\text{expected value of } I(t) \text{ at beginning of cycle}) + \\ (\text{expected value of } I(t) \text{ at end of a cycle})\end{bmatrix}$$

Expected value of I(t) during cycle = $\frac{1}{2}(r - E(X) + r - E(X) + q) = \frac{q}{2} + r - E(X)$ (2.21)

$$So,\ \text{expected annual holding cost} \cong h\left(\frac{q}{2} + r - E(X)\right). \tag{2.22}$$

(Winston, 2004).

B_r is used to determine the expected annual cost due to stockouts or back orders. B_r is defined that random variable representing the number of stockouts or back orders during a cycle if the reorder point is r.

$$\frac{Expected\ shortage\ \cos t}{Year} = \frac{c_B E(B_r)E(D)}{q} \tag{2.23}$$

$$Expected\ annual\ order\ \cos t = \frac{K \cdot E(D)}{q} \tag{2.24}$$

(Winston, 2004).

Finally, TC(q, r) is obtained by putting these costs.

$$TC(q,r) = h\left(\frac{q}{2} + r - E(X)\right) + \frac{c_B E(B_r)E(D)}{q} + \frac{K \cdot E(D)}{q} \tag{2.25}$$

(Winston, 2004).

It could be find the values of q and r that minimize TC(q, r) by determining values q^* and r^* of q and r satisfying

$$\frac{\partial TC(q^*, r^*)}{\partial q} = \frac{\partial TC(q^*, r^*)}{\partial r} = 0 \tag{2.26}$$

The value of q^* is very close to the EOQ of $\left(\frac{2KE(D)}{h}\right)^{1/2}$. To find the value of r^*, marginal analysis can be used for given a value q for the order quantity. Finally, the values of q^* and r^* for the back-ordered case are obtained as in (2.20) and (2.21).

$$q^* = \left(\frac{2KE(D)}{h}\right)^{1/2} \tag{2.27}$$

$$P(X \geq r^*) = \frac{hq^*}{c_B E(D)} \tag{2.28}$$

(Winston, 2004).

Safety stock is the difference between the reorder point and the expected lead time demand. Also, the expected annual cost of holding safety stock is h(r – E(X)) = h(safety stock level).

The situation in which all stockouts result in lost sales is called the lost sales case. A cost of c_{LS} is incurred for each lost sale. As in the back-ordered case, the optimal order quantity can be adequately approximated by the EOQ and attempt to use marginal analysis to determine the optimal point r^*. The optimal order quantity q^* and the reorder point r^* for the lost sales case are

$$q^* = \left(\frac{2KE(D)}{h} \right)^{1/2} \tag{2.29}$$

$$P(X \geq r^*) = \frac{hq^*}{hq^* + c_{LS}E(D)} \tag{2.30}$$

(Winston, 2004).

It is usually very difficult to determine accurately the cost of being one unit short. For this reason, managers often decide to control shortages by meeting a specified service level. Two measures of service level is explained as follows. Service level measure 1 (SLM_1), is defined as the expected fraction of all demand that is met on time. Also it is called as fill rate. Whereas, service level measure 2 (SLM_2), is defined as the expected number of cycles per year during which a shortage occurs.

The value of SLM_1 is computed as follows and by using a desired value of SLM_1, the reorder point is found.

$$1 - SLM_1 = \frac{\text{expected shortage per year}}{\text{expected demand per year}} = \frac{E(B_r)E(D)/q}{E(D)} = \frac{E(B_r)}{E(D)} \tag{2.31}$$

(Winston, 2004).

It is assumed that the lead time demand is normally distributed with mean E(X) and standard deviation σ_X. If X is normally distributed, the determination of $E(B_r)$

requires a knowledge of the normal loss function. Finally the equation is found as follows.

$$NL\left(\frac{r - E(X)}{\sigma_X}\right) = \frac{q(1 - SLM_1)}{\sigma_X} \tag{2.32}$$

(Winston, 2004).

The manager wants to hold sufficient safety stock to ensure that an average of s_0 cycles per year will result in a stockout. Given s_0, the reorder point is the smallest value of r satisfying

$$\frac{P(X > r)E(D)}{q} \leq s_0 \ or \ P(X > r) \leq \frac{s_0 q}{E(D)} \tag{2.33}$$

If X is a continuous random variable, then $P(X > r) = P(X \geq r)$. Thus, the reorder point r is obtained for SLM_2 for continuous lead time demand,

$$P(X \geq r) = \frac{s_0 q}{E(D)} \tag{2.34}$$

and the reorder point for SLM_2 for discrete lead time demand,

$$P(X > r) \leq \frac{s_0 q}{E(D)} \tag{2.35}$$

2.2.2 Periodic Review Models

If the amount of on-hand inventory is reviewed periodically and orders may be placed only periodically, this inventory models are called periodic review models. Also these models are called the (R, S) policy. In the (R, S) policy, every R units of time (say, years), the on-hand inventory level is reviewed and an order is placed to bring the on-order inventory level up to S. The on-order inventory level is simply the sum of on-hand inventory and inventory on order.

The review interval R has been determined and focus on the determination of a value for S that will minimize expected annual costs. All shortages are backlogged and demand is a continuous random variable whose distribution remains unchanged over time. Additional notation;

R: time (in years) between reviews
J: cost of reviewing inventory level
D_{L+R}: demand (random) during a time interval of length L + R
$E(D_{L+R})$: mean of D_{L+R}
$\sigma_{D_{L+R}}$: standard deviation of D_{L+R}

For a given choice of R and S, the expected costs given by

$$(annual \text{ exp}ected \ purchase \cos ts) + (annual \ review \cos ts) + (annual \ ordering \cos ts) + (annual \text{ exp}ected \ holding \cos ts) + (annual \text{ exp}ected \ shortage \cos ts) \tag{2.36}$$

Since 1/R reviews per year are placed, annual review costs are given by J/R and annual ordering costs are given by K/R. Also whenever an order is placed, the on-order inventory level will equal S. Both the annual ordering costs and the annual review costs are independent of S. Thus, the value of S that minimizes annual expected costs will be the value of S that minimizes (annual expected holding costs) + (annual expected shortage costs).

$$Expected \ annual \ holding \cos t = h\left[S - E(D_{L+R}) + \frac{E(D)R}{2}\right] \tag{2.37}$$

(Winston, 2004).

If a shortage occurs, the magnitude of the shortage will equal $D_{L+R} - S$.

It can be used marginal analysis to the value of S that minimizes the sum of annual expected holding and shortage costs. Increasing S to S + Δ will increase expected annual holding costs by hΔ. Increasing S to S + Δ will decrease shortages associated with an order if $D_{L+R} \geq S$ and it will be save $c_B\Delta$ in shortage costs. Finally it can be write the equation as follows

$$h\Delta = \left(\frac{1}{R}\right)c_B \Delta P(D_{L+R} \geq S) \tag{2.38}$$

For the back-ordered case

$$P(D_{L+R} \geq S) = \frac{Rh}{c_B} \tag{2.39}$$

For the lost sales case

$$P(D_{L+R} \geq S) = \frac{Rh}{Rh + c_{LS}} \tag{2.40}$$

(Winston, 2004).

2.3 ABC Classification

Many companies should improve inventory policies for their many products. It is impossible to prepare an analysis for each product. Because, maintaining inventory through counting, placing orders, receiving stock, and so on takes personnel times and costs money. In such conditions, the vastly known method is the ABC classification.

The ABC analysis lets the user to classify the products according to their degree of importance which was determined by the products' sales conditions. In fact, this analysis consists of the classification of the products according to their cumulative percent in total. The purpose of using this analysis is to determine and sort the important and unimportant products. The Class-A products include the ones which have high financial values and important for the company. So, by developing decision policies for these products, a significant saving can be made.

In the classification, the products are divided into three groups. The Class-A products include the 55 % - 65 % of the total sales and 5 % - 20 % of the total units; the Class-B products include the 20 % - 40 % of the total sales and 20 % - 30 % of the total units and the Class-C products include the 5 % - 25 % of the total sales and 50 % - 75 % of the total units (Winston, 2004). These ratios can be differed from a company to another.

CHAPTER THREE
INVENTORY CONTROL OF SLOW-MOVING ITEMS

3.1 Introduction

In literature, slow-moving items are defined as the products whose average demand in the lead time is below 10 units and which are expensive products. The demand of the slow-moving items has a discrete distribution whose values are mostly zero (Aktürk & Özkale & Fığlalı & Engin, 2005).

Managing inventory with intermittent demand has received less attention in the literature than that of fast-moving products. This is due in part, perhaps, to the lack of observable historical sales figures for inventory with intermittent demand or because slow-moving inventory does not provide the bulk of sales, despite often being the bulk of inventory on hand (Lindsey, 2007). Consequently, actually slow-moving items are important for the companies.

Inventory control of slow-moving items is essential to many organizations, since excess inventory leads to high holding costs and stockouts can have a great impact on operations performance. The difficulty in assessing good strategies for the management of slow-moving items lies in their specific nature, since highly stochastic and lumpy demands. This makes the estimation of the lead time demand (X) distributions very difficult, which is essential to obtain the control parameters of most inventory policies (Porras & Dekker, 2008).

The data demand patterns are explicitly considered in relation to the pattern and the size of the demand when it occurs. These are classified into four categories (Syntetos, 2001) based on modified Williams (1984) criteria. The definitions of the categories are as follows:

- Intermittent demand, which appears randomly with many time periods having no demand.
- Erratic demand, which is (highly) variable, erraticness relating to the demand size rather than demand per unit time period.
- Smooth demand, which also occurs at random with many time periods having no demand. Demand, when it occurs, is for single or very few units.
- Lumpy demand, which likewise seems random with many time periods having no demand. Moreover demand , when it occurs, is (highly) variable(Ghobbar & Friend, 2002).

The four resulting demand categories are represented graphically in Figure 4.1.

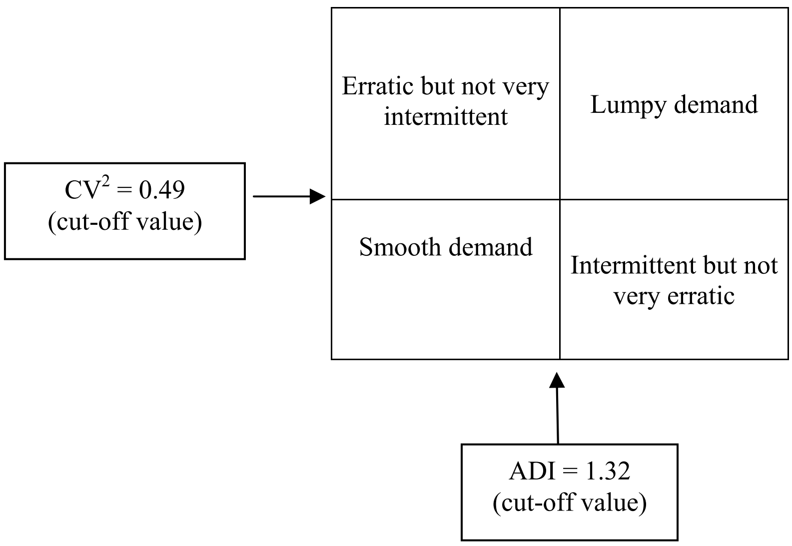

Figure 4.1 The demand categories

Traditionally the characteristics of intermittent demand are derived from two parameters: the average inter demand interval (ADI) and the coefficient of variation (CV). ADI measures the average number of time periods between two successive demands and CV represents the standard deviation of requirements divided by the average requirement over a number of time periods (Pham, 2006).

3.2 The Forecasting Methods for Intermittent Demand

Forecasting is concerned with predicting the future. Forecasts help managers by reducing some of the uncertainty, thereby enabling them to develop more meaningful plans. A forecast is a statement about the future. Forecasts play an important role in the planning process because they enable managers to anticipate the future so they can plan accordingly.

Demand that is intermittent is often also lumpy, meaning that there is great variability among the nonzero values. Accurate forecasting of demand is important in inventory control, but the intermittent nature of demand makes forecasting especially difficult for slow-moving items (Willemain & Smart & Schwarz, 2004). There has been several intermittent demand forecasting methods proposed in literature (Varghese & Rossetti, 2008). Three forecasting techniques are described below.

3.2.1 Exponential Smoothing

Exponential smoothing has proven to be a robust forecasting method and is probably the most used of the statistical approaches to forecasting intermittent demand (Willemain & Smart & Schwarz, 2004). This method is relatively easy to use and understand. Each new forecast is based on the previous forecast plus a percentage of the difference between that forecast and the actual value of the series at that point.

The mean and variance of the assumed normal distribution of lead time demand is computed as follows. The mean level of demand at time t, M(t), is estimated using

$$M(t)=\alpha X(t)+(1-\alpha)M(t-1) \qquad t = 1\ldots T, \qquad (3.1)$$

where α is a smoothing constant between 0 and 1. For each inventory item, the value of α is selected that minimized the sum of squared residuals… The smoothing is initialized using the average of the first two demands

$$M(0) = \frac{X(1) + X(2)}{2} \tag{3.2}$$

The mean of the L demands over the lead time is estimated as $L \cdot M(t)$. The variance, Var(t), is estimated as follows

$$Var(t) = \left(\frac{1}{T}\right) \cdot \sum \left[X(t) - M(t-1)\right]^2 . \qquad t=1\ldots T \tag{3.3}$$

Finally, the variance of the lead time demand distribution as $L \cdot Var(t)$ (Willemain & Smart & Schwarz, 2004).

3.2.2 Croston's Method

Croston's method was developed to provide a more accurate estimate of the mean demand per period. Like exponential smoothing, Croston's method assumes that lead time demand has a normal distribution (Willemain & Smart & Schwarz, 2004).

Croston's method estimates the mean demand per period by applying exponential smoothing separately to the intervals between nonzero demands and their sizes (Willemain & Smart & Schwarz, 2004).

Notation;
X(t): the observed demand in period t, t = 1,...,T.
I(t): the smoothed estimate of the mean interval between nonzero demands
S(t): the smoothed estimate of the mean size of a nonzero demand
z: the time interval since the last nonzero demand
α is a smoothing constant between 0 and 1.

On the other hand in literature, it is stated that a lower smoothing constant recommended for the calculations (Syntetos & Boylan, 2005).
Croston's method works as follows:

If $X(t) = 0$ then

$$S(t)=S(t-1) \quad (3.4)$$

$$I(t)=I(t-1) \quad (3.5)$$

$$z = z + 1 \quad (3.6)$$

else

$$S(t)=\alpha X(t)+(1-\alpha)S(t-1) \quad (3.7)$$

$$I(t)=\alpha z+(1-\alpha)I(t-1) \quad (3.8)$$

$$z = 1 \quad (3.9)$$

Combining the estimates of size and interval provides the estimate of mean demand per period can be calculated as,

$$M(t) = \frac{S(t)}{I(t)} \quad (3.10)$$

When demand occurs every review interval, Croston's method is identical to conventional exponential smoothing.

3.2.3 Willemain's Bootstrap (Resampling) Method

Units of population can be observed to have information about population and definition of it can be made based on knowledge obtained from the sample. Accuracy of population parameter estimation is direct related on sample. Sampling from large population will cause lacking of the time and costs. So, different sets can be constituted by replacement with the samples in the observed data set, derived from population (Yakupoğlu & Atıl, 2001).

A data set is constituted by using a substitution sampling selecting the substitutions from the individual observations. A random nonzero demand is selected and, in order to give a chance to a value which is close to the substituted one, a random variation is added.

X^* is accepted as a random demand value and Z is accepted as a random deviated value. By using these notations the process operates as below

$$\text{JITTERED} = 1 + \text{INT}(X^* + Z \sqrt{X^*}) \quad (3.11)$$

$$\text{IF JITTERED} \leq 0\text{, THEN JITTERED} = X^* \quad (3.12)$$

The Willemain's Bootstrap Method can be briefly summarized in (Willemain & Smart & Schwarz, 2004) with these steps:

Step 0– Obtain historical demand data in chosen time buckets (e.g. days, weeks, months).

Step 1– Estimate transition probabilities for two – state (zero vs. nonzero) Markov model.

Step 2– Conditional on last observed demand, use Markov model to generate a sequence of zero / nonzero values over forecast horizon.

Step 3– Replace every nonzero state marker with a numerical value sampled at random with replacement from the set of observed nonzero demands.

Step 4– Jitter the nonzero demand values.

Step 5– Sum the forecast values over the horizon to get one predicted value of LTD.

Step 6– Repeat steps 2 – 5 many times.

Step 7– Sort and use the resulting distribution of LTD values

3.3 Modeling The Lead Time Demand

In inventory decision making, one needs to determine inventory control parameters, such as re-order points and safety stocks. In order to do so, a specification of the lead time demand distribution is needed. In this way the distribution of demand over the lead time for each model, which is used in turn to evaluate the parameters of the inventory policies selected, is estimated. The performance of the system using normal and Poisson distribution based models are evaluated. These models are described below (Willemain & Smart & Schwarz, 2004).

3.3.1 Willemain's Bootstrap (Resampling) Method

Firstly, the Bootstrap method is implemented as mentioned in Section 3.2.3. The method is able to produce lead time demand estimation where many other lead time demand values are taken into account.

Once the lead time distribution is obtained, it can be used to determine a re-order point to achieve a given fill rate β as follows:

$$100\beta\% \leq \left(1 - \frac{ES(r)}{q}\right) \times 100 \tag{3.13}$$

(Willemain & Smart & Schwarz, 2004).

From the cumulative distribution function, F(x), of lead time demand obtain the list of possible re-order point values r, setting by r = x, where x are the lead time demand values, and their corresponding probabilities f(x).

ES(r) is the expected units short for a given re-order point r, which is calculated as follows:

$$ES(r) = \sum_{x|x>r} (x - r) f(x) \tag{3.14}$$

(Willemain & Smart & Schwarz, 2004).

Economic order quantity, q is obtained as follows:

$$q = \sqrt{\frac{2KE(D)}{h}} \tag{3.15}$$

By using these equations, optimal inventory policy is determined.

3.3.2 Empirical Model

In empirical model, the estimation is made by using empirical distribution of the lead time demand. Different from the traditional bootstrap method, the histogram of demand over the lead time without sampling is constructed. This method is new to the literature (Porras & Dekker, 2008).

As the empirical model uses only the demand values from the demand data set to construct the cumulative distribution function (CDF), fewer lead time demand values are produced in this CDF than in the corresponding one using the Willemain's method (Porras & Dekker, 2008). By using (3.13) and (3.14), concerned values are found. Using the empirical CDF, a re-order point for a given fill rate is determined and optimal inventory policy is obtained.

3.3.3 Poisson Model

The Poisson distribution is suitable to model the demand of slow-moving items. In order to determine a re-order point for a given fill rate using the Poisson model, a similar procedure can be applied as the one described above fort he Willemain's or the empirical method, substituting f(x) fort he Poisson probabilities (with parameter $\lambda_{LTD} = \overline{D} \cdot L$) and using r = x as the set of positive integers 1, 2 ,…(Porras & Dekker, 2008). Similarly, by describing a re-order point, an optimal inventory policy is obtained.

3.4 Accuracy of Lead Time Demand Modeling Methods

Some traditional measurements of forecast accuracy are unsuitable for intermittent demand data because they can give infinite or undefined values (Hyndman & Koehler, 2006). Some of these forecast accuracy metrics and definitions are summarized as below.

The mean absolute error or deviation (MAE or MAD) is easiest to understand and compute. However, it can not be compared across series because it is scale dependent; it makes no sense to compare accuracy on different scales (Hyndman & Koehler, 2006).

This measurement is similar to the Mean Error, except the MAD considers the absolute values of the errors. A zero MAD represents a perfect fit. It is calculated as

$$e_t = Actual\ Value\ at\ time\ t - Forecast\ Value\ at\ time\ t = Y_t - F_t \tag{3.16}$$

$$MAD = mean(\mid e_t \mid) = \frac{1}{n}\sum_{i=1}^{n} \mid e_t \mid \tag{3.17}$$

The sum of squared error (SSE) is an accuracy measure where the errors are squared then added. The lower SSE yields the more accurate forecast.

$$SSE = total\left(e_t^2\right) \tag{3.18}$$

The mean absolute scaled error (MASE) can be used to compare forecast methods on a single series and also to compare forecast accuracy between series. This metric is well suited to intermittent-demand series because it never gives infinite or undefined values (Hyndman & Koehler, 2006).

A scaled error is defined as

$$q_t = \frac{e_t}{\frac{1}{n-1}\sum_{i=2}^{n} \mid Y_i - Y_{i-1} \mid} \tag{3.19}$$

The mean absolute scaled error is simply

$$MASE = mean(\mid q_t \mid) \tag{3.20}$$

(Hyndman & Koehler, 2006).

3.5 Literature Review

In order to define the stock level for optimal slow-moving units in their studies Heyvaert & Hurt (1956) had considered a second criterion besides the criteria of cost and that criterion is customer satisfaction. The demand distribution is assumed as Poisson and the average lead time demand accepted as the values between 0,1 and 10. With the development of three different inventory models by Heyvaert & Hurt (1956), the inventory methods have arose for the slow-moving stock units. These models are shortage model, minimum cost model and service-level model. Since the slow-moving stocks are defined mostly in Class A stocks, in their application Aktürk & Özkale & Fığlalı & Engin (2005), defined the slow-moving stock units among the Class A units. They had stated the distribution of the selected units according to their previous data and selected a proper inventory model for this distribution.

The turnover ratio is a scale of how effective and efficient are the sources used. In their studies Rao & Rao (2009), defined the calculation of the turnover ratio and observed the relation between the turnover ratio and the slow-moving units. They have mentioned that the slow-moving units are the ones which never moved or moved once in a year.

In order to estimate the future needs and provide an effective stock management, first of all the demand patterns must be categorized for defining the stock control method and the estimation method. Determining the demand patterns had a limited area in literature until recent studies. In their studies, Syntetos & Boylan & Croston (2005) proposed to define the demand-modeling rules in the scope of average inter-demand interval (ADI) and the squared coefficient of variation of demand sizes (CV^2). The cut-off points of these values are determined and the selection of a proper method for these values is made. Ghobbar & Friend (2002) had also carried out a similar study. In their studies they have defined the concepts of intermittent, erratic, smooth and lumpy demand, and constituted the schema of "categorization of demand patterns" according to this. Similarly they have calculated the same ADI and CV^2 values and used the same cut-off values.

Croston (1972) stated that the favorite method for the estimation in stock control systems is exponential smoothing. The analyses have shown that erroneous results are reached in intermittent demands. Therefore, a method is defined in order to cope with this problem and called as Croston's Method. In this method different estimations are made according to the size and frequency of the demand.

Syntetos & Boylan (2001) have stated that the estimation of intermittent demand units and inventory control is a serious problem in manufacturing and worked on the bias in the intermittent demand estimations. Some errors are found in the Croston Method and a new method is developed with the help of some modifications, and this new method is named as Revised Croston Method. By keeping a simulation study a comparison between these two methods is made and Revised Croston Method is observed to be giving less bias results. Moreover, in their studies in 2005 Syntetos & Boylan, have compared the four forecasting methods for the intermittent demands and chose the best forecasting method by using some criteria. Their method in focus is a new method depending on Simple Moving Average, Single Exponential Smoothing, Croston's Method and Revised Croston Method. As a result of comparison the most efficient estimation is made by the new model developed adhere to the Croston Method. Willemain & Smart and Schwarz (2004) have held a similar comparison but observed the Exponential Smoothing, Croston and Bootstrap Methods. As a result they have proven that the Bootstrap Method is serving more precise and accurate estimations.

In statistics, in the estimation of a specific parameter/parameters of a population; the surveys of that population is used. Since the use of all the observations on the population is a waste of time and money; there is a great need for the sample data which represents the population best. By re-sampling which is made via altering the surveys randomly in a data set of any size, various data sets can be constructed in different sizes and this method is named as Bootstrap Method (Takma & Atıl, 2006). In their studies, Takma & Atıl (2006) had spoken of the advantages of this method and stated that the use of this method in applied statistics has grown gradually. Bootstrap method is introduced by Efron (1979) with the basic idea of generating a large number of sub-samples by randomly drawing observations with replacement from the original data set. An interesting feature of this method is that it can provide the standard errors of any complicated estimator without requiring any theoretical calculations. These interesting properties of the bootstrap method have to be traded off with computational cost and time (Midi & Uraibi & Talib, 2009). Bootstrap method provides solutions for non-parametric and small-sample problems and by employing over the original samples, the statistics are obtained more valid by reducing sampling errors than those from traditional statistical methods (Bai & Pan, 2008).

In the study of Porras & Dekker (2008), they notified that since the slow-moving units lead to a higher holding-cost in over-stocking conditions and have a great effect for operation performance in stock-shortage, they have a great role in inventory control. Various re-order point methods are compared. Different demand modeling techniques and inventory policies are developed by using real data sets. The defined methods are as follows: Willemain's Bootstrap method, empirical model, the model assuming that the demand is distributed normally, and the model assuming that the demand is distributed Poisson. The re-order points which serve for the intended service level are identified by using these models. The total costs for each model are calculated and the optimal inventory policy which serves the minimum cost is determined.

It is important that to measure the accuracy of the forecasts. There are different measures of accuracy in the literature. Hyndman & Koehler (2006) have defined four types of criteria for presenting the accuracy of intermittent demand estimation and comparing the methods in use. After showing that some methods are not proper for the intermittent demand data, he had presented a new criterion. This criterion is called as "the mean absolute scaled error" and Hyndman & Koehler (2006) stated that this criterion is more suitable for the intermittent demand data. Furthermore, in this study he explained the mean absolute error, percentage errors, and relative-error metrics.

CHAPTER FOUR
APPLICATION

The main objective of the inventory theory is to find a proper answer to the question of "when and in what quantity; a purchase order should be given?". This application aims to build up a stochastic inventory policy in the condition where the demand is uncertain and has a discrete distribution. With the help of the defined policy the questions will be tried to be answered.

In the process of application firstly, an ABC analysis will be held in order to determine the A class products which are important for the enterprise. Then, the turnover ratio for the A class carpets are calculated and it is found that these products are slow moving stocks. In this study, "Milas carpet" type are decided to be analyzed and the dimensions of this carpet which will be used are determined as "büyük kelle", "taban" and "karyola yolluk".

In order to acquire the reorder point and the order quantity which are essential parameters for inventory control, it is necessary to estimate the lead time demand. The following methods are used for the estimation of the lead time demand: Croston's Method, Willemain's Bootstrap Method, Empirical Model and Poisson Model. In Croston's Method, for smoothing constant α, different values are tested. As a result, two of tested values are determined as 0.1 and 0.6. This is because when the sum of squared error values are compared, the sum of squared error (SSE) is minimized by these values.

By using demand forecasting techniques, the optimal order quantity and re-order point; which provides the desired service level, are determined. Consequently, inventory policies are evaluated using real data.

4.1 The Enterprise

The data which is used in the application process is gathered from a firm which has been active since 2000 in the city of Denizli. This firm is working in the area of production and selling touristic-carpets. 95% of their sales are made to foreign customers. The carpets which were bought by the customers are delivered via export and by this way a contribution to the national export is made.

The firm is holding and monitoring the records of both their export products and purchased carpets in the computer environment by using a private packet program. With the help of the program the records are regularly reported daily. Therefore, the right information for the inventory can be accessed easily and accurately. A Stock code is given for each and every carpet in the stocks.

The following properties/features of the inventory are recorded to this program:

a. The stock code of the carpet
b. The material of the carpet
c. The name of the carpet
d. The width and length of the carpet (the dimension)
e. The weight of the carpet
f. The color data of the carpet
g. Knots per square cm of the carpet
h. The data of the production workshop/the purchase info
i. The unit price of the carpet
j. The sticker price of the carpet

In the firm where the data for this application is gathered, 36 different types of carpet is being sold. Moreover, there are different dimensions for each carpet as well. In this case, the number of the products increases too.

4.2 The Definition of the Problem

The demand is indefinite and stochastic. Since, the monthly sales numbers are going to be considered when obtaining the inventory policy, the demand has discrete distribution. After the observation of the demand data, it was found that some of the carpet types have never been sold in many monthly periods. The inventory quantity will be continuously observed and (r, q) policy (when the r level or below stock quantity is seen, q amount of product will be ordered) will be determined for the inventory policy. Shortages will not be allowed. The lead time is different from zero and differs according to the dimension of the carpet. The sales amount of the determined carpet types are obtained from the indicated firm as number and m^2 for the period of January 2004 to July 2009.

The following notations are going to be used in application:

K: Ordering cost

p: Purchasing cost per unit

h: Cost of holding a 1 unit product in stock for one year

h_d: Cost for holding 1 TL in stock for one year

L: Lead time

q^*: Optimal order quantity

D: The random variety showing the annual demand (the average is shown as E(D), the variance is shown as Var(D) and the standard deviation is shown as σ_D.)

r: Re-order point

LTD: Lead time demand

According to the firm from which we gathered our data, when the cost of the stock was being calculated the purchasing cost is being added to the ordering cost as well. The ordering cost is considered as 5 % of the 1 m^2 carpet. Unit purchasing cost is calculated by subtracting the ordering cost from the cost of the stock. According to the data of Central Bank, the deposit interest rate of 2008 is 20 %. With reference to this, the cost of holding a 1 m^2 carpet for a year is calculated as 20 % of the purchasing cost.

4.3 ABC Analysis

In order to determine the products that were going to be taken into consideration for this study, the ABC analysis, which is one of the controlling methods for the inventory; were applied.

The data of the products that are going to be analyzed was prepared regarding the year 2008. The classification percents are given in Table 4.1 and the results are presented in Table 4.2.

Table 4.1 The percentage of the classifications according to the ABC Analysis

Class A	65 % of the total sales	**7 types of carpets**
	20 % of the total items	
Class B	30 % of the total sales	**12 types of carpets**
	32 % of the total items	
Class C	5 % of the total sales	**17 types of carpets**
	48 % of the total items	

Table 4.2 Results of the Classification

Class	**No**	**Type of the Carpet**
A	**1**	İpek
	2	Floş
	3	Hereke İpek
	4	Azeri
	5	Sultan
	6	Milas
	7	Sentez Koleksiyon
B	**1**	Avşar Yün
	2	Kayseri İpek
	3	Antik Şirvan
	4	Hereke
	5	Antik Türkmen
	6	Konya Yatak
	7	Türkmen
	8	Kehribar
	9	Kayseri
	10	Kilim
	11	Saruk
	12	Otantik Koleksiyon
C	**1**	Türkmen Avantgarde
	2	Döşemealtı
	3	Kirmen
	4	Eski Halı
	5	Elvan
	6	Yahyalı
	7	Naturel
	8	Pera
	9	Ladik
	10	Azeri Gabe
	11	Anadol
	12	Harem
	13	Balıkesir Kars
	14	Otoman
	15	Yağcıbedir
	16	Taşpınar
	17	Tülü

4.4 The Turnover Ratio for the A Class Carpets

The turnover rate is a ratio showing the sales speed of the products in the stock throughout the year. There is a direct proportion between this rate and the sales speed and when this ratio is higher, this means that the product is being sold rapidly and this is a positive aspect for the firm. The low rate in the turnover rate indicates that the product has a low sale (http://www.tacirler.com.tr/arastirma/oranlar.pdf).

$$Turnover\ Ratio = \frac{The\ \cos t\ of\ the\ sales}{Average\ stock} \tag{4.1}$$

$$Average\ Stock = \frac{The\ \cos t\ of\ the\ stock\ (in\ the\ beginning\ of\ the\ term + at\ the\ end\ of\ the\ term)}{2} \tag{4.2}$$

In such cases, where the daily calculation of the turnover rate is needed, the calculation can be made by dividing 365 to the rate which was found.

The 2008 turnover ratios of the Class A carpets are given as ratio and day, below:

Table 4.3 The 2008 turnover ratios of the Class A carpets

Type of the Carpet	Turnover Rate	Turnover Rate (Daily)
İpek	**0.63**	**581**
Floş	**0.97**	**375**
Hereke İpek	**0.90**	**406**
Azeri	**0.71**	**511**
Sultan	**1.74**	**210**
Milas	**0.83**	**438**
Sentez Koleksiyon	**0.56**	**649**

In Table 4.3, it can be seen that the turnover ratio of the A class carpets are very low. Regarding to the turnover rates in their research C.M. and K.P.Rao (2009) indicated that; A turnover rate of six turns per year doesn't mean that the stock of every item will turn six times. The stock of popular, fast moving items should turn more often (up to 12 times per year). Slow moving items may turn only once, or not at all.

So, since the carpets which were determined as the class A ones have a low turnover rate, it can be said that they are slow moving items.

4.5 Modeling the Demand in the Lead Time and the Optimal Policy

As the demand for the slow moving stocks is stochastic and irregular, it is hard to develop an effective strategy. Especially, in order to acquire the reorder point and the order quantity which are essential parameters for inventory control, it is necessary to estimate the lead time demand.

In this study, the following methods are used for the estimation of the lead time demand:

- Croston's Method
- Willemain's Bootstrap (Resampling) Method
- Empirical Model
- Poisson Model

It is necessary to determine which of these methods is going to be used for each of the Class A carpet types and different dimensions.

By using the unit-sale sum of Class A carpets given in Table 4.2, in the period of 66 months (for the period from 01.01.2004 to 30.06.2009) and 19 different dimensions the CV^2 and ADI values are found. The classification of the calculated values and the demand according to every dimensions of each carpet type is listed below. The missing calculations in the table mean that there is no sale of that type of carpet in that dimensions.

Table 4.4 The demand structure of Azeri Carpet according to the dimension

CARPET DIMENSION	CV^2	ADI	DEMAND STRUCTURE
MİNDER	-	-	-
TELEFON ALTI	-	-	-
YASTIK	2.27	1.91	LUMPY
KÜÇÜK ÇEYREK	-	-	-
ÇEYREK	0.74	1.07	ERRATIC
SECCADE	1.08	1.14	ERRATIC
KARYOLA	0.94	1.35	LUMPY
BÜYÜK KARYOLA	1.02	1.27	ERRATIC
KELLE	1.20	1.20	ERRATIC
BÜYÜK KELLE	1.62	1.71	LUMPY
KÜÇÜK TABAN	1.20	1.44	LUMPY
TABAN	3.95	3.82	LUMPY
BÜYÜK TABAN	12.20	10.83	LUMPY
SÜPER BÜYÜK TABAN	-	-	-
ÇEYREK YOLLUK	12.20	10.83	LUMPY
MİNİ YOLLUK	-	-	-
SECCADE YOLLUK	1.36	1.76	LUMPY
KARYOLA YOLLUK	1.98	1.91	LUMPY
KELLE YOLLUK	7.18	6.50	LUMPY

Table 4.5 The demand structure of Ipek Carpet according to the dimension

CARPET DIMENSION	CV^2	ADI	DEMAND STRUCTURE
MİNDER	-	-	-
TELEFON ALTI	1.24	1.18	ERRATIC
YASTIK	1.27	1.44	LUMPY
KÜÇÜK ÇEYREK	1.31	1.41	LUMPY
ÇEYREK	1.69	1.41	LUMPY
SECCADE	1.15	1.30	ERRATIC
KARYOLA	2.08	2.03	LUMPY
BÜYÜK KARYOLA	1.21	1.33	LUMPY
KELLE	1.16	1.44	LUMPY
BÜYÜK KELLE	1.96	2.41	LUMPY
KÜÇÜK TABAN	-	-	-
TABAN	2.91	2.24	LUMPY
BÜYÜK TABAN	3.88	3.25	LUMPY
SÜPER BÜYÜK TABAN	-	-	-
ÇEYREK YOLLUK	-	-	-
MİNİ YOLLUK	-	-	-
SECCADE YOLLUK	2.22	2.41	LUMPY
KARYOLA YOLLUK	-	-	-
KELLE YOLLUK	-	-	-

Table 4.6 The demand structure of Floş Carpet according to the dimension

CARPET DIMENSION	CV^2	ADI	DEMAND STRUCTURE
MİNDER	1.37	1.55	LUMPY
TELEFON ALTI	-	-	-
YASTIK	0.71	1.02	ERRATIC
KÜÇÜK ÇEYREK	-	-	-
ÇEYREK	0.54	1.00	ERRATIC
SECCADE	0.40	1.02	SMOOTH
KARYOLA	0.39	1.00	SMOOTH
BÜYÜK KARYOLA	0.55	1.02	ERRATIC
KELLE	0.70	1.16	ERRATIC
BÜYÜK KELLE	1.67	1.86	LUMPY
KÜÇÜK TABAN	0.79	1.33	LUMPY
TABAN	0.73	1.38	LUMPY
BÜYÜK TABAN	6.42	5.91	LUMPY
SÜPER BÜYÜK TABAN	-	-	-
ÇEYREK YOLLUK	5.25	4.33	LUMPY
MİNİ YOLLUK	-	-	-
SECCADE YOLLUK	1.49	1.86	LUMPY
KARYOLA YOLLUK	3.80	3.61	LUMPY
KELLE YOLLUK	-	-	-

Table 4.7 The demand structure of Hereke Ipek Carpet according to the dimension

CARPET DIMENSION	CV^2	ADI	DEMAND STRUCTURE
MİNDER	-	-	-
TELEFON ALTI	0.95	1.00	ERRATIC
YASTIK	1.30	1.02	ERRATIC
KÜÇÜK ÇEYREK	2.78	1.14	ERRATIC
ÇEYREK	2.24	1.33	LUMPY
SECCADE	2.37	2.24	LUMPY
KARYOLA	2.11	2.10	LUMPY
BÜYÜK KARYOLA	3.51	2.60	LUMPY
KELLE	2.48	2.10	LUMPY
BÜYÜK KELLE	3.90	3.61	LUMPY
KÜÇÜK TABAN	-	-	-
TABAN	5.97	3.10	LUMPY
BÜYÜK TABAN	2.90	3.10	LUMPY
SÜPER BÜYÜK TABAN	-	-	-
ÇEYREK YOLLUK	-	-	-
MİNİ YOLLUK	4.54	4.06	LUMPY
SECCADE YOLLUK	11.77	4.33	LUMPY
KARYOLA YOLLUK	-	-	-
KELLE YOLLUK	-	-	-

Table 4.8 The demand structure of Milas Carpet according to the dimension

CARPET DIMENSION	CV^2	ADI	DEMAND STRUCTURE
MİNDER	18.15	8.13	LUMPY
TELEFON ALTI	-	-	-
YASTIK	4.36	2.71	LUMPY
KÜÇÜK ÇEYREK	-	-	-
ÇEYREK	0.45	1.00	SMOOTH
SECCADE	0.69	1.00	ERRATIC
KARYOLA	0.41	1.03	SMOOTH
BÜYÜK KARYOLA	0.64	1.08	ERRATIC
KELLE	0.48	1.00	SMOOTH
BÜYÜK KELLE	1.68	2.03	LUMPY
KÜÇÜK TABAN	0.95	1.33	LUMPY
TABAN	2.74	2.83	LUMPY
BÜYÜK TABAN	12.20	10.83	LUMPY
SÜPER BÜYÜK TABAN	15.50	13.00	LUMPY
ÇEYREK YOLLUK	7.20	8.13	LUMPY
MİNİ YOLLUK	65.00	32.50	LUMPY
SECCADE YOLLUK	0.68	1.05	ERRATIC
KARYOLA YOLLUK	1.78	1.97	LUMPY
KELLE YOLLUK	9.31	8.13	LUMPY

Table 4.9 The demand structure of Sentez Koleksiyon Carpet according to the dimension

CARPET DIMENSION	CV^2	ADI	DEMAND STRUCTURE
MİNDER	4.02	3.25	LUMPY
TELEFON ALTI	-	-	-
YASTIK	2.71	2.32	LUMPY
KÜÇÜK ÇEYREK	-	-	-
ÇEYREK	1.13	1.08	ERRATIC
SECCADE	0.79	1.03	ERRATIC
KARYOLA	1.75	1.30	ERRATIC
BÜYÜK KARYOLA	3.19	2.95	LUMPY
KELLE	2.37	2.71	LUMPY
BÜYÜK KELLE	-	-	-
KÜÇÜK TABAN	-	-	-
TABAN	-	-	-
BÜYÜK TABAN	-	-	-
SÜPER BÜYÜK TABAN	-	-	-
ÇEYREK YOLLUK	-	-	-
MİNİ YOLLUK	-	-	-
SECCADE YOLLUK	4.27	3.82	LUMPY
KARYOLA YOLLUK	-	-	-
KELLE YOLLUK	-	-	-

Table 4.10 The demand structure of Sultan Carpet according to the dimension

CARPET DIMENSION	CV^2	ADI	DEMAND STRUCTURE
MİNDER	-	-	-
TELEFON ALTI	-	-	-
YASTIK	3.15	2.83	LUMPY
KÜÇÜK ÇEYREK	-	-	-
ÇEYREK	0.97	1.23	ERRATIC
SECCADE	0.80	1.18	ERRATIC
KARYOLA	0.89	1.38	LUMPY
BÜYÜK KARYOLA	0.90	1.12	ERRATIC
KELLE	1.27	1.55	LUMPY
BÜYÜK KELLE	0.95	1.38	LUMPY
KÜÇÜK TABAN	1.26	1.76	LUMPY
TABAN	1.68	1.59	LUMPY
BÜYÜK TABAN	5.64	5.42	LUMPY
SÜPER BÜYÜK TABAN	14.48	10.83	LUMPY
ÇEYREK YOLLUK	-	-	-
MİNİ YOLLUK	-	-	-
SECCADE YOLLUK	1.10	1.51	LUMPY
KARYOLA YOLLUK	3.13	3.82	LUMPY
KELLE YOLLUK	5.64	5.42	LUMPY

By examining the data in Tables from 4.4 to 4.10 in none of the carpet types the "intermittent" demand structure is seen. Syntetos (2001) defined lumpy demand as those demand patterns with some zero-demands and with non-zero demand having high variability. He considered all lumpy demands as intermittent demands; however not all intermittent demand is lumpy demand (Varghese & Rossetti, 2008).

In the application stage, the Milas Carpet Type which was manufactured by the firm itself, was decided to be analyzed. While examining the dimensions of this carpet which fits the lumpy demand structure minder, yastık, küçük taban, büyük taban, süper büyük taban, çeyrek yolluk, mini yolluk and kelle dimensions whose sales are very low in 66 months period are not taken into analysis. The dimensions which will be used in application are decided as büyük kelle, taban and karyola yolluk. In the following chapters it is aimed to apply the estimation methods for these carpet type dimensions and to define the most effective and best inventory policy which fulfills the target fill rate.

4.5.1 The Optimal Policy for the Milas Carpet – Büyük Kelle Dimension

The dimensions of "Büyük Kelle" is about 7.5 m^2 and the applied forecasting methods have given a lead time of three months (Lead Time = 3 months).

4.5.1.1 The Application of Croston's Method

As it was stated in the section 3.2.2, the Croston's Method was applied on the "Büyük Kelle" dimension for the sale-numbers in the period between 01.01.2004 – 30.06.2009. In the calculations the α value was taken as 0.1 and 0.6. As a result of the study the following M(t) estimation values are calculated.

For **α = 0.1**;

Table 4.11 The M(t) estimation values for Milas – Büyük Kelle dimension by using the Croston's Method

Month	Date	X(t)	S(t)	z	I(t)	M(t)
1	January 04	1	0.85	1	1	**0.85**
2	February 04	4	1.16	1	1	**1.16**
3	March 04	2	1.25	1	1	**1.25**
4	April 04	3	1.42	1	1	**1.42**
5	May 04	3	1.58	1	1	**1.58**
6	June 04	2	1.62	1	1	**1.62**
7	July 04	1	1.56	1	1	**1.56**
8	August 04	0	1.56	2	1	**1.56**
9	September 04	0	1.56	2	1	**1.56**
10	October 04	1	1.50	1	1	**1.50**
11	November 04	1	1.45	1	1	**1.45**
12	December 04	3	1.61	1	1	**1.61**
13	January 05	1	1.55	1	1	**1.55**
14	February 05	0	1.55	2	1	**1.55**
15	March 05	4	1.79	1	1	**1.79**
16	April 05	1	1.71	1	1	**1.71**
17	May 05	2	1.74	1	1	**1.74**
18	June 05	0	1.74	2	1	**1.74**
19	July 05	0	1.74	2	1	**1.74**
20	August 05	0	1.74	2	1	**1.74**
21	September 05	0	1.74	2	1	**1.74**
22	October 05	1	1.67	1	1	**1.67**
23	November 05	3	1.80	1	1	**1.80**
24	December 05	0	1.80	2	1	**1.80**
25	January 06	0	1.80	2	1	**1.80**
26	February 06	1	1.72	1	1	**1.72**
27	March 06	3	1.85	1	1	**1.85**
28	April 06	0	1.85	2	1	**1.85**
29	May 06	0	1.85	2	1	**1.85**
30	June 06	0	1.85	2	1	**1.85**
31	July 06	0	1.85	2	1	**1.85**
32	August 06	0	1.85	2	1	**1.85**
33	September 06	0	1.85	2	1	**1.85**

Previous Table Continuing

Month	Date	X(t)	S(t)	z	I(t)	M(t)
34	October 06	0	1.85	2	1	**1.85**
35	November 06	2	1.86	1	1	**1.86**
36	December 06	2	1.88	1	1	**1.88**
37	January 07	0	1.88	2	1	**1.88**
38	February 07	0	1.88	2	1	**1.88**
39	March 07	2	1.89	1	1	**1.89**
40	April 07	0	1.89	2	1	**1.89**
41	May 07	0	1.89	2	1	**1.89**
42	June 07	0	1.89	2	1	**1.89**
43	July 07	1	1.80	1	1	**1.80**
44	August 07	0	1.80	2	1	**1.80**
45	September 07	0	1.80	2	1	**1.80**
46	October 07	1	1.72	1	1	**1.72**
47	November 07	1	1.65	1	1	**1.65**
48	December 07	1	1.58	1	1	**1.58**
49	January 08	0	1.58	2	1	**1.58**
50	February 08	0	1.58	2	1	**1.58**
51	March 08	0	1.58	2	1	**1.58**
52	April 08	0	1.58	2	1	**1.58**
53	May 08	1	1.53	1	1	**1.53**
54	June 08	0	1.53	2	1	**1.53**
55	July 08	1	1.47	1	1	**1.47**
56	August 08	1	1.43	1	1	**1.43**
57	September 08	1	1.38	1	1	**1.38**
58	October 08	0	1.38	2	1	**1.38**
59	November 08	1	1.34	1	1	**1.34**
60	December 08	0	1.34	2	1	**1.34**
61	January 09	0	1.34	2	1	**1.34**
62	February 09	0	1.34	2	1	**1.34**
63	March 09	0	1.34	2	1	**1.34**
64	April 09	1	1.31	1	1	**1.31**
65	May 09	2	1.38	1	1	**1.38**
66	June 09	0	1.38	2	1	**1.38**

The following values were calculated as it was mentioned in Section 3.4.

SSE = 127.02

MAD = 1.24

MASE = 1.37

The frequency table of the estimation values is as follows:

Table 4.12 Frequency Table of Croston's Method

Class Interval	**x**	**Frequency**	**Rational Frequency**	**Cumulative Rational Frequency**
0.500 - 1.499	1	17	0.258	0.258
1.500 - 2.499	2	49	0.742	1.000

E(D)= 1.625

q= 1

for the α = 0.1, the fullness ratio of r= 1 is found as, %25.80 and the target fill rate of 85 % is not fulfilled.

For **α = 0.6**;

Table 4.13 The M(t) estimation values for Milas – Büyük Kelle dimension by using the Croston's Method

Month	Date	X(t)	S(t)	z	I(t)	M(t)
1	January 04	1	0.93	1	1	**0.93**
2	February 04	4	2.77	1	1	**2.77**
3	March 04	2	2.31	1	1	**2.31**
4	April 04	3	2.72	1	1	**2.72**
5	May 04	3	2.89	1	1	**2.89**
6	June 04	2	2.36	1	1	**2.36**
7	July 04	1	1.54	1	1	**1.54**
8	August 04	0	1.54	2	1	**1.54**
9	September 04	0	1.54	2	1	**1.54**
10	October 04	1	1.22	1	1	**1.22**
11	November 04	1	1.09	1	1	**1.09**
12	December 04	3	2.23	1	1	**2.23**
13	January 05	1	1.49	1	1	**1.49**
14	February 05	0	1.49	2	1	**1.49**
15	March 05	4	3.00	1	1	**3.00**
16	April 05	1	1.80	1	1	**1.80**
17	May 05	2	1.92	1	1	**1.92**
18	June 05	0	1.92	2	1	**1.92**
19	July 05	0	1.92	2	1	**1.92**
20	August 05	0	1.92	2	1	**1.92**
21	September 05	0	1.92	2	1	**1.92**
22	October 05	1	1.37	1	1	**1.37**
23	November 05	3	2.35	1	1	**2.35**
24	December 05	0	2.35	2	1	**2.35**
25	January 06	0	2.35	2	1	**2.35**
26	February 06	1	1.54	1	1	**1.54**
27	March 06	3	2.42	1	1	**2.42**
28	April 06	0	2.42	2	1	**2.42**
29	May 06	0	2.42	2	1	**2.42**
30	June 06	0	2.42	2	1	**2.42**
31	July 06	0	2.42	2	1	**2.42**
32	August 06	0	2.42	2	1	**2.42**
33	September 06	0	2.42	2	1	**2.42**

Previous Table Continuing

Month	Date	X(t)	S(t)	z	I(t)	M(t)
34	October 06	0	2.42	2	1	**2.42**
35	November 06	2	2.17	1	1	**2.17**
36	December 06	2	2.07	1	1	**2.07**
37	January 07	0	2.07	2	1	**2.07**
38	February 07	0	2.07	2	1	**2.07**
39	March 07	2	2.03	1	1	**2.03**
40	April 07	0	2.03	2	1	**2.03**
41	May 07	0	2.03	2	1	**2.03**
42	June 07	0	2.03	2	1	**2.03**
43	July 07	1	1.41	1	1	**1.41**
44	August 07	0	1.41	2	1	**1.41**
45	September 07	0	1.41	2	1	**1.41**
46	October 07	1	1.16	1	1	**1.16**
47	November 07	1	1.07	1	1	**1.07**
48	December 07	1	1.03	1	1	**1.03**
49	January 08	0	1.03	2	1	**1.03**
50	February 08	0	1.03	2	1	**1.03**
51	March 08	0	1.03	2	1	**1.03**
52	April 08	0	1.03	2	1	**1.03**
53	May 08	1	1.01	1	1	**1.01**
54	June 08	0	1.01	2	1	**1.01**
55	July 08	1	1.00	1	1	**1.00**
56	August 08	1	1.00	1	1	**1.00**
57	September 08	1	1.00	1	1	**1.00**
58	October 08	0	1.00	2	1	**1.00**
59	November 08	1	1.00	1	1	**1.00**
60	December 08	0	1.00	2	1	**1.00**
61	January 09	0	1.00	2	1	**1.00**
62	February 09	0	1.00	2	1	**1.00**
63	March 09	0	1.00	2	1	**1.00**
64	April 09	1	1.00	1	1	**1.00**
65	May 09	2	1.60	1	1	**1.60**
66	June 09	0	1.60	2	1	**1.60**

SSE = 118.16

MAD = 1.05

MASE = 1.16

The frequency table of the estimation values is as follows:

Table 4.14 Frequency Table of Croston's Method

Class Interval	x	Frequency	Rational Frequency	Cumulative Rational Frequency
0.500 - 1.499	1	28	0.424	0.424
1.500 - 2.499	2	34	0.515	0.939
2.500 - 3.499	3	4	0.061	1.000

E(D)= 1.714

q= 1

Table 4.15 Croston's Method Reorder Point and Fill Rate (α = 0.6)

r	ES(r)	1 – [ES(r)/q]	Fill Rate
1	0.637	0.363	36.30%
2	**0.061**	**0.939**	**93.90%**

As it can be seen from the table 4.15 the comment on the inventory policy for the "Büyük Kelle" dimension with α = 0.6 is as follows: With the help of the continuous control method when the stock level drops to 2, one unit should be ordered.

4.5.1.2 The Application of Willemain's Bootstrap Method

While applying this method in analysis, as it was stated in section 3.2.3, the possibility of transition from non-zero demands to zero-demands are detected. A random arrangement is designated according to these transition possibilities and an estimation value is given for the non-zero demands. Since the lead time is 3 months, the demands for the passing three months of procurement are summed up and a "Lead time demand" (LTD) was formed. This procedure is repeated for 1000 times and the distribution of the lead time demand is estimated. These calculations are made by using a macro written under MINITAB program and given as in Appendix-1.

The frequency table of the 1000 estimated value can be seen in Table 4.16.

Table 4.16 Frequency Table of Bootstrap Method

x	Frequency	Rational Frequency	Cumulative Rational Frequency
4	1	0.001	0.001
5	76	0.076	0.077
6	322	0.322	0.399
7	382	0.382	0.781
8	192	0.192	0.973
9	24	0.024	0.997
10	3	0.003	1.000

$E(X) = 6.7720 \rightarrow E(D) = E(X) / L = 6.7720 / 3 = 2.2573$

$q = 1$

Table 4.17 Bootstrap Method Reorder Point and Fill Rate

r	ES(r)	1 – [ES(r) / q]	Fill Rate
4	2.772	-	-
5	1.773	-	-
6	0.850	0.150	15.00%
7	0.249	0.751	75.10%
8	**0.030**	**0.970**	**97.00%**
9	0.003	0.997	99.70%

As it can be seen in Table 4.17 the inventory policy which fulfills the target fill rate of 85 % for the “Büyük Kelle” dimension can be commented as: “By using the continuous control method when the stock level drops to 8, one unit should be ordered”.

4.5.1.3 The Application of Empirical Model

With this method the estimation is made by using the empirical distribution of the lead time demand. In Table 4.18 the frequency of the demand values in lead time is given.

Table 4.18 Frequency Table of Empirical Model

x	Frequency	Rational Frequency	Cumulative Rational Frequency
0	12	0.188	0.188
1	14	0.219	0.406
2	13	0.203	0.609
3	8	0.125	0.734
4	7	0.109	0.844
5	4	0.063	0.906
6	1	0.016	0.922
7	2	0.031	0.953
8	2	0.031	0.984
9	1	0.016	1.000

$E(X) = 2.453 \rightarrow E(D) = E(X) / L = 2.453 / 3 = 0.818$

$q \quad = 1$

Table 4.19 Empirical Model Reorder Point and Fill Rate

r	ES(r)	1 – [ES(r) / q]	Fill Rate
1	1.643	-	-
2	1.049	-	-
3	0.658	0.342	34.20%
4	0.392	0.608	60.80%
5	0.235	0.765	76.50%
6	**0.141**	**0.859**	**85.90%**
7	0.063	0.937	93.70%
8	0.016	0.984	98.40%

The inventory policy in here is that "when the stock level drops to 6, one unit should be ordered".

4.5.1.4 The Application of Poisson Model

First of all, by using the SPSS packet program, the goodness of fit test for the “Büyük Kelle” demand data to Poisson distribution is performed. The hypotheses are as follows:

H_0: Data follows Poisson distribution.

H_1: Data does not follow Poisson distribution.

The function of Poisson distribution is,

$$f(x)=P(X=x)=\frac{e^{-\lambda}\lambda^{x}}{x!} \qquad (4.3)$$

The results for the “Büyük Kelle” sales number data by using the One - Sample Kolmogorov - Smirnov test in SPSS packet program are given below.

One-Sample Kolmogorov-Smirnov Test

		Milas - Büyük Kelle
N		66
Poisson Parameter(a,b)	Mean	**,83**
Most Extreme Differences	Absolute	,081
	Positive	,081
	Negative	-,054
Kolmogorov-Smirnov Z		,654
Asymp. Sig. (2-tailed)		**,785**

a Test distribution is Poisson.
b Calculated from data.

Since the p value is 0.785, the H_0 hypothesis cannot be rejected. The data can be accepted to follow to Poisson distribution with an error of 0.05.

According to the results gathered from the SPSS packet program the λ value is calculated as 0.83 and by using the $\lambda_{LTD} = E(D)\cdot L$ formula the λ_{LTD} is calculated as 2.49. The distribution functions of the lead time demand data is obtained by using the

λ_{LTD} instead of λ in the equation (4.3). The frequency table of these data is given in Table 4.20.

Table 4.20 Frequency Table of Poisson Model

LTD	Frequency	Rational Frequency	Cumulative Frequency
0	12	0.083	0.083
1	14	0.206	0.289
2	13	0.257	0.546
3	8	0.213	0.760
4	7	0.133	0.893
5	4	0.066	0.959
6	1	0.027	0.986
7	2	0.010	0.996
8	2	0.003	0.999
9	1	0.001	1.000

$\lambda = 0.83$

$q = 1$

Table 4.21 Poisson Model Reorder Point and Fill Rate

r	ES(r)	1 – [ES(r)/q]	Fill Rate
1	1.570	-	-
2	0.860	0.140	14.00%
3	0.407	0.593	59.30%
4	0.167	0.833	83.30%
5	**0.060**	**0.940**	**94.00%**
6	0.019	0.981	98.10%
7	0.005	0.995	99.50%
8	0.001	0.999	99.90%

As it can be seen in Table 4.21 the inventory policy in here is that "when the stock level drops to 5, purchase order of one unit should be given".

4.5.2 The Optimal Policy for Milas Carpet – Taban Dimension

The taban dimension is approximately 12.5 m^2 and in the forecasting methods the procurement period is taken as 5 months (Lead Time = 5 months).

4.5.2.1 The Application of Croston's Method

As it was stated in Section 3.2.2, the Croston's Method was applied on the "Taban" dimension for the sale-numbers data in the period between 01.01.2004 – 30.06.2009. In the calculations the α value was taken as 0.1 and 0.6. M(t) estimation values for the Taban dimension are given as Appendix-2.

The following values for α = 0.1 were calculated as it was mentioned in Section 3.4.
SSE = 73.88
MAD = 0.94
MASE = 1.57

The frequency table of the estimated values is as follows:

Table 4.22 Frequency Table of Croston's Method

Class Interval	**x**	**Frequency**	**Rational Frequency**	**Cumulative Rational Frequency**
0.500 - 1.499	1	66	1.000	1.000

E(D)= 1.108
q= 1

As it can be seen from the Table 4.22, for the taban dimension, x can only get the value of 1 and since the condition of x > r cannot be ensure an inventory policy cannot be developed.

The following values for α = 0.6 were calculated as follows.
SSE = 85.38
MAD = 0.96
MASE = 1.60

The frequency table for the estimation values is as follows:

Table 4.23 Frequency Table of Croston’s Method

Class Interval	x	Frequency	Rational Frequency	Cumulative Rational Frequency
0.500 - 1.499	1	55	0,833	0,833
1.500 - 2.499	2	8	0,121	0,955
2.500 - 3.499	3	3	0,045	1,000

E(D)= 1.330

q= 1

Table 4.24 Croston’s Method Reorder Point and Fill Rate (α = 0.6)

r	ES(r)	1 – [ES(r)/q]	Fill Rate
1	0.211	0.789	78.90%
2	**0.045**	**0.955**	**95.50%**

As it can be seen from the Table 4.24, for the equation α = 0.6, the inventory policy of “Taban” dimension can be commented as: “when the stock level drops to 2, purchase order of one unit should be given”.

4.5.2.2 The Application of Willemain’s Bootstrap Method

While applying this method in analysis, as it was stated in section 3.2.3, the possibility of transition from non-zero demands to zero-demands are detected. A random arrangement is designated according to these transition possibilities and an estimation value is given for the non-zero demands. Since the lead time is 5 months, the demands for the passing five months of procurement are summed up and a “Lead time demand” (LTD) was formed. This procedure is repeated for 1000 times and the distribution of the lead time demand is estimated. These calculations are made by using a macro written under MINITAB program and given as in Appendix-1.

The frequency table of the 1000 estimated value can be seen in Table 4.25.

Table 4.25 The Frequency Table of Bootstrap Method

x	Frequency	Rational Frequency	Cumulative Frequency
3	1	0.001	0.001
4	17	0.017	0.018
5	109	0.109	0.127
6	272	0.272	0.399
7	311	0.311	0.710
8	202	0.202	0.912
9	69	0.069	0.981
10	17	0.017	0.998
11	2	0.002	1.000

$E(X) = 6.8540 \rightarrow E(D) = E(X) / L = 6.8540 / 5 = 1.3708$

$q \quad = 1$

Table 4.26 Bootstrap Method Reorder Point and Fill Rate

r	ES(r)	1 – [ES(r) / q]	Fill Rate
3	3.854	-	-
4	2.855	-	-
5	1.873	-	-
6	1.000	0.000	0.00%
7	0.399	0.601	60.10%
8	**0.109**	**0.891**	**89.10%**
9	0.021	0.979	97.90%
10	0.002	0.998	99.80%

As it can be seen in Table 4.26 the inventory policy which fulfills the target fill rate of 85 % for the “Taban” dimension can be commented as: “By using the continuous control method when the stock level drops to 8, one unit should be ordered”.

4.5.2.3 The Application of Empirical Model

With this method the estimation is made by using the empirical distribution of the lead time demand. In Table 4.27 the frequency of the demand values in lead time is given.

Table 4.27 The Frequency Table for Empirical Model

x	**Frequency**	**Rational Frequency**	**Cumulative Rational Frequency**
0	14	0.226	0.226
1	14	0.226	0.452
2	6	0.097	0.548
3	9	0.145	0.694
4	11	0.177	0.871
5	1	0.016	0.887
6	6	0.097	0.984
7	1	0.016	1.000

$E(X) = 2.339 \rightarrow E(D) = E(X) / L = 2.339 / 5 = 0.468$

$q \quad = 1$

Table 4.28 Empirical Model Reorder Point and Fill Rate

r	**ES(r)**	**1 – [ES(r) / q]**	**Fill Rate**
1	1.563	-	-
2	1.015	-	-
3	0.564	0.436	43.60%
4	0.258	0.742	74.20%
5	**0.129**	**0.871**	**87.10%**
6	0.016	0.984	98.40%

The inventory policy in here is as “when the stock level drops to 5, one unit should be ordered”.

4.5.2.4 The Application of Poisson Model

First of all, by using the SPSS packet program, the goodness of fit test for the “Taban” demand data to Poisson distribution is performed. The hypotheses are as follows:

H_0: Data follows Poisson distribution.

H_1: Data does not follow Poisson distribution.

The results for the “Taban” dimension sales number data by using the One - Sample Kolmogorov - Smirnov test in SPSS packet program are given below.

One-Sample Kolmogorov-Smirnov Test

		Milas - Taban
N		66
Poisson Parameter(a,b)	Mean	**,48**
Most Extreme Differences	Absolute	,047
	Positive	,036
	Negative	-,047
Kolmogorov-Smirnov Z		,385
Asymp. Sig. (2-tailed)		**,998**

a Test distribution is Poisson.
b Calculated from data.

Since the p value is 0.998, the H_0 hypothesis cannot be rejected. The data can be accepted to suit to Poisson distribution with an error of 0.05.

According to the results gathered from the SPSS packet program the λ value is calculated as 0.48 and by using the $\lambda_{LTD} = E(D) \cdot L$ formula the λ_{LTD} is calculated as 2.40. The distribution functions of the lead time demand data is obtained by using the λ_{LTD} instead of λ in the equation (4.3). The frequency table of these data is given in Table 4.29.

Table 4.29 The Frequency Table of Poisson Model

LTD	Frequency	Rational Frequency	Cumulative Frequency
0	14	0.091	0.091
1	14	0.218	0.308
2	6	0.261	0.570
3	9	0.209	0.779
4	11	0.125	0.904
5	1	0.060	0.964
6	6	0.024	0.988
7	1	0.008	0.997
8	0	0.002	0.999
9	0	0.001	1.000

$\lambda = 0.48$

$q = 1$

Table 4.30 Poisson Model Reorder Point and Fill Rate

r	ES(r)	1 – [ES(r)/q]	Fill Rate
1	1.484	-	-
2	0.794	0.206	20.60%
3	0.365	0.635	63.50%
4	**0.145**	**0.855**	**85.50%**
5	0.050	0.950	95.00%
6	0.015	0.985	98.50%
7	0.004	0.996	99.60%
8	0.001	0.999	99.90%

As it can be seen in Table 4.30 the inventory policy in here is as “when the stock level drops to 4, purchase order of one unit should be given”.

4.5.3 The Optimal Policy for Milas Carpet – Karyola Yolluk Dimension

The dimension of Karyola Yolluk is about 2.5 m^2 and the lead time is taken as one month. (Lead Time = 1 month)

4.5.3.1 The Application of Croston's Method

As it was stated in Section 3.2.2, the Croston's Method was applied on the "Karyola Yolluk" dimension for the sale-numbers data in the period between 01.01.2004 – 30.06.2009. In the calculations the α value was taken as 0.1 and 0.6. M(t) estimation values for the Karyola Yolluk dimension are given as Appendix-3.

The following values for α = 0.1 were calculated as it was mentioned in Section 3.4.
SSE = 211.96
MAD = 1.59
MASE = 1.34

The frequency table of the estimated values is as follows:

Table 4.31 Frequency Table of Croston's Method

Class Interval	x	Frequency	Rational Frequency	Cumulative Rational Frequency
1.500 - 2.499	2	66	1.000	1.000

E(D) = 2.075
q = 1

As it can be seen in Table 4.31 for the dimension of "Karyola Yolluk", x can only get the value of 2 and since the condition of x > r cannot be enabled an inventory policy cannot be developed.

The following values for α = 0.6 were calculated as follows.
SSE = 133.72
MAD = 1.18
MASE = 1.01

The frequency table of the estimation values is as follows:

Table 4.32 The Frequency Table of Croston's Method

Class Interval	x	Frequency	Rational Frequency	Cumulative Rational Frequency
0.500 - 1.499	1	16	0.242	0.242
1.500 - 2.499	2	41	0.621	0.864
2.500 - 3.499	3	4	0.061	0.924
3.500 - 4.499	4	4	0.061	0.985
4.500 - 5.499	5	1	0.015	1.000

E(D) = 2.012

q = 1

Table 4.33 Croston's Method Reorder Point and Fill Rate ($\alpha = 0.6$)

r	ES(r)	1 - (ES(r)/q)	Fill Rate
1	0.986	0.014	1.40%
2	0.228	0.772	77.20%
3	**0.091**	**0.909**	**90.90%**
4	0.015	0.985	98.50%

The inventory policy for the "Karyola Yolluk" dimension is as "by using the continuous control method, when the stock level drops to 3, one unit should be ordered".

4.5.3.2 The Application of Willemain's Bootstrap Method

While applying this method in analysis, as it was stated in Section 3.2.3, the possibility of transition from non-zero demands to zero-demands are detected. A random arrangement is designated according to these transition possibilities and an estimation value is given for the non-zero demands. Since the lead time is one month, the demands for the passing 1 month of procurement are summed up and a "Lead time demand" (LTD) was formed. This procedure is repeated for 1000 times and the distribution of the lead time demand is estimated. These calculations are made by using a macro written under MINITAB program and given as in Appendix-1.

The frequency table of the 1000 estimated value can be seen in Table 4.34.

Table 4.34 The Frequency Table of Bootstrap Method

x	Frequency	Rational Frequency	Cumulative Rational Frequency
2	179	0.179	0.179
3	754	0.754	0.933
4	67	0.067	1.000

E(X) = 2.888 → E(D) = E(X) / L = 2.888 / 1 = 2.888

q = 1

Table 4.35 Bootstrap Method Reorder Point and Fill Rate

r	ES(r)	1 – [ES(r) / q]	Fill Rate
2	0.888	0.112	11.20%
3	**0.067**	**0.933**	**93.30%**

As it can be seen in Table 4.35 the inventory policy which fulfills the target fill rate of 85 % for the "Karyola Yolluk" dimension can be commented as: "When the stock level drops to 3, one unit should be ordered".

4.5.3.3 The Application of Empirical Model

With this method the estimation is made by using the empirical distribution of the lead time demand. In Table 4.36, the frequency of the lead time demand values is given.

Table 4.36 The Frequency Table for Empirical Model

x	Frekans	Oransal Frekans	Birikimli Oransal Frekans
0	32	0.485	0.485
1	15	0.227	0.712
2	8	0.121	0.833
3	5	0.076	0.909
4	3	0.045	0.955
5	1	0.015	0.970
6	2	0.030	1.000

$E(X) = 1.136 \rightarrow E(D) = E(X) / L = 1.136 / 1 = 1.136$

$q \quad = 1$

Table 4.37 Empirical Model Reorder Point and Fill Rate

r	**ES(r)**	**1 – [ES(r) / q]**	**Fill Rate**
1	0.618	0.382	38.20%
2	0.331	0.669	66.90%
3	0.165	0.835	83.50%
4	**0.075**	**0.925**	**92.50%**
5	0.030	0.970	97.00%

The inventory policy in here is that “When the stock level dropped to 4, one unit should be ordered”.

4.5.3.4 The Application of Poisson Model

First of all, by using the SPSS packet program, the goodness of fit test for the “Karyola Yolluk” demand data to Poisson distribution is performed. The hypotheses are as follows:

H_0: Data follows Poisson distribution.

H_1: Data does not follow Poisson distribution.

The results for the “Karyola Yolluk” dimension sales number data by using the One - Sample Kolmogorov - Smirnov test in SPSS packet program are given below.

One-Sample Kolmogorov-Smirnov Test

		Milas – Karyola Yolluk
N		66
Poisson Parameter(a,b)	Mean	**1,14**
Most Extreme Differences	Absolute	,164
	Positive	,164
	Negative	-,062
Kolmogorov-Smirnov Z		1,331
Asymp. Sig. (2-tailed)		**,058**

a Test distribution is Poisson.
b Calculated from data.

Since the p value is 0.058, the H_0 hypothesis cannot be rejected. The data can be accepted to suit to Poisson distribution with an error of 0.05.

According to the results gathered from the SPSS packet program the λ value is calculated as 1.14 and by using the $\lambda_{LTD} = E(D) \cdot L$ formula the λ_{LTD} is calculated as 1.14. The distribution functions of the lead time demand data is obtained by using the λ_{LTD} instead of λ in the equation (4.3). The frequency table of these data is given in Table 4.38.

Table 4.38 The Frequency Table of Poisson Model

LTD	Frequency	Rational Frequency	Cumulative Frequency
0	32	0.320	0.320
1	15	0.365	0.684
2	8	0.208	0.892
3	5	0.079	0.971
4	3	0.023	0.994
5	1	0.005	0.999
6	2	0.001	1.000

$\lambda = 1.14$

$q = 1$

Table 4.39 Poisson Model Reorder Point and Fill Rate

r	ES(r)	1 – [ES(r)/q]	Fill Rate
1	0.460	0.540	54.00%
2	**0.144**	**0.856**	**85.60%**
3	0.036	0.964	96.40%
4	0.007	0.993	99.30%
5	0.001	0.999	99.90%

As it can be seen in Table 4.39 the inventory policy in here is as "when the stock level drops to 2, one unit should be ordered".

As a result, in order to determine the optimal inventory policy we have to find out the best-fit method among the applied methods. By using the order quantity gathered from the used methods and re-order points; the total cost is calculated with the help of the below cost given in equation 4.4. The comparison is made distinctly by taking the calculated cost and the realized service levels for every dimension. The answer to the question of "which of the methods fulfill the aim of low-cost and high service-level" is given. The results are listed in Table 4.40, Table 4.41 and Table 4.42.

The total cost is calculated as follows:

$$TC(r, q) = h\left(\frac{q}{2} + r - E(X)\right) + \frac{KE(D)}{q} \tag{4.4}$$

Table 4.40 Summary Table of "Büyük Kelle" dimension

METHOD	r	q	h (TL)	K (TL)	Fill Rate	Total Cost (TL)
CROSTON (α = 0.1)	1	1	17	4	25.80%	-
CROSTON (α = 0.6)	2	1	17	4	93.90%	-
WILLEMAIN'S BOOTSTRAP	**8**	**1**	**17**	**4**	**97.00%**	**38.41**
EMPIRICAL	6	1	17	4	85.90%	72.07
POISSON	5	1	17	4	94.00%	54.49

Table 4.41 Summary Table of "Taban" dimension

METHOD	r	q	h (TL)	K (TL)	Fill Rate	Total Cost (TL)
CROSTON (α = 0.1)	0	1	27	7	0.00%	-
CROSTON (α = 0.6)	2	1	27	7	95.50%	-
WILLEMAIN'S BOOTSTRAP	**8**	**1**	**27**	**7**	**89.10%**	**54.04**
EMPIRICAL	5	1	27	7	87.10%	88.62
POISSON	4	1	27	7	85.50%	60.06

Table 4.42 Summary Table of "Karyola Yolluk" dimension

METHOD	r	q	h (TL)	K (TL)	Fill Rate	Total Cost (TL)
CROSTON (α = 0.1)	0	1	18	5	0.00%	-
CROSTON (α = 0.6)	3	1	18	5	90.90%	36.84
WILLEMAIN'S BOOTSTRAP	**3**	**1**	**18**	**5**	**93.30%**	**25.46**
EMPIRICAL	4	1	18	5	92.50%	66.23
POISSON	2	1	18	5	85.60%	30.18

As a result when analyzing the summary tables presented for all dimensions, the lowest cost can be get by using the Willemain's Method. Moreover, the highest fill rate can be obtained by this method as well.

For the dimension of "Büyük Kelle", the inventory policy which accomplish the 97 % fill rate costs 38.41 TL. It can be said that the optimal policy can be given as "by using a continuous control when the stock level dropped to 8, purchase order of one unit should be given".

For the dimension of "Taban", the inventory policy which accomplish the 89.10 % fill rate costs 54.04 TL. It can be said that the optimal policy can be given as "by using a continuous control when the stock level dropped to 8, purchase order of one unit should be given".

For the dimension of "Karyola Yolluk", the inventory policy which accomplish the 93.30 % fill rate costs 25.46 TL. It can be said that the optimal policy can be given as "by using a continuous control when the stock level dropped to 3, purchase order of one unit should be given".

CHAPTER FIVE
CONCLUSION

In this study it is aimed to find out the inventory management model among the ones which will give the optimal result for the firm. To this end, by classifying all the products of the firm between the dates of 01.01.2008 - 31.12.2008, it was planned to select the products of the firm according to their degree of importance. The sales reports and data of 66 months covering the period between 01.01.2004 – 30.06.2009 are gathered from the firm. Since the demand is uncertain and stochastic there is a discrete distribution in demand structure.

The demand of the slow moving stocks has a structure of discrete distribution which mostly consists of zero. Therefore, the detection of the products about their being “slow moving or not” is made. While the intermittent demands were being determined two parameters as variation coefficient and average demand interval were used. According to the gathered data, it is aimed to develop an inventory policy for three dimensions of the Milas Carpet as the slow moving stock.

The stochastic inventory policies divide into two group as continuous review model and periodic review model. In this study the (r, q) policy which is under the continuous review model, is taken into consideration as application model. In order to develop the optimal inventory policy, under the identified assumptions the decision variables should be defined.

For defining the decision variables of the slow moving stocks, the methods for forecasting the intermittent demand are needed. In this study four different types of forecasting method was applied to the demand values and as a result, the re-order points and the order quantities which satisfying the target customer service level of the firm for each type of product was determined.

In order to evaluate the sensitivity of the forecasting methods, the comparison and contrast of the total cost and the realized customer service levels is presented. As a result, for the three dimensions the Willemain's Bootstrap Method is accepted as the most effective one among others. It is thought that the inventory policy which was found out in this study will contribute to the firm's stock management.

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APPENDIX – 1

(Willemain's Bootstrap Macro – Milas Carpet Büyük Kelle Dimension)

```
GMACRO
SEQUENCE
ERASE C2-C15
DO K15=1:1000
LET K1=0  #SAYAÇ
LET K2=1  #DEMAND TYPE
LET K3=0  #ÖRNEKTEN ÇEKİLEN DEĞER
LET K4=0  #JITTERED
LET K5=0  #YENİ ÖRNEKLEM DEĞERİ
LET K6=0   #INTEGER
LET K10=0
LET K11=0
LET K12=0,4063  #PROB. OF NONZERO TO ZERO
LET K13=0   #MEAN
NAME C1 "DATA"
NAME C2 "SEQUENCE"
NAME C3 "FORECAST"
NAME C4 "LTD"
NAME C5 "MEAN"
RANDOM 66 C10;  #RANDOM PROB.
UNIFORM 0 1.
DO K1=1:66
LET K12=0,4063
IF C10(K1)<=K12
  LET K2=0
  LET K12=0,6364
ELSE
  LET K2=1
  LET K12=0,4063
```

```
ENDIF
LET C2(K1)=K2    #SEQUENCE
ENDDO
RANDOM 66 C11
DO K1=1:66
IF C2(K1)=1
  SAMPLE 1 C1 C15;
  REPLACE.
  LET K3=C15(1)
  LET K6=ROUND(K3+C11(K1)*SQRT(K3))
  LET K4=K6
IF K4<=0
    LET K4=K3
ELSE
ENDIF
  LET K5=K3+K4
  LET C3(K1)=K5
ELSE
  LET C3(K1)=0
ENDIF
ENDDO
DO K10=1:64
LET C4(K10)=C3(K10)+C3(K10+1)+C3(K10+2)
ENDDO
LET K13=ROUND(MEAN(C4))
LET C5(K15)=K13
ENDDO
ENDMACRO
```

APPENDIX – 2

(The M(t) Estimation Values for Milas Carpet Taban Dimension by using the Croston's Method)

For **α = 0.1**;

Month	Date	X(t)	S(t)	z	I(t)	M(t)
1	January 04	1	0.53	1	1	**0.53**
2	February 04	0	0.53	2	1	**0.53**
3	March 04	0	0.53	2	1	**0.53**
4	April 04	1	0.58	1	1	**0.58**
5	May 04	0	0.58	2	1	**0.58**
6	June 04	0	0.58	2	1	**0.58**
7	July 04	0	0.58	2	1	**0.58**
8	August 04	2	0.72	1	1	**0.72**
9	September 04	1	0.75	1	1	**0.75**
10	October 04	0	0.75	2	1	**0.75**
11	November 04	1	0.77	1	1	**0.77**
12	December 04	0	0.77	2	1	**0.77**
13	January 05	1	0.80	1	1	**0.80**
14	February 05	1	0.82	1	1	**0.82**
15	March 05	1	0.84	1	1	**0.84**
16	April 05	1	0.85	1	1	**0.85**
17	May 05	0	0.85	2	1	**0.85**
18	June 05	0	0.85	2	1	**0.85**
19	July 05	0	0.85	2	1	**0.85**
20	August 05	3	1.07	1	1	**1.07**
21	September 05	3	1.26	1	1	**1.26**
22	October 05	0	1.26	2	1	**1.26**
23	November 05	0	1.26	2	1	**1.26**
24	December 05	1	1.23	1	1	**1.23**
25	January 06	0	1.23	2	1	**1.23**
26	February 06	1	1.21	1	1	**1.21**
27	March 06	1	1.19	1	1	**1.19**
28	April 06	0	1.19	2	1	**1.19**
29	May 06	0	1.19	2	1	**1.19**
30	June 06	0	1.19	2	1	**1.19**
31	July 06	0	1.19	2	1	**1.19**
32	August 06	0	1.19	2	1	**1.19**
33	September 06	0	1.19	2	1	**1.19**

Previous Table Continuing

Month	**Date**	**X(t)**	**S(t)**	**z**	**I(t)**	**M(t)**
34	October 06	0	1.19	2	1	**1.19**
35	November 06	1	1.17	1	1	**1.17**
36	December 06	3	1.35	1	1	**1.35**
37	January 07	0	1.35	2	1	**1.35**
38	February 07	0	1.35	2	1	**1.35**
39	March 07	1	1.32	1	1	**1.32**
40	April 07	0	1.32	2	1	**1.32**
41	May 07	0	1.32	2	1	**1.32**
42	June 07	0	1.32	2	1	**1.32**
43	July 07	0	1.32	2	1	**1.32**
44	August 07	0	1.32	2	1	**1.32**
45	September 07	0	1.32	2	1	**1.32**
46	October 07	0	1.32	2	1	**1.32**
47	November 07	0	1.32	2	1	**1.32**
48	December 07	1	1.29	1	1	**1.29**
49	January 08	0	1.29	2	1	**1.29**
50	February 08	0	1.29	2	1	**1.29**
51	March 08	0	1.29	2	1	**1.29**
52	April 08	0	1.29	2	1	**1.29**
53	May 08	0	1.29	2	1	**1.29**
54	June 08	0	1.29	2	1	**1.29**
55	July 08	0	1.29	2	1	**1.29**
56	August 08	0	1.29	2	1	**1.29**
57	September 08	0	1.29	2	1	**1.29**
58	October 08	0	1.29	2	1	**1.29**
59	November 08	0	1.29	2	1	**1.29**
60	December 08	1	1.26	1	1	**1.26**
61	January 09	0	1.26	2	1	**1.26**
62	February 09	1	1.23	1	1	**1.23**
63	March 09	1	1.21	1	1	**1.21**
64	April 09	3	1.39	1	1	**1.39**
65	May 09	1	1.35	1	1	**1.35**
66	June 09	0	1.35	2	1	**1.35**

For **α = 0.6**;

Month	Date	X(t)	S(t)	z	I(t)	M(t)
1	January 04	1	0.79	1	1	**0.79**
2	February 04	0	0.79	2	1	**0.79**
3	March 04	0	0.79	2	1	**0.79**
4	April 04	1	0.92	1	1	**0.92**
5	May 04	0	0.92	2	1	**0.92**
6	June 04	0	0.92	2	1	**0.92**
7	July 04	0	0.92	2	1	**0.92**
8	August 04	2	1.57	1	1	**1.57**
9	September 04	1	1.23	1	1	**1.23**
10	October 04	0	1.23	2	1	**1.23**
11	November 04	1	1.09	1	1	**1.09**
12	December 04	0	1.09	2	1	**1.09**
13	January 05	1	1.04	1	1	**1.04**
14	February 05	1	1.01	1	1	**1.01**
15	March 05	1	1.01	1	1	**1.01**
16	April 05	1	1.00	1	1	**1.00**
17	May 05	0	1.00	2	1	**1.00**
18	June 05	0	1.00	2	1	**1.00**
19	July 05	0	1.00	2	1	**1.00**
20	August 05	3	2.20	1	1	**2.20**
21	September 05	3	2.68	1	1	**2.68**
22	October 05	0	2.68	2	1	**2.68**
23	November 05	0	2.68	2	1	**2.68**
24	December 05	1	1.67	1	1	**1.67**
25	January 06	0	1.67	2	1	**1.67**
26	February 06	1	1.27	1	1	**1.27**
27	March 06	1	1.11	1	1	**1.11**
28	April 06	0	1.11	2	1	**1.11**
29	May 06	0	1.11	2	1	**1.11**
30	June 06	0	1.11	2	1	**1.11**
31	July 06	0	1.11	2	1	**1.11**
32	August 06	0	1.11	2	1	**1.11**
33	September 06	0	1.11	2	1	**1.11**

Previous Table Continuing

Month	Date	X(t)	S(t)	z	I(t)	M(t)
34	October 06	0	1.11	2	1	**1.11**
35	November 06	1	1.04	1	1	**1.04**
36	December 06	3	2.22	1	1	**2.22**
37	January 07	0	2.22	2	1	**2.22**
38	February 07	0	2.22	2	1	**2.22**
39	March 07	1	1.49	1	1	**1.49**
40	April 07	0	1.49	2	1	**1.49**
41	May 07	0	1.49	2	1	**1.49**
42	June 07	0	1.49	2	1	**1.49**
43	July 07	0	1.49	2	1	**1.49**
44	August 07	0	1.49	2	1	**1.49**
45	September 07	0	1.49	2	1	**1.49**
46	October 07	0	1.49	2	1	**1.49**
47	November 07	0	1.49	2	1	**1.49**
48	December 07	1	1.19	1	1	**1.19**
49	January 08	0	1.19	2	1	**1.19**
50	February 08	0	1.19	2	1	**1.19**
51	March 08	0	1.19	2	1	**1.19**
52	April 08	0	1.19	2	1	**1.19**
53	May 08	0	1.19	2	1	**1.19**
54	June 08	0	1.19	2	1	**1.19**
55	July 08	0	1.19	2	1	**1.19**
56	August 08	0	1.19	2	1	**1.19**
57	September 08	0	1.19	2	1	**1.19**
58	October 08	0	1.19	2	1	**1.19**
59	November 08	0	1.19	2	1	**1.19**
60	December 08	1	1.08	1	1	**1.08**
61	January 09	0	1.08	2	1	**1.08**
62	February 09	1	1.03	1	1	**1.03**
63	March 09	1	1.01	1	1	**1.01**
64	April 09	3	2.20	1	1	**2.20**
65	May 09	1	1.48	1	1	**1.48**
66	June 09	0	1.48	2	1	**1.48**

APPENDIX – 3

(The M(t) Estimation Values for Milas Carpet Karyola Yolluk Dimension by using the Croston's Method)

For **α = 0.1**;

Month	Date	X(t)	S(t)	z	I(t)	M(t)
1	January 04	6	1.63	1	1	**1.63**
2	February 04	1	1.56	1	1	**1.56**
3	March 04	4	1.81	1	1	**1.81**
4	April 04	4	2.03	1	1	**2.03**
5	May 04	0	2.03	2	1	**2.03**
6	June 04	1	1.92	1	1	**1.92**
7	July 04	0	1.92	2	1	**1.92**
8	August 04	0	1.92	2	1	**1.92**
9	September 04	1	1.83	1	1	**1.83**
10	October 04	0	1.83	2	1	**1.83**
11	November 04	2	1.85	1	1	**1.85**
12	December 04	4	2.06	1	1	**2.06**
13	January 05	2	2.06	1	1	**2.06**
14	February 05	5	2.35	1	1	**2.35**
15	March 05	3	2.42	1	1	**2.42**
16	April 05	3	2.47	1	1	**2.47**
17	May 05	2	2.43	1	1	**2.43**
18	June 05	0	2.43	2	1	**2.43**
19	July 05	0	2.43	2	1	**2.43**
20	August 05	0	2.43	2	1	**2.43**
21	September 05	2	2.38	1	1	**2.38**
22	October 05	2	2.35	1	1	**2.35**
23	November 05	0	2.35	2	1	**2.35**
24	December 05	0	2.35	2	1	**2.35**
25	January 06	1	2.21	1	1	**2.21**
26	February 06	0	2.21	2	1	**2.21**
27	March 06	3	2.29	1	1	**2.29**
28	April 06	0	2.29	2	1	**2.29**
29	May 06	0	2.29	2	1	**2.29**
30	June 06	0	2.29	2	1	**2.29**
31	July 06	0	2.29	2	1	**2.29**
32	August 06	1	2.16	1	1	**2.16**
33	September 06	0	2.16	2	1	**2.16**

Previous table Continuing

Month	Date	X(t)	S(t)	z	I(t)	M(t)
34	October 06	0	2.16	2	1	**2.16**
35	November 06	3	2.25	1	1	**2.25**
36	December 06	1	2.12	1	1	**2.12**
37	January 07	1	2.01	1	1	**2.01**
38	February 07	3	2.11	1	1	**2.11**
39	March 07	6	2.50	1	1	**2.50**
40	April 07	1	2.35	1	1	**2.35**
41	May 07	1	2.21	1	1	**2.21**
42	June 07	0	2.21	2	1	**2.21**
43	July 07	0	2.21	2	1	**2.21**
44	August 07	0	2.21	2	1	**2.21**
45	September 07	0	2.21	2	1	**2.21**
46	October 07	1	2.09	1	1	**2.09**
47	November 07	0	2.09	2	1	**2.09**
48	December 07	1	1.98	1	1	**1.98**
49	January 08	2	1.98	1	1	**1.98**
50	February 08	0	1.98	2	1	**1.98**
51	March 08	0	1.98	2	1	**1.98**
52	April 08	0	1.98	2	1	**1.98**
53	May 08	0	1.98	2	1	**1.98**
54	June 08	0	1.98	2	1	**1.98**
55	July 08	0	1.98	2	1	**1.98**
56	August 08	0	1.98	2	1	**1.98**
57	September 08	1	1.89	1	1	**1.89**
58	October 08	1	1.80	1	1	**1.80**
59	November 08	1	1.72	1	1	**1.72**
60	December 08	0	1.72	2	1	**1.72**
61	January 09	0	1.72	2	1	**1.72**
62	February 09	0	1.72	2	1	**1.72**
63	March 09	2	1.75	1	1	**1.75**
64	April 09	1	1.67	1	1	**1.67**
65	May 09	0	1.67	2	1	**1.67**
66	June 09	2	1.70	1	1	**1.70**

For **α = 0.6**;

Month	Date	X(t)	S(t)	z	I(t)	M(t)
1	January 04	6	4.06	1	1	**4.06**
2	February 04	1	2.22	1	1	**2.22**
3	March 04	4	3.29	1	1	**3.29**
4	April 04	4	3.72	1	1	**3.72**
5	May 04	0	3.72	2	1	**3.72**
6	June 04	1	2.09	1	1	**2.09**
7	July 04	0	2.09	2	1	**2.09**
8	August 04	0	2.09	2	1	**2.09**
9	September 04	1	1.43	1	1	**1.43**
10	October 04	0	1.43	2	1	**1.43**
11	November 04	2	1.77	1	1	**1.77**
12	December 04	4	3.11	1	1	**3.11**
13	January 05	2	2.44	1	1	**2.44**
14	February 05	5	3.98	1	1	**3.98**
15	March 05	3	3.39	1	1	**3.39**
16	April 05	3	3.16	1	1	**3.16**
17	May 05	2	2.46	1	1	**2.46**
18	June 05	0	2.46	2	1	**2.46**
19	July 05	0	2.46	2	1	**2.46**
20	August 05	0	2.46	2	1	**2.46**
21	September 05	2	2.19	1	1	**2.19**
22	October 05	2	2.07	1	1	**2.07**
23	November 05	0	2.07	2	1	**2.07**
24	December 05	0	2.07	2	1	**2.07**
25	January 06	1	1.43	1	1	**1.43**
26	February 06	0	1.43	2	1	**1.43**
27	March 06	3	2.37	1	1	**2.37**
28	April 06	0	2.37	2	1	**2.37**
29	May 06	0	2.37	2	1	**2.37**
30	June 06	0	2.37	2	1	**2.37**
31	July 06	0	2.37	2	1	**2.37**
32	August 06	1	1.55	1	1	**1.55**
33	September 06	0	1.55	2	1	**1.55**

Previous Table Continuing

Month	Date	X(t)	S(t)	z	I(t)	M(t)
34	October 06	0	1.55	2	1	**1.55**
35	November 06	3	2.42	1	1	**2.42**
36	December 06	1	1.57	1	1	**1.57**
37	January 07	1	1.23	1	1	**1.23**
38	February 07	3	2.29	1	1	**2.29**
39	March 07	6	4.52	1	1	**4.52**
40	April 07	1	2.41	1	1	**2.41**
41	May 07	1	1.56	1	1	**1.56**
42	June 07	0	1.56	2	1	**1.56**
43	July 07	0	1.56	2	1	**1.56**
44	August 07	0	1.56	2	1	**1.56**
45	September 07	0	1.56	2	1	**1.56**
46	October 07	1	1.23	1	1	**1.23**
47	November 07	0	1.23	2	1	**1.23**
48	December 07	1	1.09	1	1	**1.09**
49	January 08	2	1.64	1	1	**1.64**
50	February 08	0	1.64	2	1	**1.64**
51	March 08	0	1.64	2	1	**1.64**
52	April 08	0	1.64	2	1	**1.64**
53	May 08	0	1.64	2	1	**1.64**
54	June 08	0	1.64	2	1	**1.64**
55	July 08	0	1.64	2	1	**1.64**
56	August 08	0	1.64	2	1	**1.64**
57	September 08	1	1.25	1	1	**1.25**
58	October 08	1	1.10	1	1	**1.10**
59	November 08	1	1.04	1	1	**1.04**
60	December 08	0	1.04	2	1	**1.04**
61	January 09	0	1.04	2	1	**1.04**
62	February 09	0	1.04	2	1	**1.04**
63	March 09	2	1.62	1	1	**1.62**
64	April 09	1	1.25	1	1	**1.25**
65	May 09	0	1.25	2	1	**1.25**
66	June 09	2	1.70	1	1	**1.70**