T.C.
MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES IN
PURE AND APPLIED SCIENCES

IMPLEMENTATION OF INVENTORY CONTROL ON

MANUFACTURING INDUSTRY

Boğaç ÖZGEN
(Industrial Engineer)

THESIS

FOR THE DEGREE OF MASTER OF SCIENCE

IN

ENGINEERING MANAGEMENT PROGRAMME

SUPERVISOR
Prof. Dr. Emin ARCA

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FEN BİLİMLERİ ENSTİTÜSÜ

KABUL VE ONAY BELGESİ

Implementation of Inventory Control on Manufacturing Industry

Boğaç ÖZGEN'in "Implementation of Inventory Control on Manufacturing Industry" isimli Lisansüstü tez çalışması, M.Ü. Fen Bilimleri Enstitüsü Yönetim Kurulu'nun 22/03/2006 tarih ve B.30.2.MAR.0.C1.00.00.sek/973 sayılı kararı ile oluşturulan jüri tarafından Mühendislik Yönetimi Anabilim Dalı Mühendislik Yönetimi Programında YÜKSEK LİSANS Tezi olarak Kabul edilmiştir.

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Tezin Savunulduğu Tarih : 30/03/2006

ONAY

M.Ü. Fen Bilimleri Enstitüsü Yönetim Kurulu'nun .... tarih ve .... sayılı kararı

ile Boğaç ÖZGEN'in Mühendislik Yönetimi Anabilim Dalı Mühendislik Yönetimi Programında Y.Lisans (MSc.) derecesi alması onanmıştır.

Marmara Üniversitesi

Fen Bilimleri Enstitüsü Müdürü

ÖNSÖZ

Her zaman teşekkür edecek birilerini bulmak çok güzel bir duygu. Ümit ederim ki bu duyguyu birçok seferler yaşarım.

Keyifli bir çalışma oldu ve ortaya çıkması kesinlikle bireysel bir çalışmanın ürünü olmadı. Bu sebeptendir ki, teşekkür etmek istediğim insanlar var ve ben bu fırsatı kaçırmak istemem.

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Bu çalışma anneme ve babama ithaf olunur…

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FOREWORD

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I want to give my special thanks to my supervisor and mentor Prof. Dr. Emin ARCA for his guidance, encouragement, support and valuable feedback through this research, to my spiritual partner Evrim NUMANOGLU, and to my friends Baki TORUNOĞLU, Işıl GÜRATAN, Kemal GÜÇOĞLU, Utku KÖKER, Şükrü HACIYANLI for their help and valuable support that lets me finish this work.

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I could not have completed this study without help of my family, my teachers and my friends who never left me alone.

I would like to dedicate this study to my mother Nadire ÖZGEN and my father Osman Şahin ÖZGEN …

…with my best regards …

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ÖZET

Endüstri Mühendisliğinin en eski ve en çok incelenmiş konularından biri olan "Envanter yönetimi" konusu ele alındığında firmaların bu konuya profesyonelce eğilmediği görülmektedir. "Envater Yönetimi'" nin Stratejik bir yönetim aracı olması ve rekabet avantajını da beraberinde getirmesi gözden kaçırılmaması gereken iki özelliktir. "Envanter Yönetimi" ister hizmet sektörü isterse de üretim sektöründe olsun, firmaların ana faaliyet konularında daha fazla serbesti kazanabilmeleri için de gerekli ve temel bir konudur.

Bu çalışmamızda Envanter Yönetimi konusu tam olarak Stratejik bir Yönetim aracı olarak ele alınmaya çalışılmıştır. Bu çerçevede firmaların bilgi, beceri ve deneyimleri yardımıyla, kendi envanter yönetim politikalarını oluşturabilmelerine yardımcı olabilmek amaç olarak edinilmiştir. Bu amaç doğrultusunda uygun, kolay kullanımlı bir bilgisayar uygulamasının gerekliliği fark edilmiş ve bu eksiklik giderilmeye çalışılmıştır.

Bilgi ve deneyimimizi temel alarak ortaya koyduğumuz sistem analizi çalışmamız sonucunda ortaya koymak istediğimiz çözümün, tasarlanması, geliştirilmesi ve test edilip kullanıma hazır hale getirilmesi aşamaları bu çalışmanın ayrıntılarını oluşturmaktadır.

Çalışmamız, şimdiye kadar gerçekleştirilmiş olan diğer çalışmaların bir eksiğini kapatmaya yöneliktir: **Teorik altyapı kullanılarak, firmaların bilgi ve deneyimlerine dayalı "Envanter Yönetim Sistemleri" modellemek**.

Anahtar Kelimeler: Envanter Yönetim Sistemleri, Ekonomik Sipariş Miktarı, Performans Analizleri, Yazılım Geliştirme, ABC Sınıflandırması, Stratejik Yönetim, Yapay Zekâ, Öğrenen Organizasyonlar, İş Süreçleri Yeniden Yapılandırılması (Business Process Reengineering)

Mart-2006   **Boğaç ÖZGEN**

ABSTRACT

"Inventory Management" is the oldest and one of the most investigated areas of Industrial Engineering. When "Inventory Management" subject is examined, it can be briefly seen that companies do not have professional approaches and visions to this strategic tool. As a strategic management tool, "Inventory Management" brings competitive advantages and these advantages are the most powerful features of it. As an addition to this, "Inventory Management" helps companies go through their main activity areas more confidently and supports freedom for decision making in the competitive markets.

In this study, "Inventory Management" is taken as an important "Strategic Management Tool" for pro-active behaviors of companies against rapidly changing markets. Inside of this framework, there lies the objective to develop an easy to use software application to let companies build their own "Inventory Management" systems based on their accumulated experiences and knowledge and model these systems using theoretical approaches.

As a consequence of "System Analysis" approaches within this study analysis phase, designing phase, development phase and testing phase of the software application development cycle are yield as the details.

This study has an objective of completing a missing side of the existing implementations: **Modeling "Inventory Management Systems" based on the experience and knowledge of the companies by using theoretical infrastructures**.

Keywords: Inventory Management Systems, Economic Order Quantity, Performance Analysis, Software Development, ABC Classification, Strategic Management, Artificial Intelligence, Learning Organization, Business Process Reengineering

March-2006   **Boğaç ÖZGEN**

CLAIM FOR ORIGINALITY

Implementation of Inventory Control on Manufacturing Industry

In this study we aimed to develop an application that can be used to realize the simulation techniques to be used for performance measurement processes over the independent variables of the "Inventory Management Systems". Since prior, similar simulation applications are mostly handled as academic studies, there are no serious software development studies which are made for common use of the companies who can implement the application on their "Inventory Management Systems".

As our simulation environment was built up, we prepared templates for different product groups (as we called "Inventory Valuation Classes") and different periods of time in a fiscal year. These "Inventory Valuation Classes" give the opportunity to the planners to optimize the inventory levels for different groups of products and for different periods of time, based on the "Inventory Management System Models" which are particularly created, to measure the performance of the "Inventory Management System Model" compared to pre-defined theoretical or experience-driven models and to implement company related data and information to build a strategic inventory management system. Since this measurement can be made visually and easily, cost management over the inventory levels can efficiently be managed by the management levels of the companies.

By the completion of this study, we attempt to create a way for the companies to be involved in the "Learning Organization" concepts, therefore "Artificial Intelligence (AI)" studies could be started and could be used as strategic management tool.

As an addition to the importance of the application which is described above, it can be said that this is may be the first study that accepts "Inventory Management Systems" as a strategic management tool to play a pro-active role in the competitive markets using dynamic simulation techniques.

March–2006   **Prof. Dr. Emin ARCA**   **Boğaç ÖZGEN**

LIST OF SYMBOLS

$\bar{d}$	: Average daily demand
R	: Reorder point
TC	: Total annual cost
C	: Cost per unit
Q	: Quantity to be ordered (The optimum amount is termed the EOQ)
S	: Setup cost or cost of placing an order
L	: Lead time
H	: Annual holding storage cost per unit of average inventory
d_r	: A constant demand rate for some item going into production
p	: The production rate of that process that uses the item
P	: Service level desired
(1 –P)	: Unsatisfied demand
D	: Annual demand
σ_L	: Standard deviation of demand during lead time
z	: Number of standard deviations for a specified service level
σ_L	: Standard deviation of usage during lead time.
i	: Inventory Cost as percent of total cost
E (z)	: Expected number units short from a formalized table where $\sigma = 1$
P	: Service level desired
T	: The number of days between reviews
$\bar{d}$ **T**	: Demand during the review period where d is daily demand
$z\sigma_{T+L}$	: Standard deviation over the review period and lead time.
σ_{T+L}	: Standard deviation of demand over the review and lead time
I	: Current inventory level (includes items on order)

LIST OF ABBREVIATIONS

AI	**:**	Artificial Intelligence
CASE	**:**	Computer-aided software engineering
CPR	**:**	Core Processes Reengineering
EOQ	**:**	Economic Order Quantity
GUI	**:**	Graphical User Interface
IMS	:	Inventory Management System
IVC	:	Inventory Valuation Classification
MPA	**:**	Model Performance Analysis
MPR	**:**	Model Performance Reporting
MS	**:**	Microsoft® Inc.
SDLC	**:**	Software Development Life Cycle
KPI	**:**	Key Performance Indicator

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CHAPTER I. INTRODUCTION

I.1 Introduction

Effective inventory management plays a crucial role for the organization to go smoothly and efficiently. Reducing excess inventories and investing in the right inventories lead to better customer service, better investor turnover—and more profits.

This subject is a touchstone for the main functions for the organization which it is based on. "Purchasing", "Forecasting of Sales", "Production Planning", "Materials Resource Planning", "Inventory Management", "Distribution", and "Customer Relationships" are all based on the inventory control system in the organization. Therefore one of the most explored fields of industrial engineering is "Inventory Control". We can find lots of publications that are having a either great theoretical or practical attitude and based on the studies going back to the bgining of the last century with a basic literature survey (For example, Harris Economic Lot Size Equation). These are all powerful sources for the field and also for the academicians.

But there is a weak side of this field. A small amount of publications give details about the study that is told from the inception to the implementation of the model, the results with a set of independent variables by using a simulation application. This type of study will be a significantly simple, adaptable and easy to understand.

In Bachelor's degree at the universities, commonly the terms are tried to be explained with a well known system model. But the real life is different than the one we are learning at the college. Just the following list can give an idea about the system that we are trying to explain the environment:

- Demand is known and constant
- Lead time is known and constant
- Receipt of inventory is instantaneous

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- Quantity discounts are not possible
- The only variable costs are the cost of setting up or placing an order, and the cost of holding or storing inventory over time
- Stockouts can be completely avoided if orders are placed at the appropriate time
- ...

In our study we will explain an analytical solution for the model then try to define the boundaries of the system, develop an application for the simulation of the system to be able to make comparison with the simulated data and the real data by using "Super Impose" technique.

I.2 DEFINITION OF THE PROBLEM

The problem is that the existing software applications in the market do not support using and creating dynamic models according to the experience and knowledge of the companies. These applications forces companies to work with the rigid models to establish an inventory management system as the scope of the applications which are limited to warehouse management systems and systems that are integrated to accounting and production information systems. Integration is generally very useful and an eventually needed feature, but also it limits the type of the platforms that the companies try to build thier own inventory management system, consequently it costs more then gain.

As companies do not make detailed impact analysis of the costs of the inventory management systems the above limitations ever look irritating.

According to the limitations explained above companies do not have a chance to use their own formulized models built with the parameters and constants with the weights that have been determined by the experiences of the company itself.

As a result, companies can not give required importance on the inventory management systems. They try to focus on the other processes in the company to make more profitable, but can not understand how much its worth and how much they afford. Generally gaining small amounts from the purchasing of the materials and

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inventory management systems make more difference then the other processes can make.

I.3 OBJECTIVES OF THE STUDY

The master objective of this study is to develop an application that will be used to determine the environment (independent) variables by using the simulation technique and to see the efficiency of the technique that is being used to evaluate the variables values.

After we develop the simulation environment we will be able to create templates for the independent variables and the subject of the problem. After these steps we will have real life data to be compared with the simulated data. This comparison will be done by using the "Superimpose" technique.

As we develop processes on this study, there appeared a huge need to develop a methodology that companies need to use in their "Inventory Management System" development. The brief explanation of the methodology can be found in this study.

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CHAPTER II. INTRODUCTION TO INVENTORY MANAGEMENT[4]

I.1 DEFINITION OF INVENTORY

Inventory is the stock of any item or resource used in an organization. An inventory system is the set of policies and controls that monitors levels of inventory and determines what levels should be maintained, when stock should be replenished, and how large orders should be.

Inventory Systems may involve the below functionality [1]:

- Planning
  - Inventory Policy
  - Inventory Planning
  - Forecasting
- Purchase Ordering
  - Positive ordering
  - Negative Ordering
- Inventory Handling
  - Receiving
  - Physical Inventory Control
  - Inventory Accounting
- Distribution
  - Liquidation
  - Distribution

By convention, manufacturing inventory generally refers to materials entities that contribute to or become part of a firm's product output. Manufacturing inventory is typically classified into **raw materials, finished products, component parts, supplies,** and **work in process.** Generally the materials flow can be shown as a general production system model as Figure I-1.
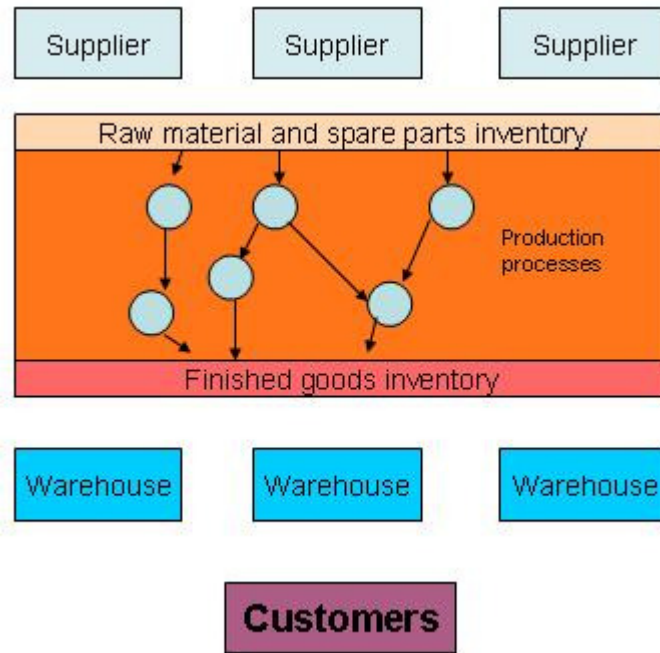
Figure I-1, Materials Flow System [2].

In service sector, "Inventory" generally refers to the tangible goods to be sold and the supplies necessary to administer the service.

The basic purpose of inventory analysis in manufacturing and stockkeeping services is to specify when items should be ordered and how large the order should be. Many firms tend to enter into longer-term relationships with vendors to supply their needs for –perhaps- the entire year. This changes the questions "when" and "how many to order" to more helpful questions "when" and "how many to deliver".

II.2 PURPOSES OF INVENTORY

All firms (including JIT operations inside) keep a supply of inventory for the following reasons [4]:

- To maintain independence of operations. A supply of materials at a work center allows that center to be flexible in its operations. For example, for the reason that there are costs for making each new production setup, inventory allows management to reduce the number of setups.

- Independence of workstations is desirable on assembly lines as well. The time required for doing identical operations naturally varies from one unit to the other. Therefore it is desirable to have a cushion of several parts within the

workstation so that shorter performance times can compensate for longer performance times. This way of average output can be fairly stable.

- To meet variation in product demand. If the demand for the product is known precisely, it may be possible (though not necessarily economical) to produce the product to exactly meet the demand. Usually, however, demand is not completely known, and a safety or buffer stock must be maintained to absorb variation.

- To allow flexibility in production scheduling. A stock of inventory relieves the pressure on the production system to get the goods out. This causes longer lead times, which permit production planning for smoother flow and lower cost operation through larger lot size production. High setup costs for example favor the production of a larger number of units once the setup has been made.

- To provide a safeguard for variation in raw material delivery time. When material is ordered from a vendor, delays can occur for a variety of reasons: a normal variation in shipping time, a shortage of material at the vendor's plant causing backlogs, an unexpected strike at the vendor's plant or at one of the shipping companies, a lost order, or a shipment of incorrect or defective material.

- To take advantage of economic purchase order size. There are costs to place an order: labor, phone calls, typing, postage, and so on. There fore, the larger the size of each order, the fewer the number of orders that need be written. Also, shipping costs favor larder orders—the larger the shipment, the lower the per-unit cost.

For each of the preceding reasons, we should be aware that inventory is costly and large amounts are generally undesirable. Long cycle times are caused by large amounts of inventory and are undesirable as well.

II.3. INVENTORY COSTS

In making any decision that affects inventory size, the following costs must be considered [4].

- Holding (or carrying) costs. This broad category includes the costs for storage facilities, handling, insurance, pilferage, breakage, obsolescence, depreciation,

taxes, and the opportunity cost of capital. Obviously, high holding costs tend to favor low inventory levels and frequent replenishment.

- Setup (or production change) costs. To make each different product involves obtaining the necessary materials, arranging specific equipment setups, filling out the required papers, appropriately changing time and materials, and moving out the previous stock of material. In addition, other costs may e involved in hiring, training, or laying off workers, and in idle time or overtime. If there were no costs or loss of time in changing from one product to another, many small lots would be produced. This would reduce inventory levels, with a resulting savings in cost. One challenge today is to try to reduce these setup costs to permit smaller lot sizes. (This is the goal of a JIT system.)

- Ordering costs. These costs refer to the managerial and clerical costs to prepare the purchase or production order. Ordering costs included all the details, such as counting items and calculating order quantities.

- Shortage costs. When the stock of an item is depleted, an order for that item must either wait until the stock is replenished or be canceled. There is a trade-off between carrying stock to satisfy demand and the costs resulting from stockout. This balance is sometimes difficult obtain, since it may not be possible to estimate lost profits, the effects of lost customers, or lateness penalties. Frequently, the assumed shortage cost is little more than a guess, although it is usually possible to specify a range of such costs.

Establishing the correct quantity to order from vendors or the size of lots submitted to the firm's productive facilities involves a search for the minimum total cost resulting form the combined effects of four individual costs; holding costs, setup costs, ordering costs and shortage costs.

II.4. INDEPENDENT VERSUS DEPENDENT DEMAND

In inventory management it is important to understand the difference between dependent demand and independent demand. The reason is that entire inventory systems are predicted on whether demand is derived from an end item or is related to the item itself.

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Briefly, the distinction between independent and dependent demand is this: In independent demand the demands for various items are unrelated to each other. For example a workstation may produce many parts that are unrelated but meet some external demand requirement. In dependent demand, the need for any one item is a direct result of the need for some other item, usually a higher level item of which it is part.

In concept, dependent demand is a relatively straightforward computational problem. Needed quantities of a dependent demand item are simply computed based on the number needed in each higher level item where it is used. For example, if an automobile company plans on producing 500 cars per day, then obviously it will need 2000 wheels and tires. The number of wheels and tires needed is dependent on the production levels and not derived desperately. The demand for cars, on the other hand, is independent – it comes from many sources external to the automobile firm and is not a part of the products and so is unrelated to the demand for other products.

To determine the quantities of independent items that must be produced, firms usually turn to their sales and market research departments. They use variety of techniques including customer surveys, forecasting techniques, and economic and sociological trends, because independent demand is uncertain [4].

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II.5. INVENTORY SYSTEMS

An inventory system provides the organizational structure and the operating policies for maintaining and controlling goods to be stocked. The system is responsible for ordering and receipt of goods; timing the order placement and keeping track of what has been ordered, how much, and from whom. The system must also follow up to answer such questions as: Has the vendor received the order? Has it been shipped? Are the dates correct?

There are two general types of inventory systems:

- **Fixed-order quantity models** (economic order quantity, EOQ, and **Q model**)
- **Fixed-time period models** (periodic system, periodic review system, fixed-order interval system, and **P model**)

The basic distinction is that fixed-order quantity models are "event-triggered" and fixed-time period models are "time triggered". That is, a fixed-order quantity model initiates an order when the event of reaching a specified reorder level occurs. This event may take place at any time, depending on the demand for the items considered. In contrast, the fixed-time period model is limited to placing orders at the end of a predetermined time period: only the passage of time triggers the model.

To use the fixed-order quantity model (which places an order when the remaining inventory drops to a predetermined order point, R), remaining must be continually monitored. Thus, the fixed-order quantity model is a perpetual system, which requires that every time a withdrawal from inventory or an addition to inventory is made, records must be updated to ensure that the reorder point has or has not been reached. In a fixed-time period model counting takes place only at the review period.

Some additional differences that tend to influence the choice of systems are :

- The fixed-time period model has a larger average inventory since it must also protect against stockout during the review period, T: the fixed-quantity model has no review period.
- The fixed-order quantity model favors more expensive items since average inventory is lower.

- The fixed-order quantity model is more appropriate for important items such as critical repair parts since there is closer monitoring and therefore quicker response to potential stockout.
- The fixed-order quantity model requires more time to maintain since every addition or withdrawal is logged.

Figure II-1, The differences of Fixed-Order Quantity Model and Fixed-Time Period Models [4]

Feature	Q Fixed-Order Quantity Model	P Fixed-Time Period Model
Order quantity	Q—constant (the same amount ordered each time)	q—variable (varies each time order is placed)
When to place order	R—when quantity on hand drops to the reorder level	T—when the review period arrives
Recordkeeping	Each time a withdrawal or addition is made	Counted only at review period
Size of inventory	Less than fixed-time period model	Larger than fixed-order quantity model
Time to maintain	Higher due to perpetual recordkeeping	
Type of items	Higher-priced, critical, or important items	

Figure II-1 shows what occurs when each of the two models is put into use and becomes an operating system. The fixed-order quantity system focuses on order quantities and reorder points. Procedurally, each time a unit is taken out of stock, the withdrawal is logged and the amount remaining in inventory is immediately compared to the reorder point. If it has dropped to this point, an order for Q items is placed. If it has not, the system remains in an idle state until the next withdrawal.

In the fixed-time period system, a decision to place an order is made after the stock has been counted or reviewed. Whether an order is actually placed depends on the inventory status at that time.

If we try to figure out the differences in the flows of the processes then Figure II-2 helps us to make the comparison clearly.
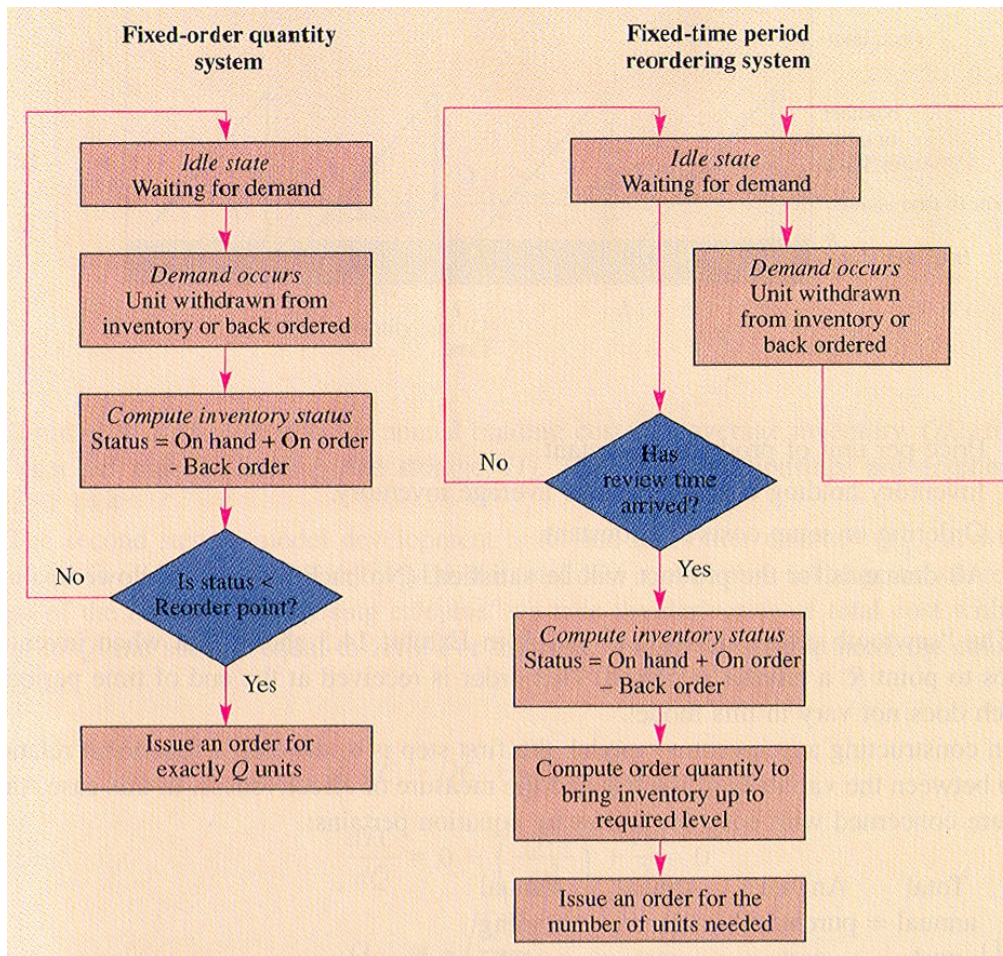
Figure II-2, The differences of Fixed-Order Quantity Model and Fixed-Time Period Models based on the procedures of flows [4].

We should better to emphasize that this inventory management systems are going through the records of the inventory system itself. So this system of control is no better than the accuracy of its records and inaccurate records are worse than no records at all [6].

II.5.1. Fixed Order Quantity Models

II.5.1.1 Basic Economic Order Quantity Model

Fixed order quantity models attempt to determine the specific point R: at which an order will be placed and the size of that order. Q – The order point, R. is always a specified number of units actually in inventory. The solution of fixed order quantity model may stipulate something like this: When the number of units of inventory on hand drops to 36, place an order for 57 more units.

The simplest models in this category occur when all aspects of the situation are known with certainly. If the annual demand for a product is 1000 units, it's precisely 1000 – not 1000 plus or minus 10 percent. The same is true for setup costs and holding costs. Although the assumption complete certainty is rarely valid, it provides a good starting point for our coverage of inventory models.

Figure II-3 and the discussion of deriving the optimal order quantity are based on the following characteristics models. These assumptions are unrealistic, but they represent a starting point and allow us to use a simple example.
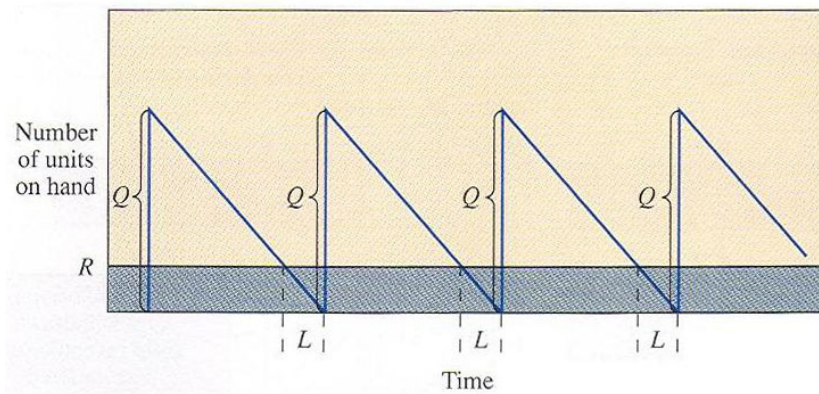
Figure II-3, Derivation of Optimal order quantity based on some assumptions [4].

- Demand for the product is constant and uniform throughout the period.
- Lead time (time from ordering to receipt) is constant.
- Price per unit of product .s constant.
- Inventory building cost is based on average inventory.
- Order or setup costs are constant.
- All demands for product will be satisfied. (No back orders are allowed.)

The "saw tooth effect" relating Q and R in Figure II-3 shows that when inventory drops to point R. A record is placed. This order is received at the end of time period L, which does not vary in this model.

In constructing any inventory model, the first step is to develop a functional relationship between variables interest and the measure of effectiveness. In this case since we are concerned with cost, the following equation pertains.

$$\begin{array}{ccccccc} \text{Total} & & \text{Annual} & & \text{Annual} & & \text{Annual} \\ \text{annual} & = & \text{purchase} & + & \text{ordering} & + & \text{holding} \\ \text{cost} & & \text{cost} & & \text{cost} & & \text{cost} \end{array}$$

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or

$$TC = DC + \frac{D}{Q}S + \frac{Q}{2}H$$

Equation II-1, Formulation of Total Cost of inventory of the model [4]

On the right side of the equation, DC is the annual purchase cost for units, (D/QS) is the annual ordering cost (the actual number of orders placed, D/Q, times the cost each order, S) and (Q/2) H is the annual holding cost (the average inventory, Q/2, times the cost per unit for holding cost and storage, H). These cost relationships are graphed in Figure II-4.
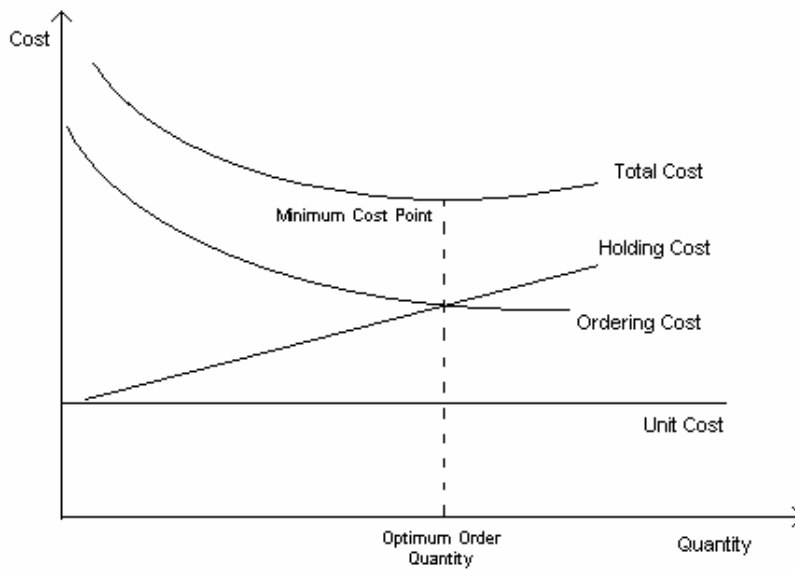
Figure II-4, The relationship of cost parameters [4]

The second step in model development is to find that order quantity Q_{opt} at which total cost is a minimum. In Figure II-4, the total cost is a minimum at the point where the slope of the curve is zero. Using calculus, we take the derivative of total cost with respect to Q and set this equal to zero. For the basic model considered here, the calculations are:

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$$TC = DC + \frac{D}{Q}S + \frac{Q}{2}H$$

$$\frac{dTC}{dQ} = O + (\frac{-DS}{Q^2}) + \frac{H}{2} = 0$$

$$Q_{opt} = \sqrt{\frac{2DS}{H}}$$

Equation II-2, Derivation of Economic Order Quantity [4]

Since the simple model assumes constant demand and lead time, no safety stock is necessary and the reorder point R is simply

$$R = \bar{d} L$$

Equation II-3, Calculation of Reorder Point [4]

II.5.1.2 Economic Order Quantity Model with usage

In many situations, in fact, production of an inventory item and usage of that item take place simultaneously. This is particularly true where one part of a production system acts as a supplier to another part. For example where aluminum extrusions are being made to fill and order for aluminum windows, the extrusions are cut and assembled before the entire extrusion order is completed. Also companies are beginning to enter longer-term arrangements with vendors. Under such contracts, a single order may cover product or material need over six-month or year period, with the vendor making deliveries weekly or sometimes even mode frequently. If we let

$$TC = DC + \frac{D}{Q}S + \frac{(p - d_r)QH}{2p}$$

Equation II-4, Formulation of Total Cost of inventory of the model with usage [4]

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Again differentiating with respect to Q and setting the equation equal to zero, we obtain

$$Q_{opt} = \sqrt{\left(\frac{2DS}{H}\right).\left(\frac{p}{p-d}\right)}$$

Equation II-5, Derivation of Economic Order Quantity from the model with usage [4]

The model is shown in Figure II-5. We can see that the number of units on hand is always less then the order quantity, Q.
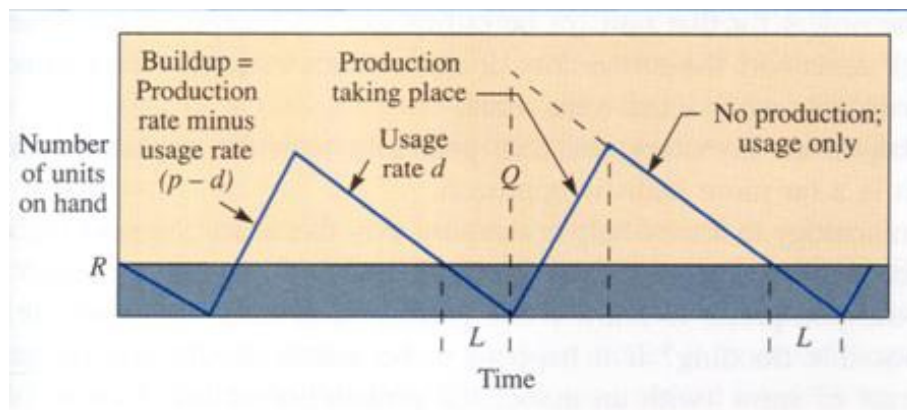
Figure II-5, Derivation of Optimal order quantity from the model with usage [4]

II.5.1.3 Economic Order Quantity Model with Specified Service Level

A fixed-order quantity system perpetually monitors the inventory level and places a new order when stock reaches some level, R. The danger of stockout in this model occurs only during the lead time, between the time an order is placed and the time it is received. As shown in Figure II-6, an order is placed when the inventory level drops to the reorder point, R. During the lead time (L), a range of demand is possible. This range is determined either from an analysis of past demand data or from an estimate (if past data are not available).
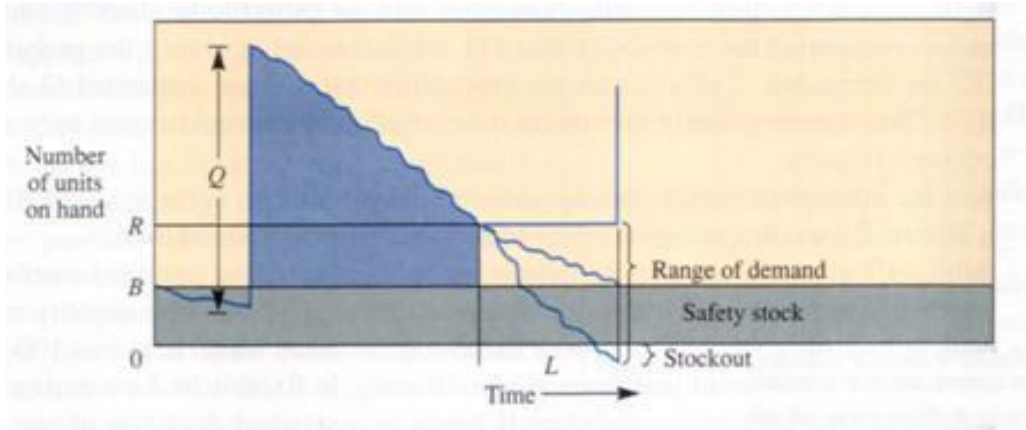
Figure II-6, Determination of Reorder Point [4]

The amount of safety stock depends on the service level desired, as previously discussed. The quantity to be ordered, Q, is calculated in the usual way considering the demand, shortage cost, ordering cost, holding cost, and so forth. A fixed-order quantity model can be used to compute Q such as the simple Q_{opt} model previously discussed. The reorder point is then set the cover the expected demand during the lead time plus a safety stock determined by the desired service level. Thus, the key difference between a fixed-order quantity model, where demand is known and one where demand is uncertain is in computing the reorder point. The order quantity is the same in both cases. The uncertainty element is taken into account in the safety stock.

The reorder point is

$$R = \bar{d}\,L + z\sigma_L$$

The term $z\sigma_L$ is the amount of safety stock. Note that if safety stock is positive, the effect is to place reorder sooner. That is, R without safety stock is simply the average demand during the lead time. If lead time usage was expected to be 20, for example, and safety stock was computed to be 5 units, then the order would be placed sooner, when 25 units remained. The greater the safety stock, the sooner the order is placed.

Computing $\bar{d}$, σ_L and z: Demand during the lead time to receive a replenishment order is really an estimate or forecast of what is expected. It may be a single number (for example, if the lead time is a month, the demand may be taken as the previous year's demand divided by 12), or it may be a summation of expected demands over the lead time (such as the sum of daily demands over a 30-day lead

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time). For the daily demand situation, d can be a forecasted demand using any of the models on forecasting. For example, if a 30-day period was used to calculate d, then a simple average would be where n is the number of days.

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n} = \frac{\sum_{i=1}^{30} d_i}{30}$$

Equation II-6, Daily Average Demand

The standard deviation of the average đ is:

$$\sigma_d = \sqrt{\frac{\sum_{i=1}^{n} \left(d_i - \bar{d} \right)^2}{n}} = \sqrt{\frac{\sum_{i=1}^{30} \left(d_i - \bar{d} \right)^2}{30}}$$

Equation II-7, Standard deviation of Daily Average Demand [4]

Since refers to one day, if lead time extends over several days we use the statistical premise that the standard deviation of a series of independent occurrences is equal to the square root of the sum of variances. That is, in general,

$$\sigma_s = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + ... + \sigma_i^2}$$

Equation II-8, Sum of the variances of Standard deviation of Daily Average Demand [4]

For example, suppose we computed the standard deviation of demand to be 10 units per day. If our lead time to get an order is five days, the standard deviation for the five-day period, since each day can be considered independent, is

$$\sigma_s = \sqrt{10^2 + 10^2 + 10^2 + 10^2 + 10^2} = 22.36$$

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Next we need to compute z, it is done by computing E(z), the number of units short that meets our desired service level, and then looking this up in following table for the appropriate z.

Figure II-7, Expected number of stock versus the standard deviation [4]

E(z)	z	E(z)	z	E(z)	z	E(z)	z
4.500	-4.50	2.205	-2.20	0.399	0.00	0.004	2.30
4.400	-4.40	2.106	-2.10	0.351	0.10	0.003	2.40
4.300	-4.30	2.008	-2.00	0.307	0.20	0.002	2.50
4.200	-4.20	1.911	-1.90	0.267	0.30	0.001	2.60
4.100	-4.10	1.814	-1.80	0.230	0.40	0.001	2.70
4.000	-4.00	1.718	-1.70	0.198	0.50	0.001	2.80
3.900	-3.90	1.623	-1.60	0.169	0.60	0.001	2.90
3.800	-3.80	1.529	-1.50	0.143	0.70	0.000	3.00
3.700	-3.70	1.437	-1.40	0.120	0.80	0.000	3.10
3.600	-3.60	1.346	-1.30	0.100	0.90	0.000	3.20
3.500	-3.50	1.256	-1.20	0.083	1.00	0.000	3.30
3.400	-3.40	1.169	-1.10	0.069	1.10	0.000	3.40
3.300	-3.30	1.083	-1.00	0.056	1.20	0.000	3.50
3.200	-3.20	1.000	-0.90	0.046	1.30	0.000	3.60
3.100	-3.10	0.920	-0.80	0.037	1.40	0.000	3.70
3.000	-3.00	0.843	-0.70	0.029	1.50	0.000	3.80
2.901	-2.90	0.769	-0.60	0.023	1.60	0.000	3.90
2.801	-2.80	0.698	-0.50	0.018	1.70	0.000	4.00
2.701	-2.70	0.630	-0.40	0.014	1.80	0.000	4.10
2.601	-2.60	0.567	-0.30	0.011	1.90	0.000	4.20
2.502	-2.50	0.507	-0.20	0.008	2.00	0.000	4.30
2.403	-2.40	0.451	-0.10	0.006	2.10	0.000	4.40
2.303	-2.30	0.399	0.00	0.005	2.20	0.000	4.50

Suppose we wanted a service level of P, (For example, P might be 95 percent). In the course of a year we would be short (1- P) D units, or 0.05D, where D is the annual demand. If we ordered Q units each time, we would be placing D/Q orders per year. Figure II-6 is based on $\sigma_L = 1$. Therefore, any E(z) that we read from the table needs to be multiplied by σ_L if it is other than 1. The number of units short per order, therefore, is E(z) σ_L. For the year, the number of units short is E(z) σ_L D/Q. Stated again, we have,

$$
\begin{array}{ccccccc}
\text{Percentage} & & \text{Annual} & & \text{Number} & & \text{Number of} \\
\text{Short} & \text{x} & \text{Demand} & = & \text{Short per} & \text{x} & \text{Orders per} \\
& & & & \text{Order} & & \text{year}
\end{array}
$$

$$(1-P)\times D = E(z)\sigma_L \times \frac{D}{Q}$$

Equation II-9, Equation of Total number of shortages [4]

which simplifies to

$$E(z) = \frac{(1-P)Q}{\sigma_L}$$

Equation II-10, Number of shortages per order [4]

Note that D (annual demand) drops out of Equation II-10. This is because E(z) is the number short each order cycle. (There are D/Q cycles per year.)

II.5.1.4 Basic Economic Order Quantity Model with volume discounts

Price - break models deal with the fact that generally the selling price of an item vary with the order size. This is a discrete or step change rather than a per unit change. For example wood screws may cost $0.02 each for 1 to 99 screws $1.60 per 100, and $13.50 per 1,000. To determine the optimal quantity of any item to order, we simply solve for the economic   order quantity for each price and at the point of price change. But not all the economic order quantities determined by the formula are feasible. In the wood screw example, the Q_{opt} formula might tell us that the optimal decision at the price of 1.6 cents is to order 75 screws. This would be impossible, however, because 75 screws would cost 2 cents each.

The total cost for each feasible economic order quantity and price break order quantity is tabulated, and the Q that leads to the minimum cost is the optimal order size. If holding cost us based on a percentage of unit price, it may not be necessary to compute economic order quantities at each price. Procedurally, the largest order quantity (lowest unit price) is solved first; if the resulting Q is valid, that is the answer. If not the next largest quantity (second lowest price) is derived. IF that is feasible, the cost of this Q is compared to the cost of using the order quantity at the price break above, and the lowest cost determines the Q [4].
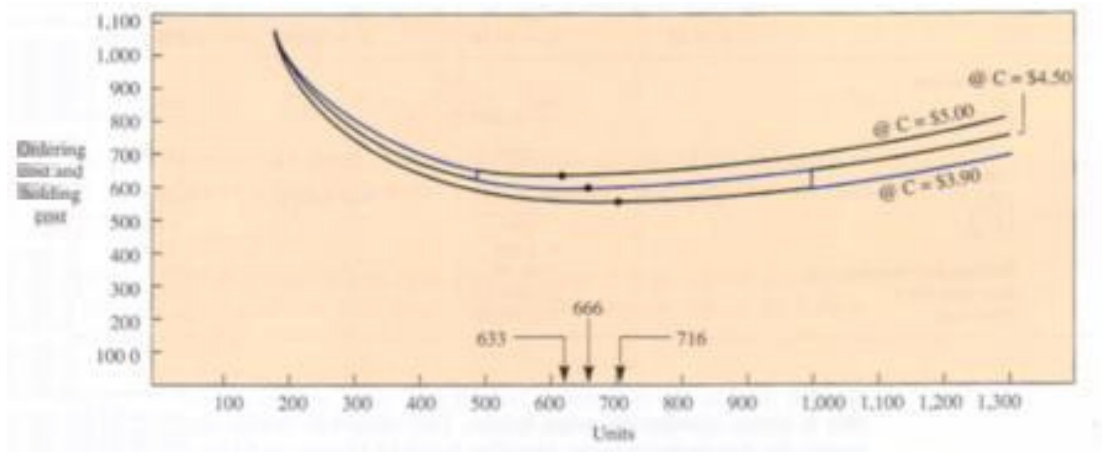
Figure II-8, Figure Units versus Holding and ordering costs [4]

EXAMPLE

Consider the following case, where:

D = 10, 000 units (annual demand)

S = $20 to place each order

i = 20 percent of cost (annual carrying cost, storage, interest, obsolescence, etc.)

C = Cost per unit (According to the order size; orders of 0 to 499 units, $5.000 per unit; 500 to 999, $4.50 per unit; 1,000 and up, $3.90 per unit)

What quantity should be ordered? [4]

Solving for the economic order size at each price, we obtain.

@C = $5.00, Q = 633

@C = $4.50, Q = 666

@C = $3.90, Q = 716

In Figure II-8, which displays the cost relationship and order range, note the most of the order quantity –cost relationship lie outside the feasible range and only a single, continuous range results. This should be readily apparent since, for example, the first order quantity specifies buying 633 units at 55.00 per unit. However, if 633 units are ordered, the price is $4.50, not $5.00. The same holds true for the third order quantity, which specifies an order of 716 units at $3.90 each. This $3.90 price is not available on orders of less than 1,000 units.

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Figure II-9 itemizes the total costs at the economic quantities and at the price breaks. The optimal order quantity is shown to be 1,000 units.

Figure II-9, Relevant Costs in a Three-Price-Break Model [4]

	$Q = 633$ where $C = \$5$	$Q = 666$ where $C = \$4.50$	$Q = 716$ where $C = \$3.90$	Price Break 1,000
Holding cost $\left(\frac{Q}{2}iC\right)$		$\frac{666}{2}(0.20)4.50$ $= \$299.70$		$\frac{1,000}{2}(0.20)3.90$ $= \$390$
Ordering cost $\left(\frac{D}{Q}S\right)$	Not feasible	$\frac{10,000(20)}{666}$ $= \$300$	Not feasible	$\frac{10,000(20)}{1,000}$ $= \$200$
Holding and ordering cost		$\$599.70$		$\$590$
Item cost (DC)		$10,000(4.50)$		$10,000(3.90)$
Total cost		$\$45,599.70$		$\$39,590$

One practical considering in price-break problems is that the price reduction from volume purchases frequently makes it seemingly economical to order amounts larger than the Q_{opt}. Thus when applying the model we must be particularly careful to obtain a valid estimate of product obsolescence and warehousing costs.

We see that order quantities are solved from the lowest unit price to the highest, until a valid Q is obtained. Then the order quantity at each price break above this Q is used to find which order quantity has the least cost – the computed Q or the Q at one of the price breaks.

$$TC = DC + \frac{D}{Q}S + \frac{Q}{2}iC$$

$$Q = \sqrt{\frac{2DS}{iC}}$$

Equation II-11, Derivation of Economic Order Quantity from the model with shortages allowed [4]

II.5.2 Fixed Time Period Models

In a fixed time period system, inventory is counted only at particular times such as every week or every month. Counting inventory and placing orders on a periodic basis is desirable in situations such as when vendors make routine visits to customers and take orders for their complete line of products, or when buyers want to

combine orders to reduce transportation costs. Other firms operate on a fixed time period to facilitate planning their inventory count: For example distributor X calls every two weeks and employees know that all Distributor X's product must be counted.

Fixed time period models generate order quantities that vary from period to period depending on the usage rates. These generally require a higher level of safety stock than a fixed order quantity system. The fixed order quantity system assumes continual counting of inventory on hand, with an order immediately placed when the reorder point in reached. In contrast, the standard fixed time period models assume that inventory is counted only at the time specified for review. Is it possible that some large demand will draw the stock down to zero right after an order is placed? This condition may not be noticed until the next review period. Then the new order, when placed, still takes time to arrive. Thus it is possible to be out of stock throughout the entire review period, T, and order lead time, L. Safety stock, therefore, must protect us against stockout during the review period itself as well as during the lead time from order placement to order receipt.

In a fixed time period system, reorders are placed at the time of review (T), and the safety stock that must be reordered is
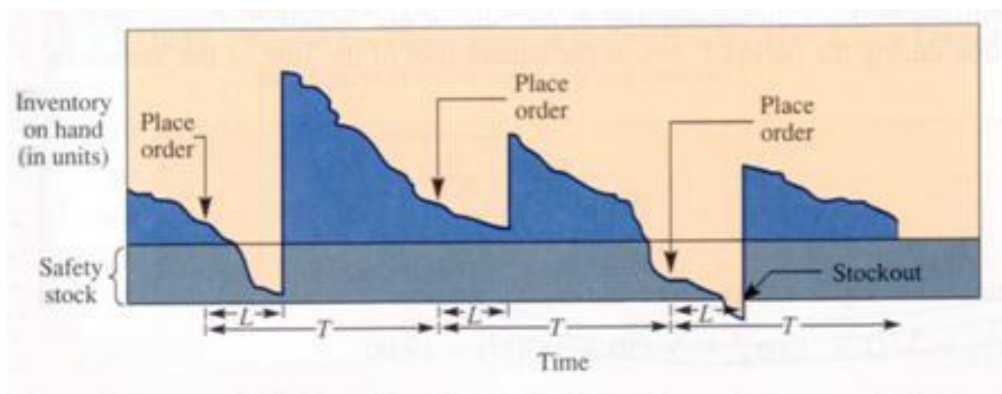
$$\text{Safety stock} = z\sigma_{T+L}$$

Figure II-10, Fixed time period system [4]

Figure II-10 shows a fixed time period system with a review cycle of T a constant lead time of L. In this case, demand is randomly distributed about a mean $\overline{d}$. The quantity to order, q, is:

Order Quantity	=	Average demand over the vulnerable period	+	Safety Stock	-	Inventory currently on hand (plus on order, if any)

$$q = \overline{d}(T + L) + z\sigma_{T+L} - I$$

Equation II-12, Order Quantity based on Fixed Time Period Models [4]

The demand, lead time, review period, and so forth can be any time units such as days, weeks, or years so long as it is consistent throughout the equation.

In this model, demand $\overline{d}$ can be forecast and revised each review period if desired, or the yearly average may be used if appropriate.

The value of z can be obtained by solving the following equation for E(z) and reading the corresponding z value from the related table:

$$E(z) = \frac{\overline{d}T(1-P)}{z\sigma_{T+L}}$$

Equation II-13, Number of shortages per order based on Fixed Time Period Models [4]

II.5.3 ABC Inventory Planning

Maintaining inventory through counting, placing orders, receiving stock and so on takes personnel time and cost money. When there are limits on those resources, the logical move is to try to use the available resources to control inventory in the best way. In other words, focus on the most important items in inventory.

In 19th century, Vilfredo Pareto, in a study of the distribution of wealth in Milan, found that 20 percent of the people controlled 80 percent of the wealth. This logic of the flew having the greatest importance and the many having little importance

has been broadened to include many situations and is termed the Pareto Principle. This is true in our everyday lives (most of our decisions are relatively unimportant, but a few shape our future) and is certainly true in inventory systems (where a few items account for the bulk of our investments)

Any inventory system must specify when an order is to be placed for an item and how many units to order. Most inventory control situations involve so many items that it is not practical to model and give thorough treatment to each item. To get around this problem, the ABC classification scheme divides inventory items into three groupings: high dollar volume (A), moderate dollar volume (B) and lower dollar volume (C). Dollar volume is a measure for the importance; an item low in cost but high in volume can be more important than a high cost item with low volume.

ABC Classification

If the annual usage of items in inventory is listed according to dollar volume, generally the list shows that a small number of items account for a large dollar volume and that a large number of items account for a small dollar volume. Figure II-11 illustrates the relationship.

Figure II-11, Annual Usage of Inventory by Value [4]

Item Number	Annual Dollar Usage	Percentage of Total Value
22	$ 95,000	40.8%
68	75,000	32.1
27	25,000	10.7
03	15,000	6.4
82	13,000	5.6
54	7,500	3.2
36	1,500	0.6
19	800	0.3
23	425	0.2
41	225	0.1
	$ 233,450	100.0%

Figure II-12, ABC Grouping of Inventory Items [4]

Classification	Item Number	Annual Dollar Usage	Percentage of Total
A	22, 68	$ 170,000	72.9%
B	27, 03, 82	53,000	22.7
C	54, 36, 19, 23, 41	10,450	4.4
		$ 233,450	100.0%

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The ABC approach divides this list into three groupings by value. "A" group items constitute roughly the top 15 percent of items, "B" group items the next 35 percent, and "C" group items the last 50 percent.

From observation it appears that the list in Figure II-11 may be meaningfully grouped with A including 20 percent (2 of 10), B including 30 percent, and C including 50 percent. These points show clear delineations between sections. The result of this segmentation is shown in Figure II-12.

Segmentation may not always occur so neatly. The objective, though, is to try to separate the important from the unimportant. Where the lines actually break depends on the particular inventory under question and on how much personnel time is available. (With more time, a firm could define larger A or B categories.)

The purpose of classifying items onto groups is to establish the appropriate degree of control over each item. On a periodic basis, for example class "A" group items may be more clearly controlled with weekly ordering. "B" group items may be ordered biweekly and "C" group items may be ordered monthly or bimonthly. Note that the unit cost of items is not related to their classification. An A item may have high dollar volume through a combination of either low cost and high usage or high cost and low usage. Similarly, C items may have a low dollar volume because of either low demand or low cost. In an automobile service station, gasoline would be an A item with daily or weekly tabulation; tires, batteries, oil grease, and transmission fluid may be B items and ordered every two or four weeks and C items would consist of valve stems, windshield wiper blades, radiator caps, fan belts, oil and gas additives, car wax and so forth. C items may be ordered every two or three months or even be allowed to run out before reordering since the penalty for stockout is not serious.

Sometimes an item may be critical for systems if its absence creates a sizable loss. In this case, regardless of item's classification, sufficiently large stock should be kept on hand to prevent runout. One way to ensure closer control is to designate this item an A or B, forcing it into the category even if its dollar volume does not warrant such inclusion [4].

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CHAPTER III. LITERATURE REVIEW

As we mention in this study, simulation based approaches are rare in the both academic publications and practical implementations, though we had discussed some of the existing simulation studies published or presented before in the conferences or academic meetings. Most of the published studies subjected "Supply Chain Management" problems but they could not pass the "Inventory Management" base without saying a word about it.

In this chapter, we discuss the priorly mentioned requirements of simulation aided systems and their strategic importance under 5 different sections:

- Importance of Simulation
- Cost Reduction
- Strategic Behaviour
- Model Development
- Base Model – Target Model Comparison

III.1. IMPORTANCE OF SIMULATION

Since one of the objectives of our study is to build a simulation application which uses superimpose technique to compare the reference model and the target model, simulation is the focus point. There may be lots of lists of importance subjects telling about where the simulation lies;

- Simulation is cost effective.
- Simulation and real-case restrictions are nearly same.
- The success rate of simulation softwares is good enough.
- Etc…

According to Dong Won Yi, Soung Hie Kim, Nak Hyun Kim [26] there is a growing need for simulation in some types of industries;

"… the harbor and maritime industry has been an area for simulation. Due to the costs and complexity of both harbors and vessels, the use of simulation has been

justifies in this area from many years. There is a wide range of papers [14, 16] devoted to different aspects of harbor container terminal simulation. However, there is growing need in developing global supply chain perspectives for the management and control of harbor and maritime transportation." [26].

We enlarge the subjects of occurrences of this need and say that simulation is a key enabler of strategic competency. Therefore not for only the supply chain management systems but all types of operations management problems need to be solved according to the appropriate models supported by "Decision Support Systems" applications.

Since simulation is such a powerful tool in the practical life, academicians, students and employees can not use this tool effectively due to lack of habit and information about the building algorithms and rules of this tool. "James A. Pope" [18] indicates this lack in his valuable paper;

"…An important part of courses in quantitative methods is helping students gain an intuitive feeling for formulation structures and solution techniques. The Inventory Management Simulation (IMS) program is designed to allow students to manage a simulated inventory interactively. The computer generates random demands and keeps the inventory records for the student who selects and applies the appropriate inventory policy. The student thus experiences what he has learned from the equations and formulas in inventory theory. We also have found IMS to be an excellent bridge between the subjects of inventory models and simulation.

The purpose of simulation and gaming in the pedagogical setting is to give students the chance to apply theories and techniques learned in the classroom. In business oriented simulations, especially those involving quantitative techniques, it is often difficult to isolate the decision making process from the mechanics of the simulation. This is particularly true with inventory simulations because of the amount of bookkeeping required for inventory management." [18].

In our study the main objective is to develop a simulation to realize the "Model Performance Analysis" using superimpose technique. As an addition to this feature simulation can be a strategic vision implementing tool which manages the

relationships between the customers, vendors and our company. C. Ann Goodsell, Thomas J. Van Kley [22] explains the situations simulation might be performed;

"…Simulations are performed in two different situations. One of these situations is a consulting engagement or proposal development phase for potential clients (Figure 3). During this phase Cat Logistics acquires an understanding of the market and business goals from the client, and then designs the best network utilizing simulation / modeling tools.
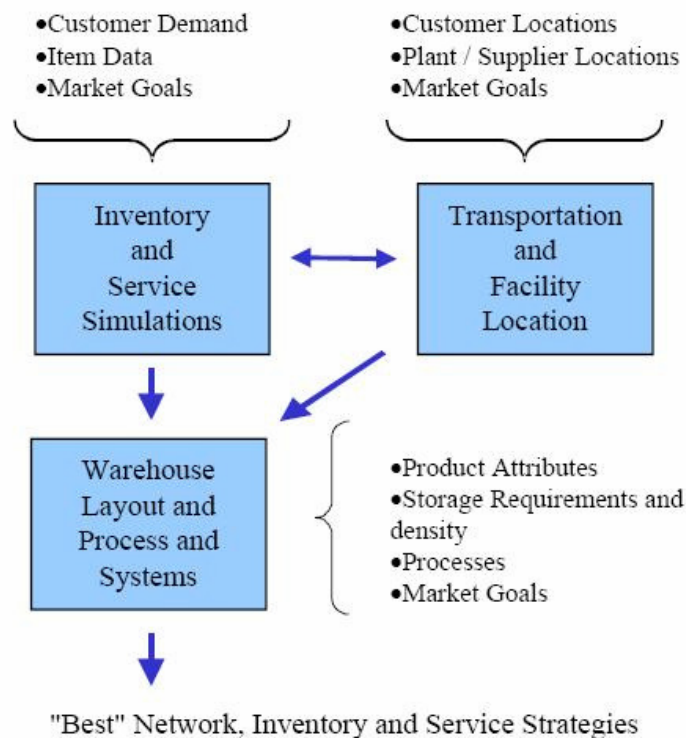
Figure III-1: Network planning and design

The second situation in which inventory simulations are performed is for ongoing client support. To ensure customer service and inventory objectives are being met, inventory managers support the client by monitoring performance in several ways, including:

Using the online / real time backorder analysis Supply Chain Performance Management (SCPM) tool. SCPM identifies customer sales order lines not satisfied and determines specific reasons for the service losses, allowing inventory managers to take appropriate action on the areas of greatest concern.

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Reviewing key statistics regularly to determine if a change in the business environment has dictated a change in user parameters to achieve client goals.

Reviewing operational reports that track inventory, purchase orders, demand forecasts and other statistics. Through monitoring, inventory managers may propose strategy enhancements to the client. Additionally, the client may request changes to service strategies or may want to test the effects of proposed changes prior to installation. Examples of such changes include:

- *Revising service targets*
- *Revising inventory targets*
- *Changing stocking policies*
- *Varying receipt volumes*
- *Introducing new products*
- *Increasing / decreasing the number or scope of warehouses*
- *Increasing / decreasing manufacturing / vendor lead times*
- *Changing minimum buy policies*
- *Changing costs.*

Simulations allow inventory managers to evaluate results of these and other strategies prior to implementation, saving time and money. This on going support process typically spans 1 to 2 months and greatly reduces risks associated with change." [22].

III.2. COST REDUCTION

In this type of publications authors try to compare their studies with a reference study based on a "Key Performance Indicator" (KPI). This study relies on a comparison based on the costs of the "Inventory Control Models". An application is coded to use a graphical user interface to let the users decide what type of changes occurs while the users evaluate their mathematical models with different types of parameters. This graphical user interface creates graphics using superimpose technique to show how product quantities and costs are varies.

Additionally there must be said that cost reduction is a method which has strategic importance against the managerial departments. Also informational

developments are driving the competition to higher levels as subjected in A. Muriel, A. Somasundaram and Y. Zhang [16];

"…Recent developments in communications and production technologies are making it possible for companies to offer high product variety at low cost while providing high service levels and on-time delivery performance." [16]

Inventory Management Systems are born because the companies need to beat the rivals in the sector and they need to have a view point different then the others may have. Holding costs and ordering costs are the very first parameters which are distinguished. Donna L. Retzlaff-Roberts, Mohammad Amini [21] tells us the situation;

"…Many organizations have wrestled with the issues of inventory locations and stocking levels. When it is critical to have inventory available for customers, the traditional approach has been to place a large amount of inventory at all locations. Carrying an excessive amount of inventory achieves a high service level, but can be enormously costly, especially if the product has a high cost per unit." [21]

All different then these decisions there are some traditional behaviours that organizations tend to behave like and in spite of the existence of this critical fact Donna L. Retzlaff-Roberts, Mohammad Amini [21] do not hesitate to indicate that;

"All too often organizations underestimate the cost of carrying inventory." [21]

In today's competitive markets, all the costs have fatal importance and the organizations which have the ability to reduce these costs will increase their competency in against its rivals. C. Ann Goodsell, Thomas J. Van Kley [22] indicates this important fact as;

"…Traditionally, providing high levels of item availability / service to customers means boosting inventory investments. To avoid expensive stock out situations, many firms keep a large bank of inventory on hand to fill customer orders.

The Cat Logistics approach allows companies to step beyond traditional inventory management. Upon implementation of the initial strategies developed through simulation, clients realize improved customer service in the form of increased service levels while inventory investment and other distribution costs decrease." [22]

III.3. STRATEGIC BEHAVIOUR

One of the main features of our application is it lets the orgarnisations to know how to respond sudden economic changes immediately. It manages this development path with "Knowledge Management" studies. Orgarnisational knowledge and experience is the main factor to understand the reactions and responses of individuals and organizations itself. It is also a strategic behaviour since it is mentioned by Dong Won Yi, Soung Hie Kim, Nak Hyun Kim [26];

"In order to sustain competitive advantage, it is not enough to construct efficient supply chains. They must have the flexibility to modify and redesign their supply chains to respond to sudden economic changes." [26]

As JIT like systems have a rise, it becomes more and more obvious not to have so much holding cost for inventory. A. Muriel, A. Somasundaram and Y. Zhang [16] explains this need with the following paragraph:

"…In a pure make-to-order system, the firm holds no final goods inventory. However, it does need to keep inventory of components with long lead times to cope with the variability in consumer demands and ensure timely delivery. In addition, the firm can invest in flexible capacity to accommodate this variability." [16]

"…We model such a system and develop an optimization-based simulation tool to analyze the impact of different levels of flexible capacity on system performance at the operational level. Our objective is to provide valuable managerial insights and a support tool to guide the decision making process of a firm in planning the extent to which it should invest in flexible capacity and in deciding how flexibility should be managed later." [16]

"Being at the right place, at the right time!" this phrase is the most important vision that an organization must have. James A. Pope[18] tells about it as the following:

"…In today's increasingly competitive marketplace organizations can not afford to carry excessive levels of inventory. At the same time customer service, which includes having the product available for the customer at the right place and the right time, is increasingly important. To balance these two issues it is critical for an organization to set a service level goal and strategically plan their inventory logistics to achieve this goal at minimum cost." [18]

As a brief explanation of the traditional systems KRISZTIÁN BÓNA[11] indicates the strategies of them as;

"The job of the simulator of the inventory mechanisms is the simulation of the operation of the inventory system by the specified inventory mechanism using the data contained in the input database of simulation. In case of the application of classical inventory mechanisms this can involve the following strategies (CHIKÁN[2]):

- *[t; q] placing fixed orders (q) in fixed intervals (t);*
- *[t; S] placing orders in fixed intervals (t) and ordering such a quantity, which – when received – completes the stock level to a previously specified maximum level (S);*
- *[s; q] the order should be placed, when the stock level falls below a specified minimum (s) and the quantity to be ordered is fixed (q);*
- *[s; S] the order should be placed, when the stock level falls below a specified minimum (s) and the order specifies a volume, which – when received – completes the stock level to a previously specified maximum level (S)."* [11]

These strategies have some restrictions due to the nature of the traditional inventory control methods. In order to avoid from the effects of these restrictions the role of the simulation is inevitably usable. This is mentioned in the Köchel, Peter; Nieländer, Ulf[12] as;

"Multi-location inventory models are one of the most widely investigated fields in mathematical inventory theory, but the analytically tractable models suffer from various restrictive assumptions. To overcome these restrictions simulation can be used. However, simulation itself is not an optimisation approach. Therefore, we propose the simulation optimisation approach where a simulator is combined with an appropriate optimisation tool." [12]

III.4. MODEL DEVELOPMENT

Continues model development is one of the main features of this study. While simulating the results of the being developed model, it is very easy to see and change the value of the parameters according to the usage of the parameter in the mathematical modeling. This drives the organizations learn how the parameters change and affect the costs and quantities of the inventory items. This is a way which

organizations may increase their knowledge against their internal processes and organizational behaviours. A. Muriel, A. Somasundaram and Y. Zhang [16] explain as:

"As the pressure mounts to give consumers exactly what they want, where they want it, when they want it and at a competitive price, many firms, whose production has traditionally been driven by demand forecasts, are looking for ways to move from predominantly make-to-stock to make-to-order systems (Bish et al. (2001))." [16]

III.5. BASE MODEL – TARGET MODEL COMPARISON

"Model Performance Analysis" is one of the key points of this study. The application lets the users develop their mathematical models step by step as they compare it with a reference model which it is again a mathematical model. As it may be seen in the references model comparison applications are rare especially in the inventory management subject. Some simulation studies exist but these are mainly targets the "Supply Chain Management" field as it is more popular then ever.

But Heikki Rasku, Juuso Rantala, Hannu Koivisto [19] have created a study that performs a model comparison implementation against "Inventory and Supply Chain Management". They explain their study as:

"A method of model reference control is investigated in this study in order to present a more suitable method of controlling an inventory or a supply chain. The problem of difficult determining of the cost of change made in the control in supply chain related systems is studied and a solution presented. Both model predictive controller and a model reference controller are implemented in order to simulate results. Advantages of model reference control in supply chain related control are presented. Also a new way of implementing supply chain simulators is presented and used in the simulations." [19]

Consequently, as it may seen, there is not so many studies either in simulation field although it is a strategic and successful tool, or in the model comparison and continues model development fields. This study aims to close this hole as it successfully implements the "Superimpose Technique" and "Model Performance Analysis".

CHAPTER IV. IMPLEMENTATION OF INVENTORY MANAGEMENT SYTEMS

IV.1. CURRENT STATUS AND DEFICIENCIES

IV.1.1. Factors affecting Inventory Management Systems

IV.1.1.1 Organizational Departments

Inventory Management, as discussed before, is one of the first steps of pre-defined processes (the steps after Sales Forecast) occurred in the enterprise. This feature brings a relative superior position on controlling of the measures that have been taken as basis to analyse the whole flow performance.

In this respect, "Inventory Management System" (IMS) should be taken as a structure of input and output which has own operational mentality.

Figure IV-1, Inventory Management System as a system

This system can be shown in Figure IV-2 according to Total Quality Management:

Figure IV-2, Inventory Management System from the TQM point of view

Inner suppliers, in short, are the units that provide data, information, product, semi-product etc. to company's inner customers in a process.

According to these figures, we can show that IMS gets data from Sales Forecast, Production and Production Control departments and send data and information to Purchase and Supply, Sales and Distribution departments.
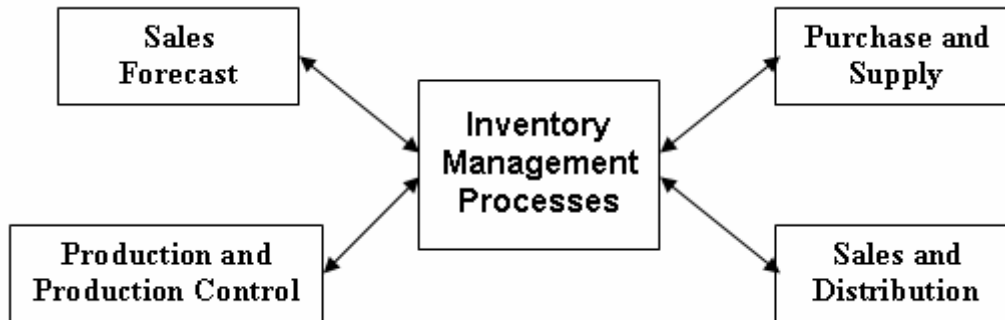

Figure IV-3, Relationship between "Inventory Management System" and other systems

As shown in the Figure IV-3, there is an interaction in both ways between departments.

IV.1.1.2 Costs

In daily life, companies, non-profit organizations and humans try to realize an engineering principle real without being aware of it:

Gaining the most by spending the least.

Costs may be related to resource usage percentages in this formula as well as other factors such as time.

Let us remember the proof here which was made while Simple EQM was introduced:

Total Cost = Holding Cost + Ordering Cost
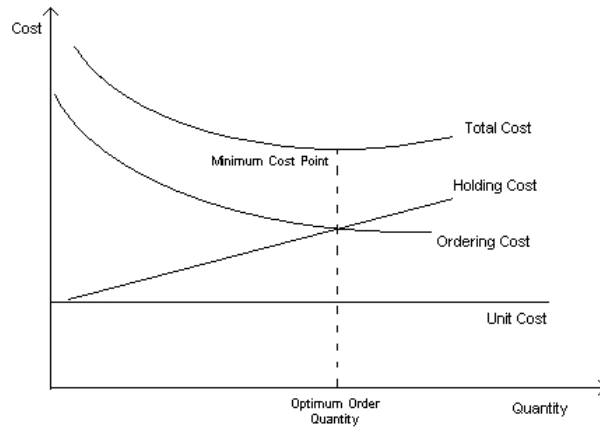
www.manaraa.com

Figure IV-4, The relationship of cost parameters

In the Figure IV-4, total cost is on its lowest position when the sum of Inventory Cost and Ordering Cost are at their minimums. This is a mathematical principle and it can be described as below:

There are 3 possibilities to supply a request of 100 units of product:

- Ordering 100 units in once and storing them
- Ordering the same quantity of request as they appeared (JIT type systems)
- Arranging stock-order rates so that the costs will be minimum

The first possibility, as shown in Figure IV-5, means an increase on inventory cost. In this option, "Total Cost" equals to "Inventory Cost" and a decrease on the costs can be gained by strategic administrative decisions according to cost types, not by process based approaches.
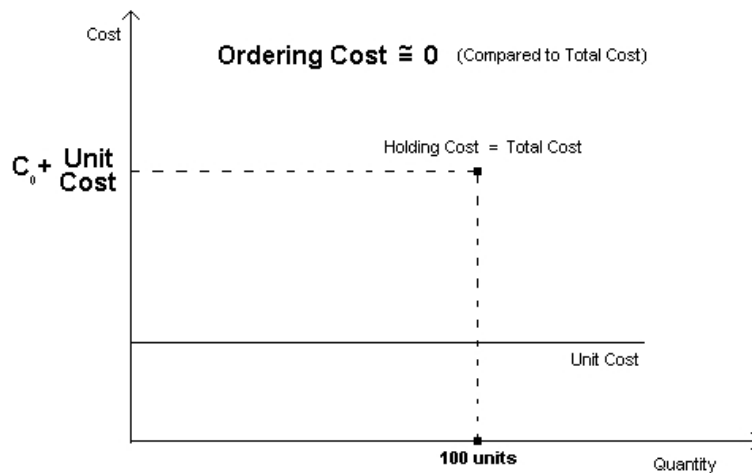

Figure IV-5, Cost relations when ordering the materials at one time

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However, the second option, Figure IV-6, increases the ordering cost while getting the inventory cost near to zero. Here, the total cost is equal to ordering cost. In this option, the decrease on the costs can be realized by administrative decisions just as it is on the former option.
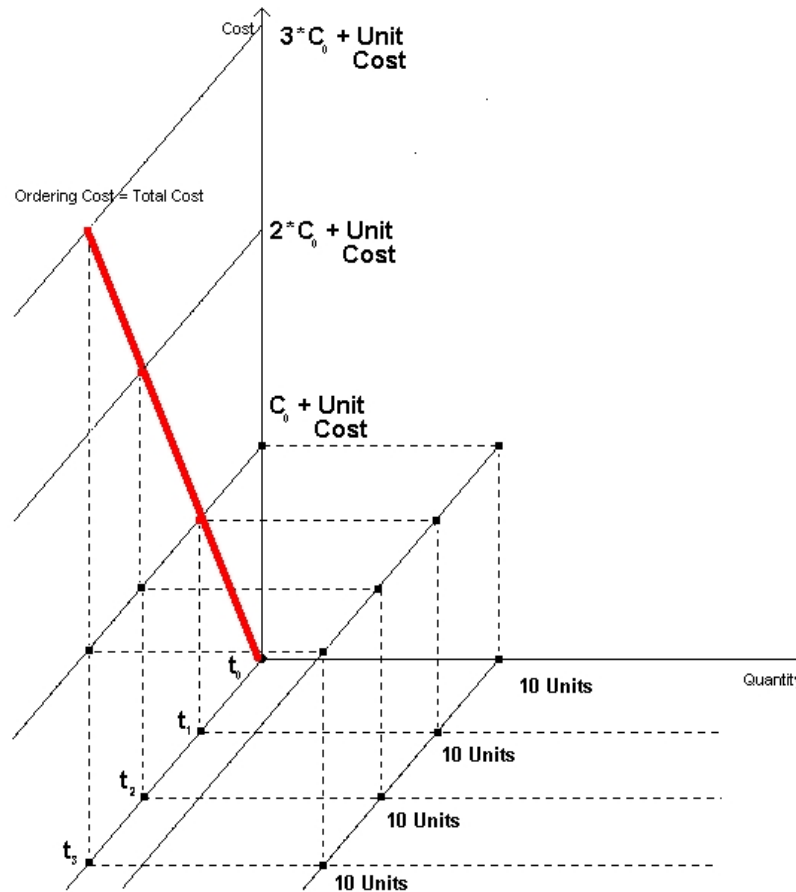

Figure IV-6, Cost relations when ordering the materials when demand arises

The last option, working to find the optimum point according to costs, is just the real life itself. The main subject of our work is to formulize this option.

Here, total cost is equal to sum of inventory cost and ordering cost. Decreasing the costs can be done by determining and also minimizing the mathematical relationship between these two costs. Figure IV-7 shows this relationship.

As described before the lowest point of total cost curve is the one which derivation of the curve equals to zero.
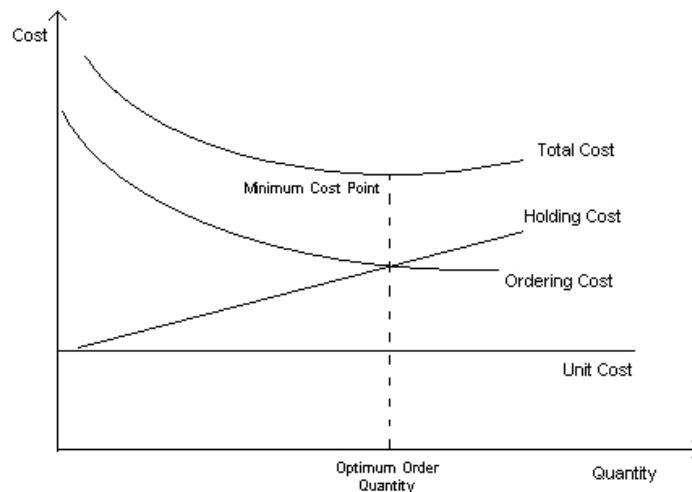
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Figure IV-7, The optimum relationship of cost parameters

$$f(x)' = \left(TC + HC\right)' = 0$$

Equation IV-1, Slope of the curve is equal to zero, minimum cost

This inference brings us to a model which we can minimize our inventory costs against a linear and regular request.

Costs are so important factors of systems; therefore it must be emphasized by the help of costs management [9]:

- Determination of price of the products
- Determination the profitability of the products
- Managing the inventory
- Setting the value of inventory
- Testing the efficiency of the different systems, processes, departments
- Detection of the losses, wastes, scraps

As one of the main factors of this model is our costs, let us try to investigate our costs [7].

- Ordering Costs
  - Unit Cost
    - If the product is produced inside the company:

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- Indirect workmanship
- Direct workmanship
- General Expenses
- Etc.

o If the product is purchased from outside
  - Unit Price

o Supplying (Preparation) Costs
  - Secretaryship
  - Wages
  - Order follow-up costs
  - Ordering costs
  - Taking the products into inventory and locating physically

o Inventory (Holding) Costs
  - Money bounded to inventory costs
  - Keeping the Stock area as empty costs
  - Transportation costs
  - Insurance costs
  - Scrapping costs caused by out-dating of stocking products (See Figure IV-8 to see the importance of the cost of scraps in TOYOTA's production)
  - Quality grow old costs
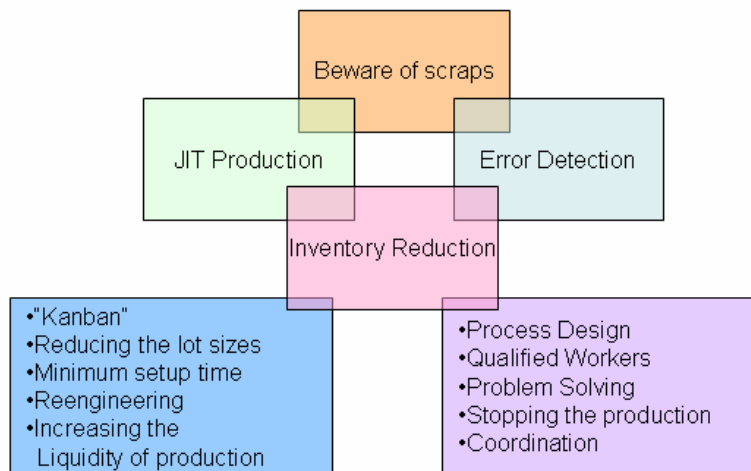 - Inventory recording processes costs

Figure IV-8, Key elements in the production of TOYOTA [8]

- Shortage Costs
  - Overtime costs
  - Administrative costs
  - Speeding up the order costs
  - Cost of losing goodwill because of delay
  - Special carrying and packaging costs
  - Lost of production time costs

Addition to these costs, there may be some other hidden costs related to several factors. For example "Customer Costs". Sometimes, in some companies, some certain customers may require special services, for which they are not charged [23].

As seen, inventory management systems are very sensitive structures. They are affected by many cost factors in the company. That's why the companies whose inventory management systems are working effectively can increase their rivalry capacity to extreme levels.

These cost types may depend on the factors such as product quantity, time, etc. or they can be occured as static parameters in the inventory management systems. Cost parameters described with these properties can be used as parameters to construct companies their own models.

IV.1.2. Symptoms of Problems and Facts

Planning is one of the main subjects which is the cause of the need for industrial engineering. The importance of the planning and the continual reviewing as a result of planning has been perceived better as time passes. Consequently, "System Analysing Approach" became one of the basics of industrial engineering.

This approach, which has been implemented in this project, is used to identify the problems by using "Analysing of Current Situation Method".

IV.1.2.1 Symptoms and Facts

- High Costs

o Increase at fixed costs

o Increase at scrap cost caused by spoiled and wasted materials in the stock.

- Lack of control at transportation and ordering costs.

- Bad timing at responding new orders (Lower service quality)

- There may be lots of different efforts on other processes other then inventory management process in order to increase the revenue, but these efforts worth more then the ones spent on the inventory management systems.

IV.1.2.2 Deficiencies at Current Situation

IV.1.2.2.1. Structural Deficiencies

There are some common technical deficiencies of implementations in the market. Those are called as "Structural deficiencies" in this project.

Structural deficiencies are those which are technically eligible but not have been included in the existing implementation processes. Below are those properties:

- Model Definition:

The main deficiency of existing implementations is that the special inventory management model which is launched by considering the special needs of the organization is not used in the implementation itself. This situation forces us to work with the common mathematical methods by ignoring the differences between organizations' political, geographical, sociological etc. properties.

- Models based on warehouse management:

Implementations usually focus on "Warehouse Management" rather than "Inventory Management". This makes organizations to use reviewing techniques to evaluate the purchasing requests within the inventory management processes. This means it is usually necessary to use a specific model.

One of the most important deficiencies at implementation of these models/systems is the uncertainty at organizations' behaviours.

Uncertainty at organizational behaviours causes disability to react against impacts, thus, organizations can be disabled to take preventive actions.

- Parameter Selection

There are many factors which effect inventory management systems. However, those have different effect scales. As a result of that, some parameters need to be eliminated or included in the system. Besides, the usage of some parameters should be revaluated.

Systems which are mostly used today don't allow that flexibility.

- Comparison of Models

It is hard to mention the comparison of models due to the lack of model definition approach.

To measure the performance of the current method by using quantitative data, enables organizations to define and analyse their own system.

Although those which have been written here are structural deficiencies, are also inadequacies from business perspective.

IV.1.2.2.2. Strategic Deficiencies

- Inventory Management Systems: as a key method to increase the margin of profit.

  Organizations usually don't need to measure the performance of their systems unless inventory management costs are not within the acceptable levels. Therefore, organizations focus on processes which require more resources rather than "Inventory Management Systems" in order to increase the margin of profit. Whereas, a more controlled and efficient "Inventory Management Systems" would lead organizations increase the margin of profit and to a more competitive position with less effort.

- ABC Analyzes as Strategic Material Classification

  Inventory management studies are generally seen as some parts of the valuation studies

For his reason, the importance and the handling methods of inventory levels of the materials in the system are not considered in a realistic way, because the real classification is not known.

For instance, there is a product which its price changes so often because of an inflationist market, if the inventory value of that product is not re-evaluated because of the changes in the inventory valuation classification, the cost of this changes wouldn't be reflected to the cost of the inventory management system correctly. This might cause uncompetitive results for the organization.

- Model Performance Analysis (MPA)

    This property which has been described in the structural deficiencies section has strategic importance for the organizations. Therefore, it should be evaluated under "Strategic Deficiencies" as well.

    Material control/management systems of many organizations are usually based on experience rather than mathematical models. In that kind of organizations, material control/management departments are not in a position to analyse the effects of inventory management system on cost advantages. Organizations usually compare the costs of last two periods and measure performance accordingly.

    When a new model is decided to be implemented, this would cause important changes in the organization and also big costs.

    However, models can be created by using parameters and formulized with the help of the experiences and examines. Therefore the idea of putting the values of the parameters directly in the formula will make cost reflections easy to the overall model in the application.

    The idea we are trying to explain here is this opportunity (yielding the results as product, time interval or cost parameters are changed) which is coming within the application is a significant tool for decision making processes. In the Figure IV-9 stages of the decision making process can be seen. Our study takes place near the DSS balloon, between the managerial and strategic levels of the organization.
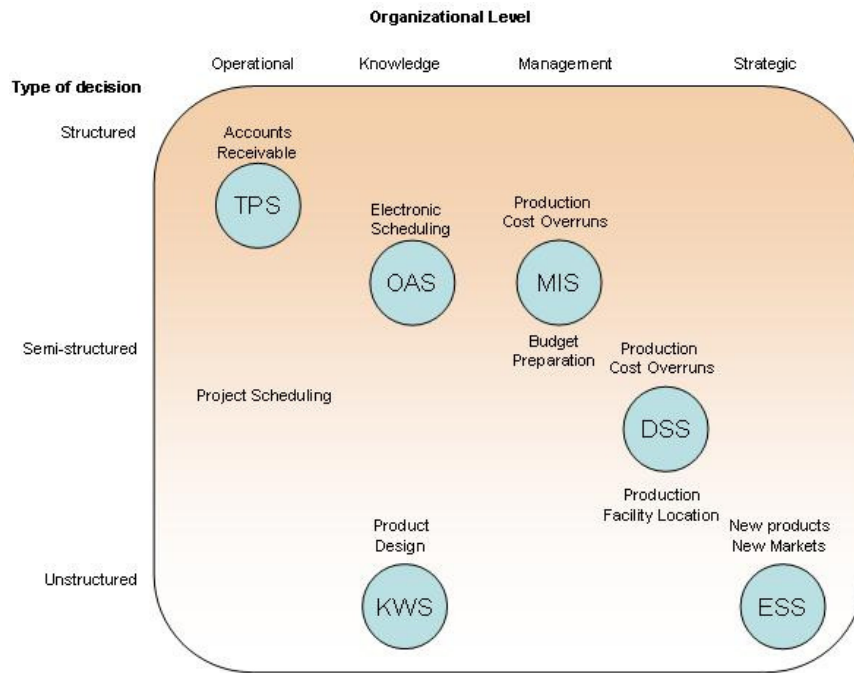
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Figure IV-9, Stages of Decision Making [13]

- Company Specialised Inventory Management Models

    The best model for an organization is the one which has been created with the organization's own experience and knowledge. To measure the performance of models (MPA) would enable the organization to improve cost management. Thus, organization can manage its inventory in different inventory valuation classes during changes at implementations.

    As a result of that, organizations can be dominant in the sector and determine the behaviours in the market.

- Sensitivity Analysis

    Sensitivity analyses which are mostly used in economic analyses are one of the main tools to determine the marginal change quantities.

    The ability of monitoring the quantitative and qualitative effects of parameters at periodic and total costs is a big advantage from business perspective.

IV.1.3. Problem Description

Regarding to the symptoms, defined facts; the Current situation can be described as:

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Companies are;

- Using empiric methods for inventory management.
- Not adopting a predefined inventory management model or system
- Not rapidly reacting to inventory cost changes
- Making cost analysis regularly and those analyses create their own problems.
- Can not choose the suitable inventory models for them.
- Can not make parametric inventory management model designs.
- Face with difficulties in comparing the model performances by quantitative measures (like cost)
- Are not being able to perform sensitivity analysis against the models.

IV.2. OBJECTIVES OF THE PROJECT

IV.2.1. Results aimed to be reached

- Creating a Methodology

One of the most important aims of our study is to create a complementary flow which can be shown as a method which can be followed up while starting an inventory management project. The basic components of the methodology are "System analysis" (Figure IV-10) and "Continuous development" (Figure IV-11).
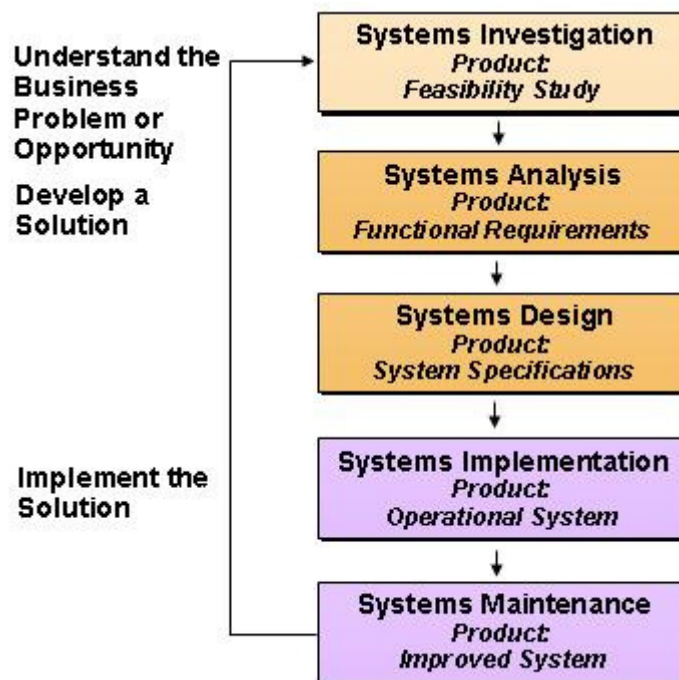

Figure IV-10, The System Analysis Life Cycle [4]

This methodology includes the steps of identification of "Inventory valuation classes", cost analysis, model preparation and structuring the inventory management system with strategic decision making of the company.

The explained part through this paragraph is realized with the help of "System analysis".

After this point it is described using "Continuous Development" perspective- generally is being told about software development. But here it will be used to explain the "Continues Improvement" of the systems. This process includes the questions; what is the compatibility of the system and the company, and how it increases the efficiency of the model.
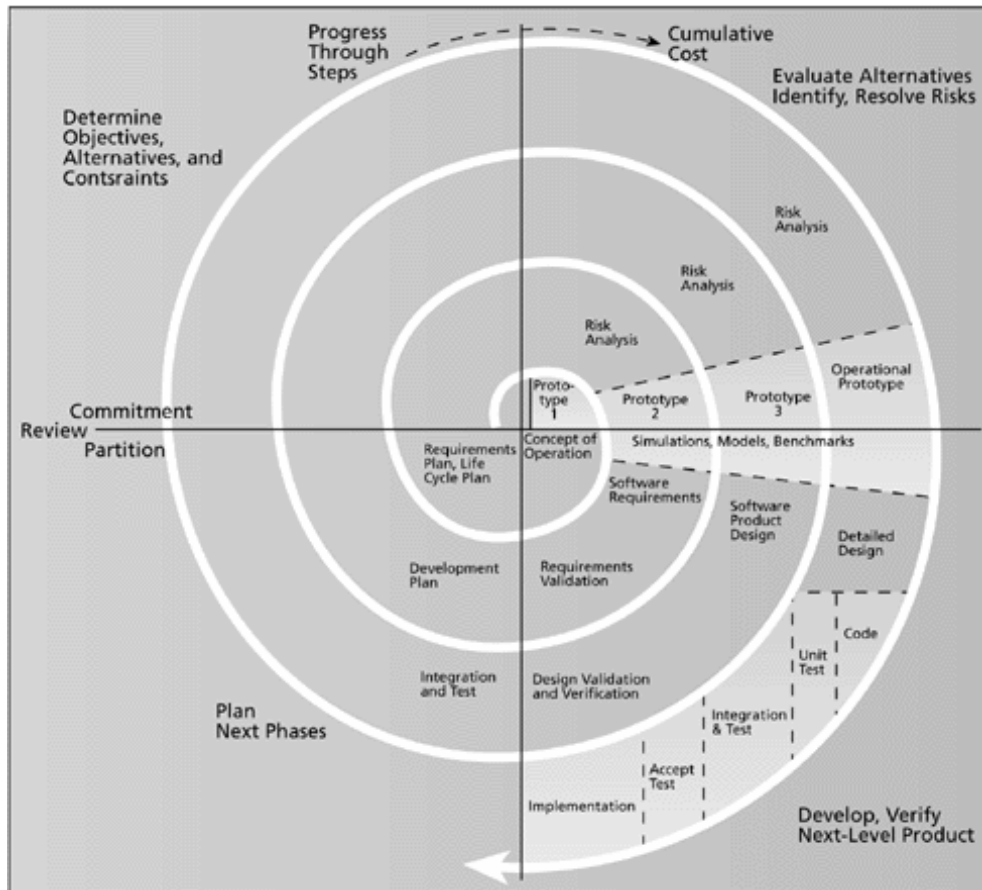
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Figure IV-11, The Spiral Method for Continues Improvement [24]

- Applying the model approach in Inventory management

  Using the ease and straightforwardness of mathematical equations while implementing inventory management systems will be a comfortable solution. Regarding to this objective, our implementation will have a property which makes inventory management by parametric mathematical equations.

- Model performance Analysis

  Describing the periodic model comparisons and total cost comparison is a requirement.

- Realizing the cost analysis

  Detailed analysis of total and periodical costs of the model, which depends on parameters, is a must.

- Using models varying on inventory value classes

  Tracking different inventory value class products with different models will be a very important property according to costs.

- Sensitivity Analysis

    Analyzing the marginal cost changes depending on parameter changes will be a tool to measure the performance and accuracy of the model.

IV.2.2. Methodology

Nowadays, "continuous querying" is the key of "continuous development". Every company has to improve its own abilities to react to facts rapidly, on-time and with the right reactions. They have to gain pro-active behaviours to such situations.

The querying which we mentioned above must concern the reasons of the activities. After identifying the reasons, it will be possible to decide what should be the organizational behavior.

Activities bridge the strategic and operational plans. Plans and strategies are implemented properly by identifying and directing those activities and actions necessary to accomplish the organization's short and long term goals [15].

As all the social and human science contents are becoming more specific, planning and estimating a reaction is becoming more important.

As science is improved, technology and communication systems are developed. Although alt the products/services are not the same, they have some common characteristics. Most of the products/services meet the requirements coming with the standarts. As a result; understanding internal processes and organization behaviours will be an advantage beside some kinds of marketing strategies like product differentiation and market division.

As and addition to these companies are powered with the strategic planning, supported by Total Quality Management.

Among all those subjects, the methodology developed which its flow can be seen in Figure IV-12, is an advantage for the company in the market, according to comparative and analytical cost measurements.

This flow is a sample of system analysis with a subject oriented and summarized concept. The model we describe is useful for the executives or inventory controllers, in order to help them to measure how good they do their jobs.
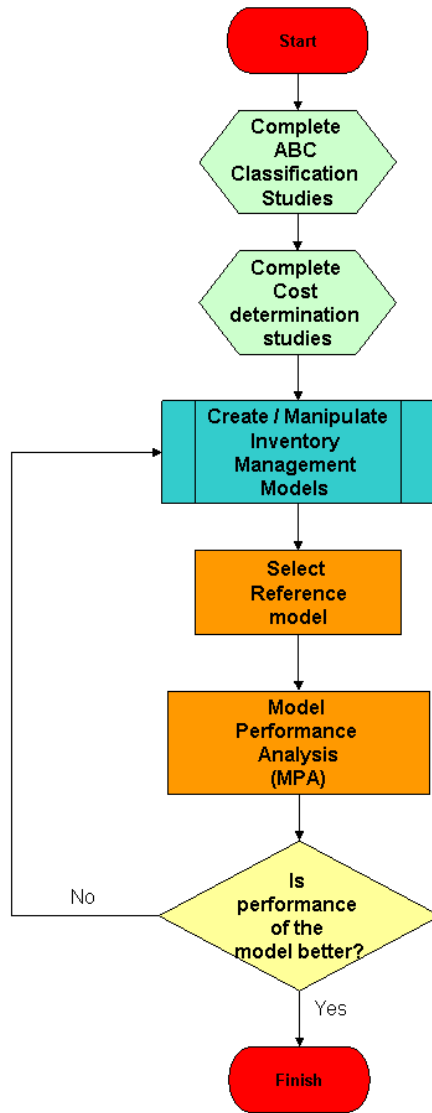
Figure IV-12, Flowchart of Methodology which this study aims to create

Studies until now are analyzing the current condition. Next we will describe our study and its properties which reorganize the lacks and uncertainty.

IV.3. IMPLEMENTATION

Software is designed to support companies besides its low hardware, software and education costs. It can be integrated to current systems.

IV.3.1. Technical Features

- All Microsoft operating systems supported

    Most of the companies use MS operating systems because of easy management and usage ratios on personal computers. This software application is compatible with all versions of MS operating systems.

- TCP/IP Protocol Usage

    All of the systems used in the company and database processes are integrated with an industry standard interface; TCP/IP communication protocol. This application can work independent of other systems.

- Database Independent Structure

    Our implementation keeps the data in a database which can be chosen by the users. These systems are easy to find and use. It connects to the database management systems with a common connection interface (Appendix - Figure App. 4).

- Simple Development Interface

    We developed our software with MS Visual Studio 6.0, which is a simple development interface. It has an open, object oriented architecture which is updateable.

- Simple User Interface with Interactivity

    It is a user friendly decision support system implementation. A graphic library (Microsoft MSChart) is used and user interface became easy to use (Appendix - Figure App. 7).

- Integration with the current systems

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Our implementation supports both entered values and integrated values from outer data sources. This structure unifies the process of data entrance. Our software exports the entered data to text based format.

IV.3.2. Business Features

- The ability to add new models

  One of the most crucial features of the application is the ability to add new and user-defined inventory management models.

  Users may prepare their own inventory management models by the help of the parameters and ratios which are found appropriate for their firms. These prepared models can be evaluated within the "Model Performance Analysis" after they are compared to the reference inventory management model.

  As an outcome of the ability to add new models within the application, users are able to change the models of various inventory valuation classes at different periods of time and under different economical and financial circumstances. And as a result, it is possible to react against the changes so fast and to evaluate the performance of the change from the cost point of view (Appendix - Figure App. 3).

- Applying Changes to the Reference Model

  All the models are constructed by determining the mathematical relations of the parameters and constants entered. This relation brings a flexible structure at the end.

  For example, the weight of the same parameters may vary from a firm to another. In this case, it is available to change it on the application by a slight modification in the model formula.

  This feature provides the same flexibility and dynamic structure to the models while the parameters are used so flexibly (Appendix - Figure App. 3).

- The ability to define the independent product demand

  Constant product demand pattern is used in the academic works as a basis to form a beginning point to explain the phenomena. Therefore, the

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initial models which the firms will analyse will be the models that are defined from this assumption.

This application is capable of the use dynamic demand forecasts. So the capabilities increase the probability of making more accurate forecasts which will be closer to the real results (Appendix - Figure App. 6).

▪ The ability to change instantly the quantities used

This application also provides making changes to handle the model analysis of the input data and this feature is far beyond the integration of the application to the firms' data systems.

Accordingly, the information of how successfully the changes in demand are used on the model constructed from the "model-performance-analysis" can be obtained accurately (Appendix - Figure App. 7).

▪ Decision support via visual elements

In the company oriented model construction process, the modifications made to the user data can be understood more meaningfully by their graphs and this overall processing provides the opportunity of instant decision making beside the model performance analysis to the client.

As a result, clients can understand what the changes made in stock quantities mean more easily (Appendix - Figure App. 6, 7).

▪ To determine the hidden trends about graphical interfaces

There are 3 kinds of usage types of the graphs in practice:

- Linear graphs
- Logarithmic graphs
- Percentage graphs

Linear structure shows the magnitude and trends of the periodic changes.

Logarithmic structure acts as a superior tool to determine sudden impacts and trends. Realising the relative magnitude of a change in a given period may act so critically in preparing the reactions or getting precautions.

Percentage structure is rather an assistant tool in determining how much portion of the whole belongs to each different unit (Appendix - Figure App. 7).

- Ability to use periodic focuses

Parameters' effects to the model should be able to adopt to the conditions of chosen time periods and those effects should be observed without having a limitation of choosing "1 year" as the unique time quota (Appendix - Figure App. 6, 7).

- Sensitivity Analysis

Sensitivity analysis property of the application is used to determine the marginal change, effects and the direction of the model while working on the projects.

Performance measurement of the model that is constructed is succeeded by measuring each separate (marginal) effect of all model parameters during the analysis phase. It must be noticed that such an analysis shows the usage types of the parameters in the model by this way.

Finally it is concluded that knowledge on parameter usage is given to the clients by the Model Performance Analysis (Appendix - Figure App. 7, 8).

IV.3.3. Implementation

IV.3.2.1. What is our Project

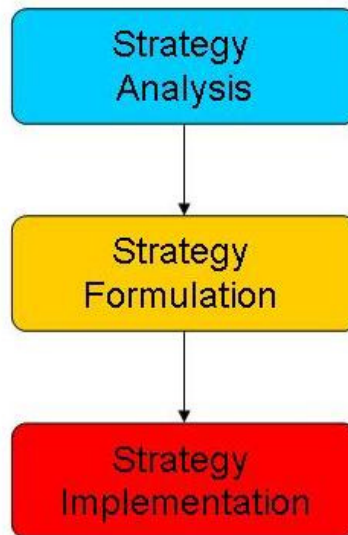The development cycle of this project follows the below path:

Figure IV-13, Strategic Path for Strategic Development [14]

Our methodology resides in the Strategy Analysis part of this strategic development path. With this methodology we try to figure out the basic and basis systems analysis approaches to determine the existing status of the Inventory management systems of the companies.

After realizing the cost-model-time relationships, companies will be capable of formulating their own inventory management policies through the application which was developed as an implementation of the second element of the above path, "Strategy Formulation".

The last step which includes the development of the software application yields the requested reports and analysis results through its easy to use interface. The significance of this tool is the ability for "Creation of the Company oriented inventory management models" and "Determination of the reorder points and quantities".

Consequently, this application will help the companies to implement our methodology which accepts the "Inventory Management Systems" as "Strategic Management and Planning System".

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IV.3.3.2. What is the scope of our Project

This study was built from an idea of reference publication "Industrial Inventory Control" which was published from Gordon Breach Science Publishers in 1972 [20]. The main idea in this publication is there is no any study, sufficiently explains the importance of an industrial and applicable inventory control in the market. As this idea is developed, after 30 years, we are again trying to point out the same problem, the lack of a study which is simply applicable, easy to use and powerful to help management roles in the "Inventory Management Systems".

According to these goals, there are two rigid objectives of our study:
- Create a Methodology
- Develop a software application to help implementation of this methodology

This methodology will be used during the systems analysis and "Business Process Reengineering" studies. And software application will be used to automate the inventory management systems and formulize the results of the implementation of the methodology as inventory management models.

IV.3.3.3. General Information on Behaviours of Companies

IV.3.3.3.1. Data and Materials Flow

In the previous chapters, we had to mention some common properties of the companies from the departments' point of view which were pointed out in the Chapter II. As we see in the Figure IV-14 the Sales persons take orders, invoices prior to sales from the customers, enter data about the customers into the system, deliver products and do lots of additional tasks.

In this flow after the sales force closes its tasks, customer billing details are forwarded to finance department in the head office, and financial operations such as invoice and payments are completed.

Meanwhile, the orders are delivered to the warehouse information system to let the warehouse management system handle production inventory and shipping

operations. By the time these actions are taken, the order information is sent to the warehouse management system.
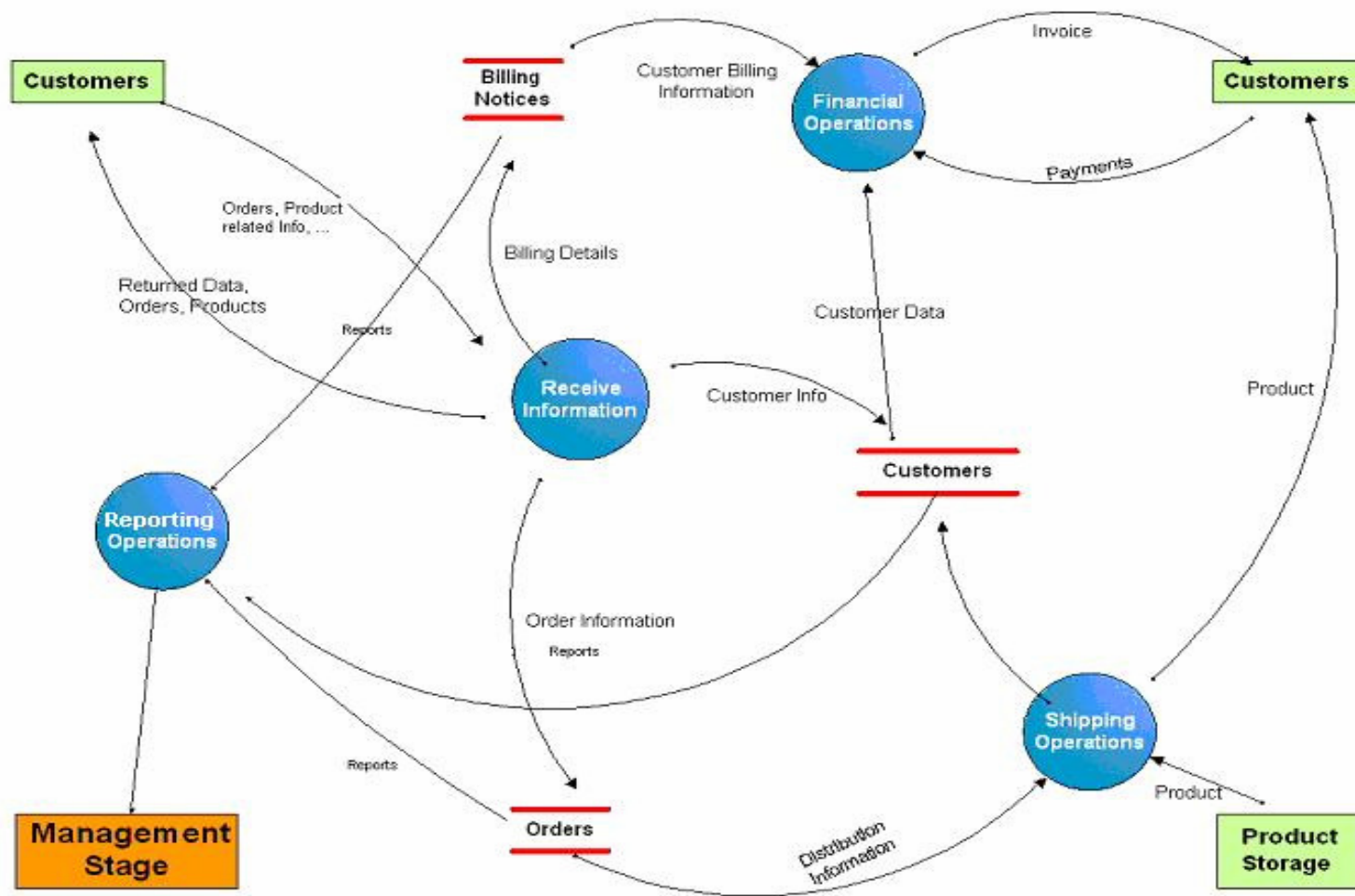
Figure IV-14, Common Data Flow Diagram of Sales Oriented Operations

IV.3.3.3.2. Product Distribution

Manufacturing companies have a distribution network like the one in the Figure IV-15. They produce the products and send them to their warehouses. Then they send the products to customers from the warehouses if the company has a distribution network or otherwise to the distributors directly.
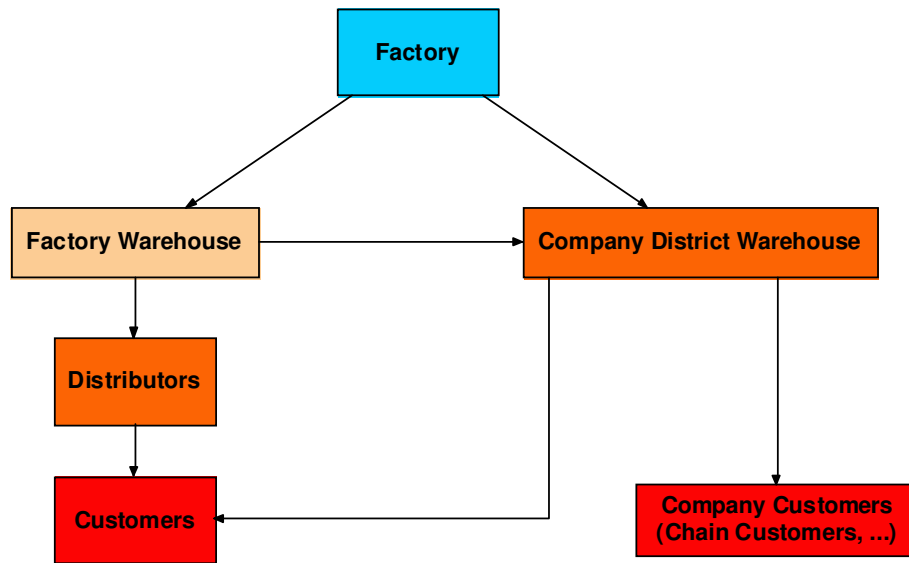

Figure IV-15, Product Distribution Diagram

Information which is given up to this point briefly explains the flow of the materials and data about the production and sales functions of a company. The next phase of the study is the development cycle of the solution.

IV.3.3.4. Development Method of the Project

Many organizations have new product development methodologies that provide a standard framework for planning and managing development efforts like this [30]:
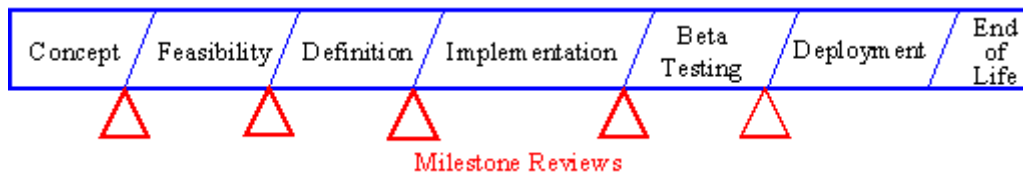
Figure IV-16, Standard framework for planning and managing development efforts [32]

The engineering development life cycle is a subset of the overall product and process development cycle. The formal development effort may come under the definition, implementation, and testing phases. The development life cycle, shown here for a software project (using the old waterfall approach) shows the distinct activities that need to happen either in series, with overlaps, or iteratively using a spiral methodology which is told before.
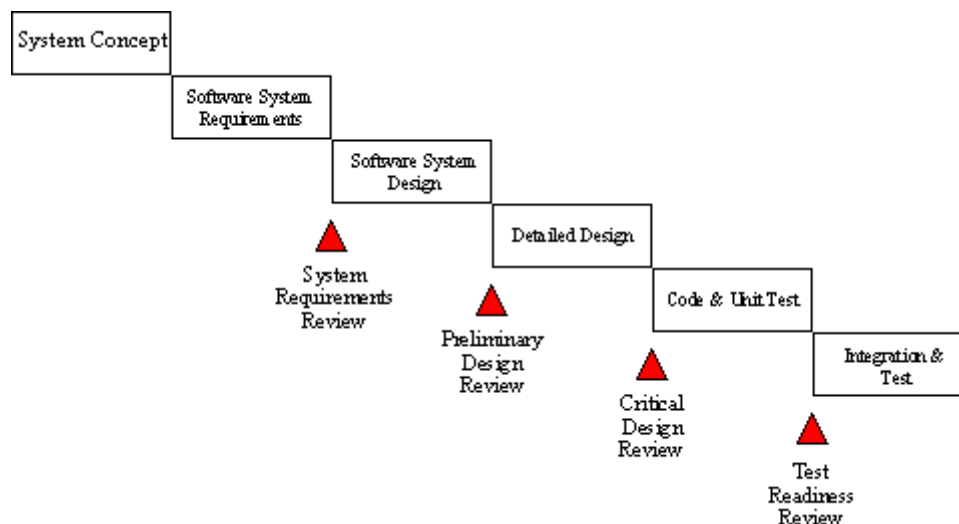

Figure IV-17, Standard framework for planning and managing development efforts with design [32] reviews

This figure provides the framework for understanding the relationship between the major milestones in the project approval process and the design reviews that are part of a normal engineering development methodology. Here are the procedures of design reviews [32]:

- **System Requirements Review (SRR)**

The purpose of the SRR is to review the system **requirements specification** document, to ensure the documented requirements reflect the current knowledge of the customer and market requirements, to identify requirements

that may not be consistent with product development constraints, and to put the requirements document under version control to serve as a stable baseline for continued new product development.

- **Preliminary Design Review (PDR)**

The purpose of the PDR is to review the **conceptual design** to ensure that the planned technical approach will meet the requirements.

- **Critical Design Review (CDR)**

The purpose of the CDR is to review the **detailed design** to ensure that the design implementation has met the requirements.

- **Test Readiness Review (TRR)**

The purpose of the TRR is to review preparations and **readiness for testing of software** configuration items, including adequate version identification of software and test procedures.

- **Production Readiness Review (PRR)**

The purpose of the PRR is to ensure that the design is completely and accurately documented and ready for **formal release to manufacturing**.

IV.3.3.4.1. Defining the symptoms

The idea of carrying out the study comes with the occurrence of some problems and deficiencies in the companies' inventory management systems. In the very first steps of this study, it is important to separate the symptoms from the problems. The symptoms are the obvious side of the problems. Therefore, this step will help us define the basic problems accurately.

Although we have mentioned the symptoms before, the symptoms found in this study are as the following:

- High Costs
  - o Increase at fixed costs
  - o Increase at scrap cost caused by spoiled and wasted materials in the stock.
- Lack of control at transportation and ordering costs.
- Bad timing at responding new orders (Lower service quality)

- There are lots of different efforts on other processes other then inventory management process in order to increase the revenue, but these efforts worth more then the ones spent on the inventory management systems.

IV.3.3.4.2. Defining the Problem

Regarding to the symptoms explained above, the Current situation can be described as, Companies are:

- Using empiric methods for inventory management.
- Not adopting a predefined inventory management model or system
- Not rapidly reacting to inventory cost changes
- Making cost analysis regularly and those analyses create their own problems.
- Can not choose the suitable inventory models for them.
- Can not make parametric inventory management model designs.
- Face with difficulties in comparing the model performances by quantitative measures (like cost)
- Are not being able to perform sensitivity analysis against the models.

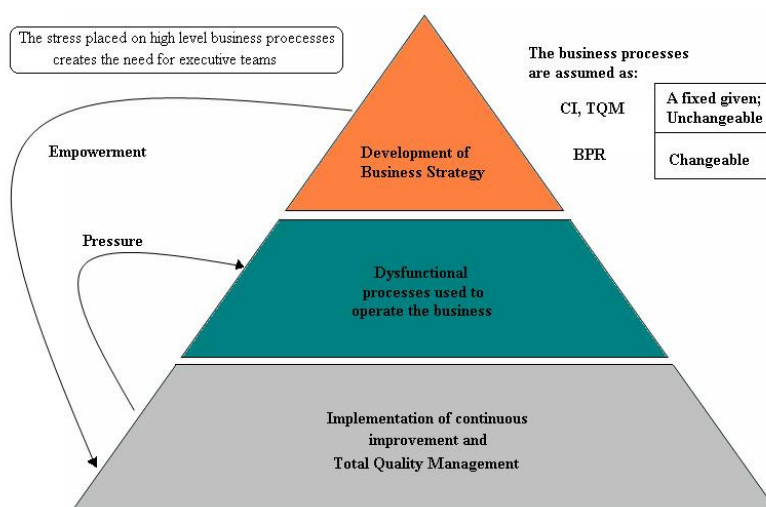The implicit affects of the business layers are shown in the Figure IV-18, to find the real problem.

Figure IV-18, Finding the real problem [5]

According to these definitions, the objective of our software application is to remove the deficiencies and problems in the strategic processes of the inventory management systems of the companies.

After implementation of our application, the symptoms will be removed and problems and deficiencies will be disappeared. But, as matter of fact, according to basic approach that we have taken it as a master guide to this study, the continuous improvement approach will not stop to develop and change the structures and implementation figures of this study.

As a consequence the solution and the real problem correspondence will affect the success of the project. Otherwise, it will cause high time consumption and high cost.

IV.3.3.4.3. Development Phase

IV.3.3.4.3.1. Gathering the Requirements

End user requirements are collected and documented during the process of gathering the requirements. Gathering of the requirements is often taken as a kind of activity that includes end users in the business process and information analysis environments. On the other hand, it is an approach aiming to determine the core of the problem domain, in which the modeling will be implemented as a next step. End user needs are mostly documented informally at this stage, or they are not plotted on the schemas in detail.

Traditional techniques such as interviews with end users, study of existing documents and reports, and monitoring the ongoing information analysis activities are the methods for gathering the requirements. As an addition, experience with information analysis and business process reengineering are important assets that contribute significantly at this stage. The outputs of the process of gathering the requirements are utilized as the basis for the further dimensional model producing stage.

Generally, all requirements can be put in any or both of those two headlines. The kind of needs and the degree of precision with which the needs will be mentioned often depend on two parameters: the kind of information analysis problem being

thought for the implementation project and the degree that the end users are able to define their requirements

After completing the interviews, we have documented out the user requirements informally. That was concerned as a model for our software application.

IV.3.3.4.3.1.1. Information-Oriented Requirements

Information-oriented requirements represent an initial perception of the kind of information end users use in their information analysis activities.

- **Information subject areas**

Information subject areas are high-level categories of business information. Information subject areas are usually used to build the high-level enterprise data model. When available, information subject areas indicate the scope of the data warehouse project.

In this project, information subject areas of interest are: vendors/suppliers, customers and the company itself. They are depicted in Figure IV-19.
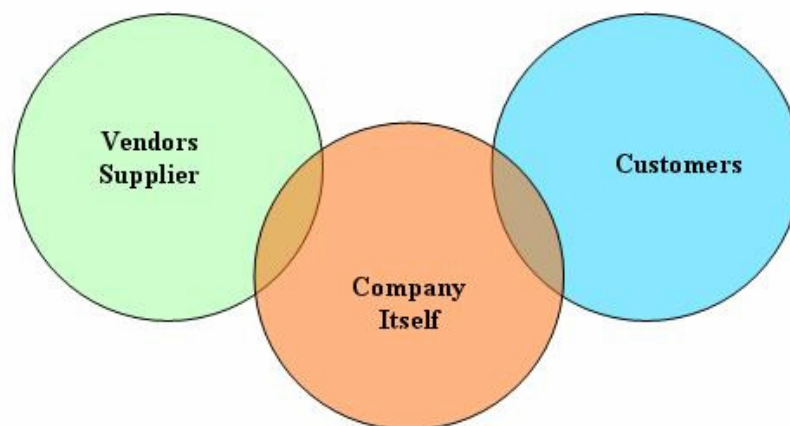

Figure IV-19, Information subject areas

If we think on the technical abstraction layer of the solution, information subject areas are the correspondents of the entities in the ER Diagrams.

IV.3.3.4.3.1.2. Process-Oriented Requirements

Several types of process-oriented requirements may be available.

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- **Business Objectives**

The highest-level expressions of information analysis objectives expressed in business terms are 'business objectives'. Numerous business objectives can be set for the implementation of this project.

In this project, the business objectives are stated according to the interview held with the users. These objectives;

- o Creating a Methodology
- o Applying the model approach in Inventory management
- o Model performance Analysis
- o Realizing the cost analysis
- o Using models varying on inventory value classes
- o Realizing Sensitivity Analysis

- **Business Queries**

Various queries, hypothesis and analytical questions the end users issue and try to resolve in the course of the information analysis activities are modeled by business queries. Business queries, which could not be formulated precisely and could not be coded directly with the programming languages, are expressed in business terms.

This session is completed with an analytical tool, brain-storming. Business queries helped us to separate the symptoms and the problems from each other.

- **Defining the Performance Criteria Set**

There are four kinds of companies. Some companies do not collect data about the internal operations. They think they do not need any reviewing sessions for internal operations.

Some other companies collect data, but they never investigate these data.

The third kind of companies collects data, do some analysis, yet they do nothing more than these. These companies do not know why they collect data.

The successful companies are in the fourth group. They make analysis and they make decisions. After these sessions, they take actions. These actions are based on some performance key indicators in this study.

After we have completed the definition of the problems we have modeled the solution according to the information we had. And it came to the point where we must indicate the performance criteria set to put the importance and significance of the solution out.

IV.3.3.4.3.2. Analyzing the Requirements

Requirement analysis phase includes the investigation of the informal requirements of the end users and the preparation of the data models. The output models of the requirements analysis phase must be simple in nature, since they are not yet discussed and confirmed by the end users.

Requirements analysis techniques are utilized to prepare the entity relationship models reflecting the end-user requirements that are noted previously in an informal way. Requirement analysis gives a schematic representation of the model that the information analyst can contribute directly. The outputs of requirements analysis will be the primary input for data modeling once the requirements validation phase is successfully accomplished.

The scope of work of requirement analysis can be summarized as follows:

- Determination of the entities in the processes.
- Determination of the relationship between entities.
- Building the initial data model.

IV.3.3.4.3.3. Modeling the Requirements

Validated initial models are further developed into detailed models, showing all elements of the model and their properties. Detailed models can further be extended and optimized. Many techniques in this area should be thought of as advanced modeling techniques. Not every project requires all of them to be applied.

Requirement modeling consists of several activities that are performed with the intent of producing a detailed conceptual model representing the problem domain of the information analyst.

For our study we have used Platinum ERwin 3.5.2 CASE tool while modeling the ER diagrams, data models and the requirement models.

Computer-aided software engineering (CASE) is the use of software tools to assist in the development and maintenance of software. Tools used to assist in this way are known as CASE Tools.

ERwin has many powerful features that let the user design entity relation data models and dimensional models. With Platinnum Erwin CASE Tool, many different target databases and database objects can be created and maintained. However, perhaps ERwin's most powerful feature is its simplicity and ease of use.

ERwin uses many of the standard Windows features and conventions. Just as a user can create, modify, save, and print documents in other Windows applications, the user can perform these same tasks in ERwin by using familiar Windows dialogs.

IV.3.3.4.3.4. Solution Design

IV.3.3.4.3.4.1. Database Design

The data model is one part of the conceptual design process. The other is the functional model. The data model focuses on what data should be stored in the database while the function model deals with how the data is processed. To put this in the context of the relational database, the data model is used to design the relational tables. The functional model is used to design the queries that will access and perform operations on those tables.

Data modeling is preceded by planning and analysis. The effort devoted to this stage is proportional to the scope of the database. The planning and analysis of a database intended to serve the needs of an enterprise will require more effort than one intended to serve a small workgroup.

The information needed to build a data model is gathered during the requirements analysis. Although not formally considered part of the data modeling stage by some methodologies, in reality the requirements analysis and the ER diagramming part of the data model are done at the same time.

While ER model lists and defines the constructs required to build a data model, there is no standard process for doing so. Typically, the entities and relationships are modeled first, followed by key attributes, and then the model is finished by adding non-key attributes. Other experts argue that in practice, using a phased approach is impractical because it requires too many meetings with the end-users. The sequence used for this document is [28]:

- Identification of data objects and relationships
- Drafting the initial ER diagram with entities and relationships
- Refining the ER diagram
- Add key attributes to the diagram
- Adding non-key attributes
- Diagramming Generalization Hierarchies
- Validating the model through normalization
- Adding business and integrity rules to the Model

In practice, model building is not a strict linear process. As noted above, the requirements analysis and the draft of the initial ER diagram often occur simultaneously. Refining and validating the diagram may uncover problems or missing information which require more information gathering and analysis

The ER diagram is the key point when starting of the database design. In the Figure IV-20 we can see the tables as entities and their relationship.

After ER Diagrams are created it is time to create the database structure with tables, views and relationship between them. In this step Platinum ERwin is used to build the structure. As we have mentioned before our application is database independent, besides Platinum ERwin is also a database independent application which gives the power of database independence to our project.

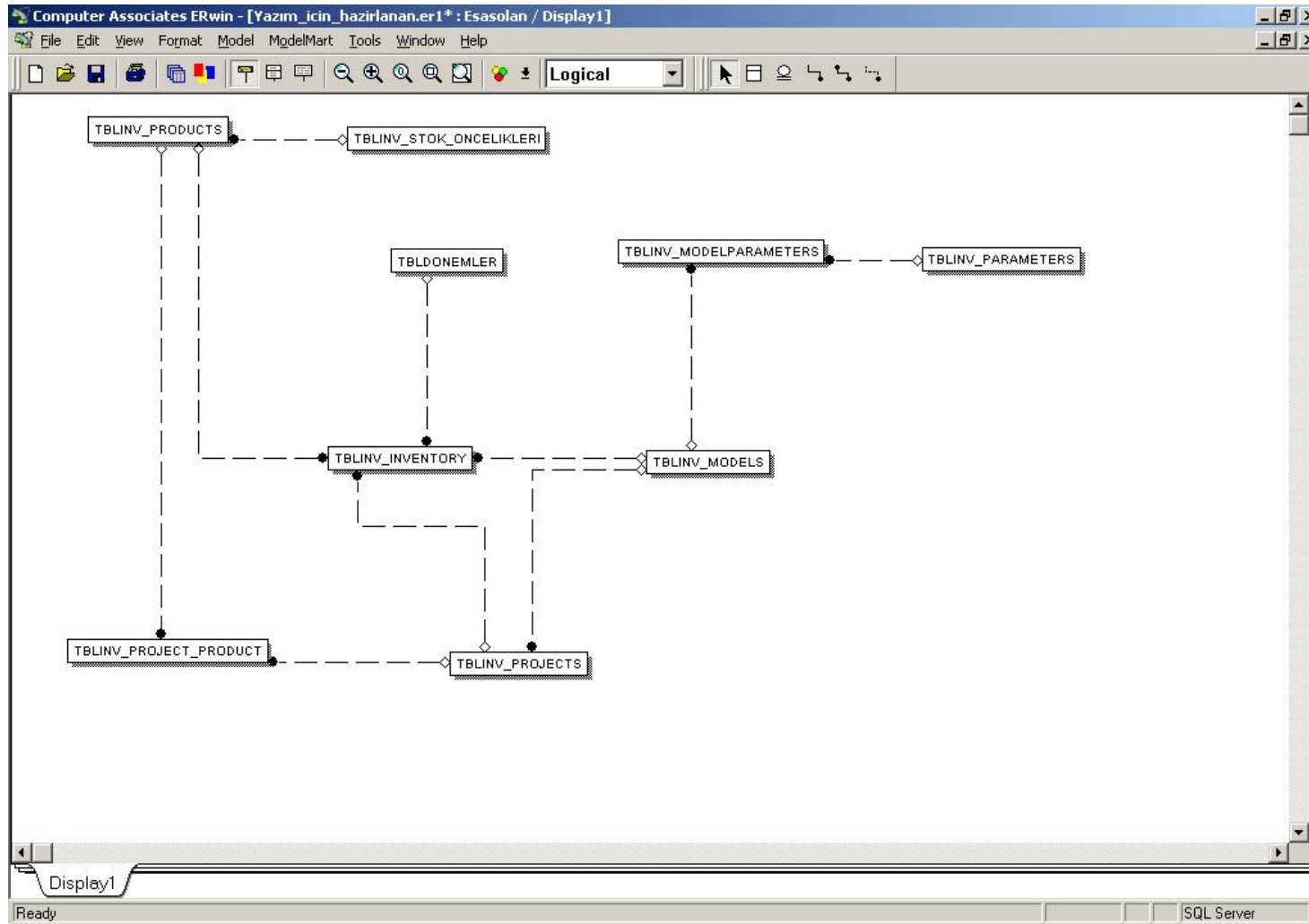Database structure can be seen in the Figure IV-21.
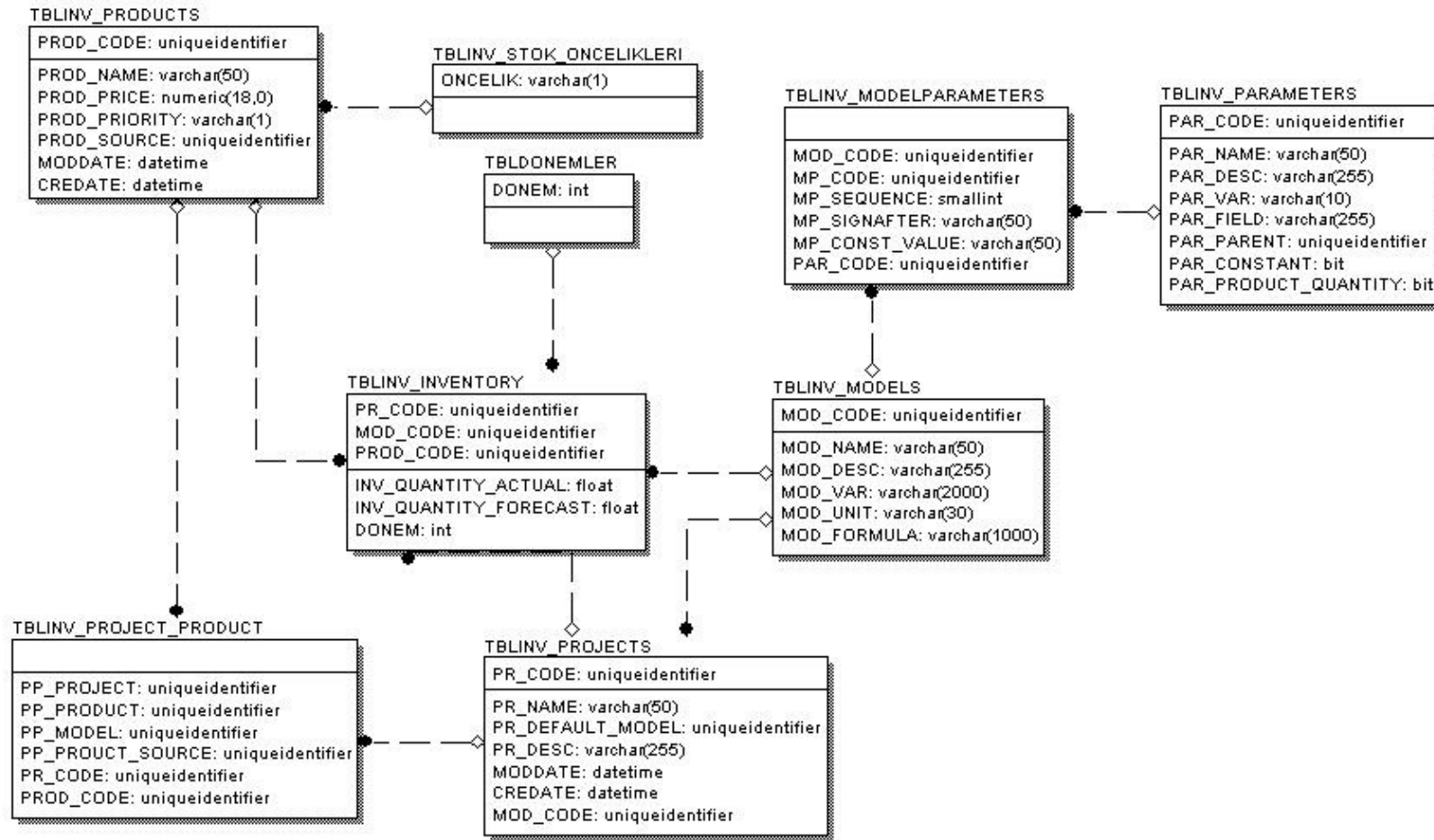
www.manaraa.com

Figure IV-20, Entity Relationship Diagram

TBLINV_PRODUCTS
- PROD_CODE: uniqueidentifier
- PROD_NAME: varchar(50)
- PROD_PRICE: numeric(18,0)
- PROD_PRIORITY: varchar(1)
- PROD_SOURCE: uniqueidentifier
- MODDATE: datetime
- CREDATE: datetime

TBLINV_STOK_ONCELIKLERI
- ONCELIK: varchar(1)

TBLDONEMLER
- DONEM: int

TBLINV_MODELPARAMETERS
- MOD_CODE: uniqueidentifier
- MP_CODE: uniqueidentifier
- MP_SEQUENCE: smallint
- MP_SIGNAFTER: varchar(50)
- MP_CONST_VALUE: varchar(50)
- PAR_CODE: uniqueidentifier

TBLINV_PARAMETERS
- PAR_CODE: uniqueidentifier
- PAR_NAME: varchar(50)
- PAR_DESC: varchar(255)
- PAR_VAR: varchar(10)
- PAR_FIELD: varchar(255)
- PAR_PARENT: uniqueidentifier
- PAR_CONSTANT: bit
- PAR_PRODUCT_QUANTITY: bit

TBLINV_INVENTORY
- PR_CODE: uniqueidentifier
- MOD_CODE: uniqueidentifier
- PROD_CODE: uniqueidentifier
- INV_QUANTITY_ACTUAL: float
- INV_QUANTITY_FORECAST: float
- DONEM: int

TBLINV_MODELS
- MOD_CODE: uniqueidentifier
- MOD_NAME: varchar(50)
- MOD_DESC: varchar(255)
- MOD_VAR: varchar(2000)
- MOD_UNIT: varchar(30)
- MOD_FORMULA: varchar(1000)

TBLINV_PROJECT_PRODUCT
- PP_PROJECT: uniqueidentifier
- PP_PRODUCT: uniqueidentifier
- PP_MODEL: uniqueidentifier
- PP_PROUCT_SOURCE: uniqueidentifier
- PR_CODE: uniqueidentifier
- PROD_CODE: uniqueidentifier

TBLINV_PROJECTS
- PR_CODE: uniqueidentifier
- PR_NAME: varchar(50)
- PR_DEFAULT_MODEL: uniqueidentifier
- PR_DESC: varchar(255)
- MODDATE: datetime
- CREDATE: datetime
- MOD_CODE: uniqueidentifier

Figure IV-21, Database structure of the application

After a brief explanation of database design, we have to tell about database structure of our application. We have eleven tables, one temporary table and one view created in our database:

Tables

- TBLINV_INVENTORY
- TBLINV_MODELPARAMETERS
- TBLINV_MODELS
- TBLINV_PARAMETERS
- TBLINV_PRODUCTS
- TBLINV_PRODUCT_DEMANDS
- TBLINV_PROJECTS
- TBLINV_PROJECT_PRODUCT
- TBLINV_STARTUP_INVENTORY
- TBLINV_STOK_ONCELIKLERI
- TBLDONEMLER

View

- VIEW VI_INV_FORMULATED_VALUES

Temporary Table

- TEMP_INVENTORY

Here the view is used to make easy the data selection from tables. Sometimes data gathering may be so hard for the RDBMS or host data source applications then pre-determined structures supply rapid command handling and data gathering from data files or other data source structures.

The database object creation scripts can be found in Appendix-B

IV.3.3.4.3.4.2. Application Design and coding

The Application Development phase of a software development project involves the actual programming and other related tasks necessary to produce the final software product. The source code is modularized to promote efficiency, and use of existing code is stressed to improve reliability and reduce development costs.

Elements of Application Development

- Reference the application development specifications
- Develop "alpha" version for internal testing
- Develop "beta" version for client evaluation
- Develop final version based on client feedback

We can make a detailed explanation of all the stages of the application design and development phase with the help of the Quality Management Systems point of view [3]:

- **Design and development planning:**

  The organization shall plan and control the design and development of product.

  During the design and development planning, the organization shall determine

  - The design and development stages
  - The review, verification and validation that are appropriate to each design and development stage
  - The responsibilities and authorities for design and development.

  The organization shall manage the interfaces between different groups involved in design and development to ensure effective communication and clear assignment of responsibility.

  Planning output shall be updated, as appropriate, as the design and development progresses.

- **Design and development inputs:**

  Inputs relating to product requirements shall be determined and records maintained. These inputs shall include:

  - Functional and performance requirements
  - Applicable statutory and regulatory requirements

- o Where applicable, information derived from previous similar designs

- o Other requirements essential for design and development.

These inputs shall be reviewed for adequacy. Requirements shall be complete, unambiguous and not in conflict with each other.

- **Design and development outputs:**

The outputs of design and development shall be provided in a form that enables verification against the design and development input and shall be approved prior to release.

Design and development outputs shall:

- o Meet the input requirements for design and development,

- o Provide appropriate information for purchasing, production and for service provision,

- o Contain or reference product acceptance criteria, and

- o Specify the characteristics of the product that are essential for its safe and proper use.

- **Design and development review**

At suitable stages, systematic reviews of design and development shall be performed in accordance with planned arrangements

- o To evaluate the ability of the results of design and development to meet requirements, and

- o To identify any problems and propose necessary actions.

Participants in such reviews shall include representatives of functions concerned with the design and development stage(s) being reviewed. Records of the results of the reviews and any necessary actions shall be maintained.

- **Design and development verification:**

Verification shall be performed in accordance with planned arrangements to ensure that the design and development outputs have met the design and development input requirements. Records of the results of the verification and any necessary actions shall be maintained.

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- **Design and development validation:**

    Design and development validation shall be performed in accordance with planned arrangements to ensure that the resulting product is capable of meeting the requirements for the specified application or intended use, where known. Wherever practicable, validation shall be completed prior to the delivery or implementation of the product. Records of the results of validation and any necessary actions shall be maintained.

- **Control of design and development of changes:**

    Design and development changes shall be identified and records maintained. The changes shall be reviewed, verified and validated, as appropriate, and approved before implementation. The review of design and development changes shall include evaluation of the effect of the changes on constituent parts and product already delivered. Records of the results of the review of changes and any necessary actions shall be maintained.

Here we would better to summarize the managerial requirements of the design and development phases according to Quality Management Systems:

- Determination of design and development stages
- Determination of the review, verification, and validation that are appropriate to each design and development stage
- Determination of the responsibilities and authorities for design and development.

At the end of the application development phase, the developer prepares the application for the next phase in the Software Development Life Cycle (SDLC) which is client testing. The steps involved in this process include checking all of the associated objects and documentation [10, 20].

As can be seen in the figure our application interacts with the data sources and user interfaces. Users can see, modify existing data, or enter new data through the user interfaces.

Figure IV-22, Designed System Structure

Prior phases of the development process help us to reference the development specifications, all requirements and models based on these requirements are clear. Starting from this step the coding session starts. We have coded our software application using MS Visual Basic 6.0 SP6. In the Figure IV-23 MS Visual Basic 6.0 SP6 integrated development environment can be seen.
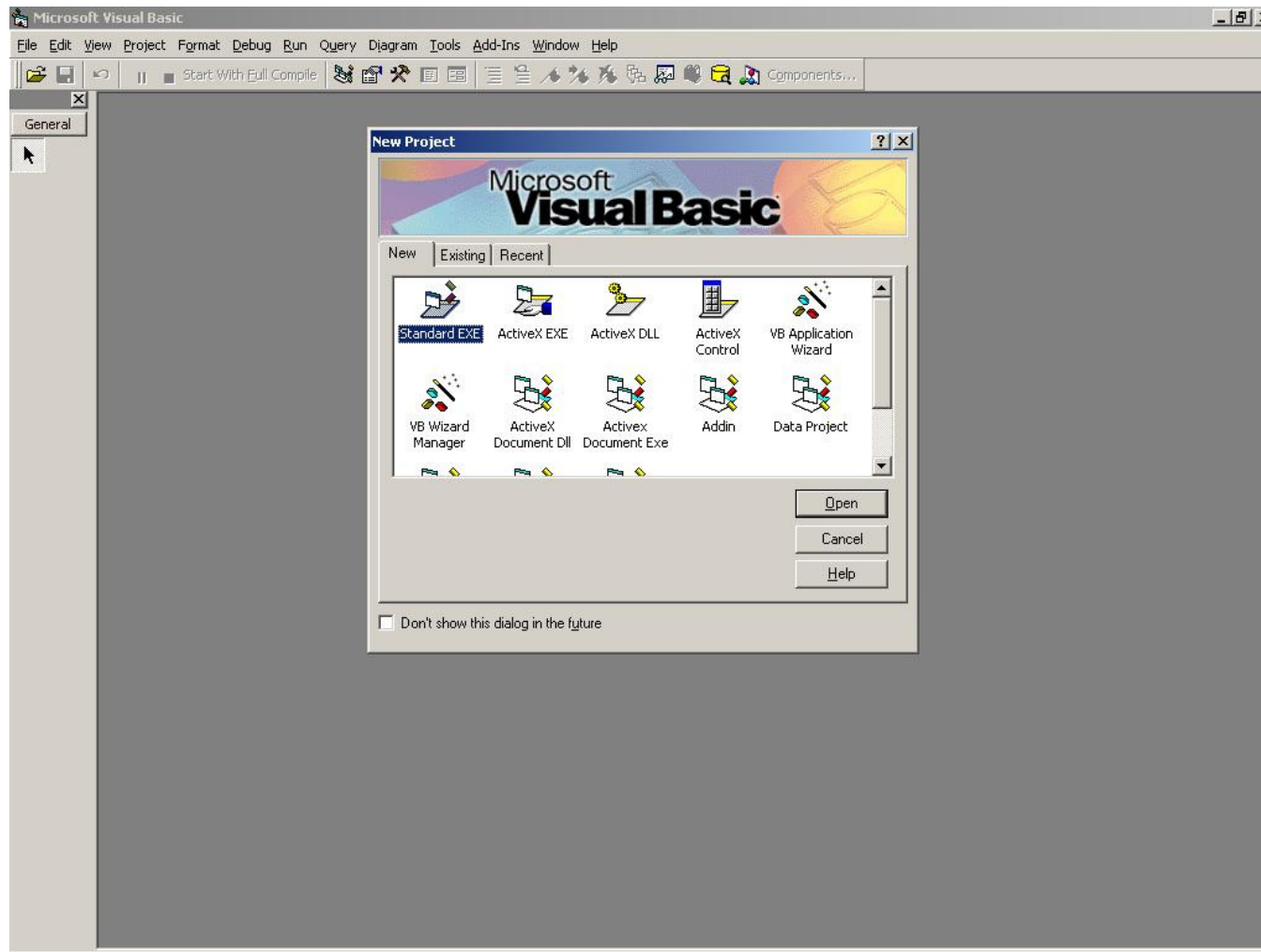
Figure IV-23, MS Visual Basic 6.0 Integrated Development Interface

After the coding session finishes, developer-testing session starts. In this session developers test their own application by themselves. They use existing sample data and examine the features of the application due to the specifications that have been referenced by the prior steps of the software development life cycle.

When the developers finish their testing sessions, here it comes the solution validation phase. In this phase of the SDLC users interacts with the graphical user interfaces (GUI). They start to test the application against the requirements analysis and requirements modeling which validated before buy the users themselves. This session may be the most important session in the SDLC, because any bugs or errors exists in the application will affect directly the live systems.

We have completed our developer-testing phase with a sample database taken from a leading sales and distribution-retail sector company in Turkey.

All the coding phase is finished then it comes the implementation and deployment phase. In the figure we can see the implementation activities during a Information system development project.
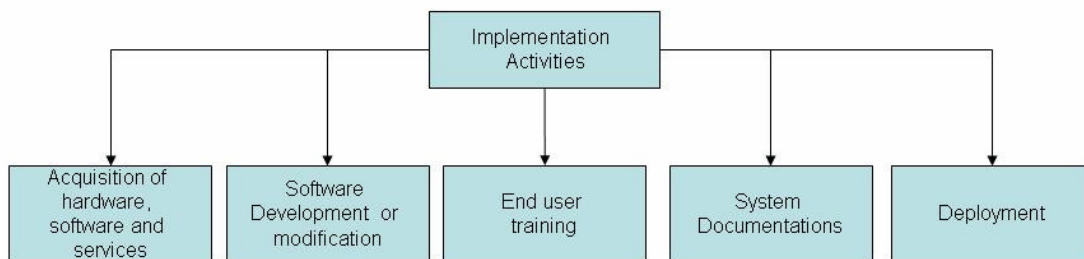
Figure IV-24, Implementation activities during an Information system development project [17]

CHAPTER V. CONCLUSION

The beginning of this century came with a different approach called "Information Age". It can also be defined as a revolution on the professional life of people who are the players of competitions. Today nothing is more valuable then information. If you know what to do then you have the power in your hands. Marketing, management, accounting, manufacturing, human resources, etc. all of the functions of the organisations need to get information about their jobs in order to have a knowledge base for know-how and experiences to make decisions. Getting information is crucial for the companies to fulfill the requirements and feed the needs of the customers who are waiting for services and products from the service and product providers.

Since information is so important, it can be defined as a key-enabler of the strategic operations which are inevitably important from the competitive advantages point of view. Companies need to make plans based on the goals of their managerial decisions. The first thing that can be thought is information and knowledge of the companies itself over its behaviors and actions.

The changing economic and technological environment has led to an increasing interest in process innovation by progressive firms around the world by using their knowledge of internal processes. Based on this simple fact, the basic objective of this study is to develop integrated inventory management system and logistics strategies based on the business process. Once you have made a decision that your company must innovate to remain or to become competitive, you should establish a rational, logical and dynamic model to guide you during the entire course of action.

In the traditional inventory management models "Saw Tooth" approach is the base of the mathematical modelling. This limits the user in a linear model which is very different from the real life cases. In real life cases we never be sure that all the parameters in the traditional model are stable, keep their conservative and static behaviour against the changing environmental variables. Certainly, the static behaviour is based on some restrictions and in

the traditional model the number of these restrictions is very high. Besides, it is very clear that the more number of restrictions the more bias in the model result set.

Above sentences are describing the importance of the information to make decisions for future possibilities, so this study began.

The very first objectives of this study were:

- To develop an application that can be used to realize the simulation techniques to be used for performance measurement processes over the independent variables of the "Inventory Management Systems", especially by using the "Superimpose Technique".
- To make performance measurements of the "Inventory Management Systems" of the companies themselves compared to a pre-selected, theoretical inventory management model.

As we get on the way a need is raised to develop a methodology to implement our application to the companies. This methodology consists of steps that group the products or services into categories, make a cost analysis on the existing inventory management systems, build an inventory management system model based on the experiences of the company itself and make performance analysis of the models which are planned to be implemented.

This need is coming with the acceptance of the "Inventory Management System" as a strategic management tool for the companies who want to make decisions over the inventory levels and materials usage trends. These decisions drive the companies to a point that these companies at last have the opportunity to take actions before incidents occur. There is no need to talk about the importance of the correct plans made for the future incidents and see that companies are ready for the coming events due to these plans.

From this starting point, we developed a software application and a methodology to be used in the implementation of "Strategic Management Systems" on the "Inventory Management Systems".

The objectives are implemented by developing a new software application which lets the users define their own parameters (dynamic or static) and mathematical models based on the knowledge of their own companies and their experiences. After creating the mathematical modelling, users compare their new models with a reference model via "Curve Fit Analysis" method. This makes the users aware of unnecessary part of the inventory costs coming from the lack of knowledge of their internal processes and the large quantities of their safety stock levels.

The brief features of the software application are:

- The ability to add new models
- Reference Model can be changed
- The ability to define the independent product demand
- The ability to change the quantities used instantly
- Decision support via visual elements
- To determine the hidden trends about graphical interfaces
- Ability to use periodic focuses
- Sensitivity Analysis

As it can be seen form the list and explanation of the application, the study fulfilled the requirements of the starting objectives of this study. Addition to these it brings an easy to use user interface and a strong decision support system which uses visual methods to help users while making decisions.

A model formula designer is developed to use independent variables in the inventory management system models which can be defined by the users of the application.

A comparative graphical interface is designed to use the Superimpose comparison technique to be the users able to be aware of the changes and deficiencies in the models while making performance model analysis using a reference and a dynamic model.

As a consequence it can be accepted that we have achieved to implement the plans we had built up before we start this study.

Our study should open a way for the coming researchers to implement the theoretical academic subjects of the "Inventory Management Systems" more efficiently and completely.

As we emphasized before, a company need to be a learning organization in the competitive markets in order to have an advantage against their rivals. Starting to be a learning organization gives the opportunity to implement the decision making processes into their internal procedures. This means the implementation of **"Artificial Intelligence"**.

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Appendix – A

Application Screenshots

Figure App. 1

Project Selection screen

Users can select, create projects that will be a cover for the inventory management models to manage the reorder points and reorder quantities of the products.

Figure App. 1

Figure App. 2

Create New Project screen

Users can create new project as well as modifying existing projects' details and select the products which will be determined within the selected project.

Figure App. 2

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Figure App. 3

Create New Model screen

Users can create new models as well as modifying existing models' details and recreate the formulation of the model.
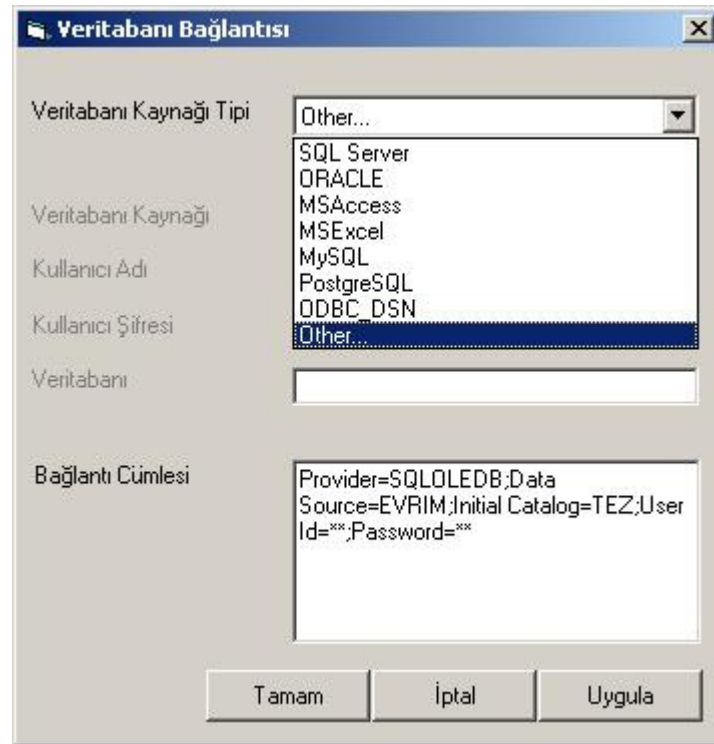
Figure App. 3

Figure App. 4

Database Connection Settings

Application is database independent. This means users can store their data within the most popular and easy-to find database management systems. Technically MS ADODB is used in the coding phase of the application. This allows users use their existing database management systems as far as they define a connection string via the network infrastructure of the company.

Figure App. 4

Figure App. 5

Product Entry- Modification Screen

   Application is capable of integrating with the existing data sources. But at the mean time it allows the users change the properties of the existing products or create a new entry for a new product with the required properties entered.

Figure App. 5

Figure App. 6

Independent Product Demand Entry-Modification Screen

As the application gets demand values based on the periods from the existing systems with integration, it gives us an opportunity to modify the demand values for the whole periods within the application itself. When modifying the values users can get the trends and periodic demand values via a visually enhanced graph.
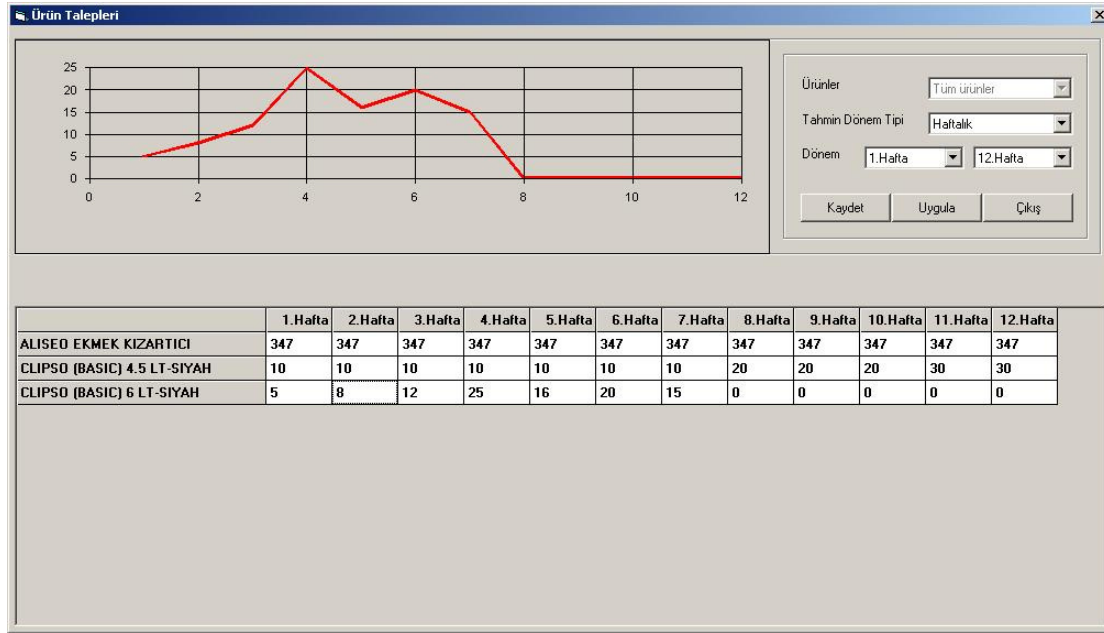

Figure App. 6

Figure App. 7

Model Performance Analysis – Main Screen

The most important screen is this one in the application. This screen allows the users compare different models by comparing the total and period based costs for a particular product.

The features of this screen are as listed below:

- Cost analysis of inventory of products based on the selected periods
- Reorder time determination
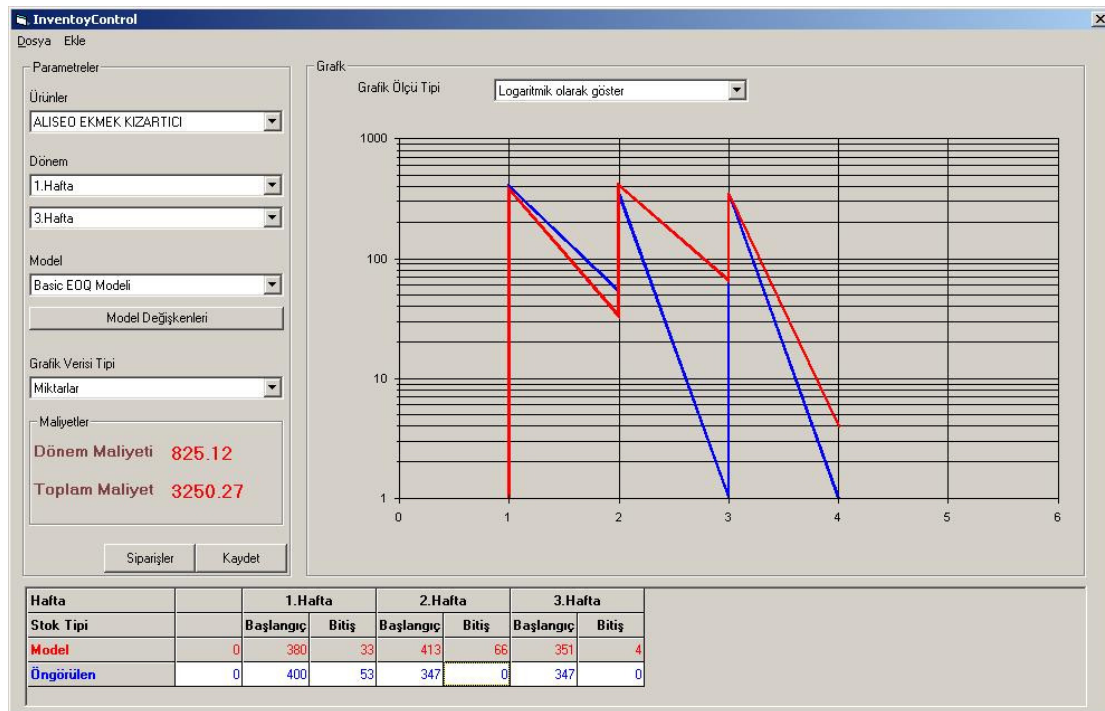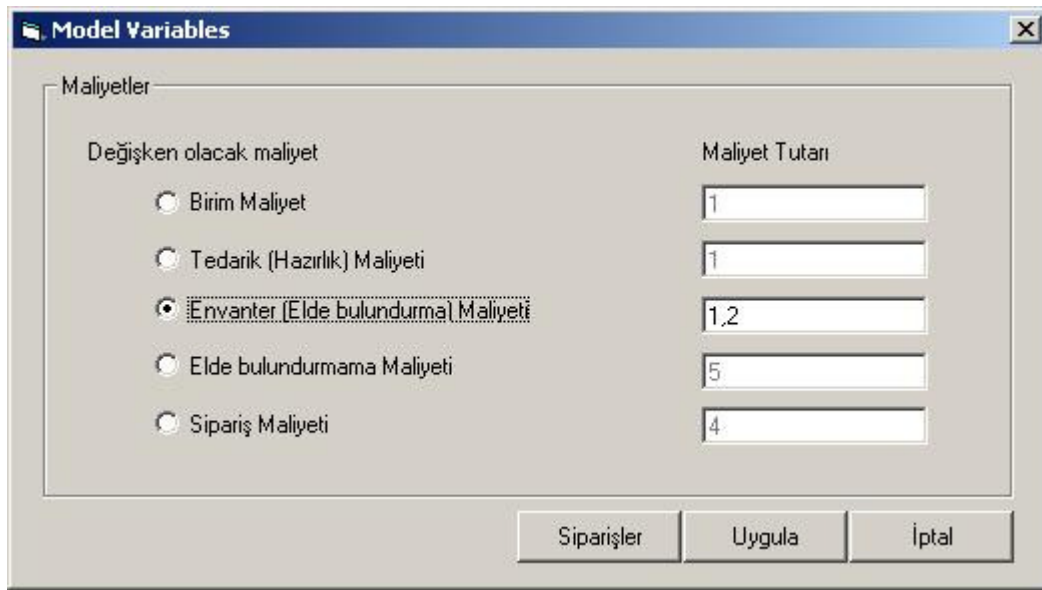- Reorder quantity determination
- Sensitivity Analysis
- …

Figure App. 7

Figure App. 8

Sensitivity Analysis Screen

In this application models are formulated using cost and time based parameters. Main screen of the application gives chance to the users, to examine the total cost and period cost of the models for a particular product, from the parameters of the models' formula point of view.

Figure App. 8

Figure App. 9

Model Performance-Detail Reporting Screen

As indicated before main screen is capable of creating the reorder times and quantities. This screen is the reporting screen for reorder times, quantities and total cost of the model for the selected product.

Figure App. 9

Appendix – B

Database Structure of Application

```
CREATE TABLE TBLDONEMLER (
    DONEM           int NOT NULL
)
go


ALTER TABLE TBLDONEMLER
    ADD PRIMARY KEY (DONEM ASC)
go


CREATE TABLE TBLINV_INVENTORY (
    INV_QUANTITY_ACTUAL  float NOT NULL,
    INV_QUANTITY_FORECAST float NOT NULL,
    PR_CODE         uniqueidentifier NOT NULL,
    PROD_CODE        uniqueidentifier NOT NULL,
    MOD_CODE         uniqueidentifier NOT NULL,
    DONEM           int NULL
)
go


ALTER TABLE TBLINV_INVENTORY
    ADD PRIMARY KEY (PR_CODE ASC, MOD_CODE ASC, PROD_CODE
ASC)
go
```

```sql
CREATE TABLE TBLINV_MODELPARAMETERS (
    MOD_CODE        uniqueidentifier NOT NULL,
    MP_CODE         uniqueidentifier NOT NULL,
    MP_SEQUENCE     smallint NOT NULL,
    MP_SIGNAFTER    varchar(50) NOT NULL,
    MP_CONST_VALUE  varchar(50) NULL,
    PAR_CODE        uniqueidentifier NULL
)
go


CREATE TABLE TBLINV_MODELS (
    MOD_CODE        uniqueidentifier NOT NULL,
    MOD_NAME        varchar(50) NOT NULL,
    MOD_DESC        varchar(255) NULL,
    MOD_VAR         varchar(2000) NULL,
    MOD_UNIT        varchar(30) NULL,
    MOD_FORMULA     varchar(1000) NULL
)
go


ALTER TABLE TBLINV_MODELS
    ADD PRIMARY KEY (MOD_CODE ASC)
go


CREATE TABLE TBLINV_PARAMETERS (
    PAR_CODE        uniqueidentifier NOT NULL,
    PAR_NAME        varchar(50) NOT NULL,
    PAR_DESC        varchar(255) NULL,
    PAR_VAR         varchar(10) NOT NULL,
    PAR_FIELD       varchar(255) NULL,
    PAR_PARENT      uniqueidentifier NULL,
    PAR_CONSTANT    bit NOT NULL DEFAULT 0,
    PAR_PRODUCT_QUANTITY bit NOT NULL DEFAULT 0
)
go


ALTER TABLE TBLINV_PARAMETERS
    ADD PRIMARY KEY (PAR_CODE ASC)
go


CREATE TABLE TBLINV_PRODUCT_DEMANDS (
    PD_PRODUCT      uniqueidentifier NOT NULL,
    PD_PERIOD       int NOT NULL,
    PD_PERIOD_TYPE  smallint NOT NULL,
    PD_QUANTITY     float NOT NULL
```

```sql
)
go


ALTER TABLE TBLINV_PRODUCT_DEMANDS
    ADD PRIMARY KEY (PD_PRODUCT ASC, PD_PERIOD ASC)
go


CREATE TABLE TBLINV_PRODUCTS (
    PROD_CODE          uniqueidentifier NOT NULL,
    PROD_NAME          varchar(50) NOT NULL,
    PROD_PRICE         numeric(18,0) NULL,
    PROD_PRIORITY      varchar(1) NULL,
    PROD_SOURCE        uniqueidentifier NULL,
    MODDATE            datetime NULL,
    CREDATE            datetime NULL,
    PROD_HOLDINGCOST   float NOT NULL DEFAULT 0,
    PROD_SHORTAGECOST  float NOT NULL DEFAULT 0,
    PROD_SUPPLYCOST    float NOT NULL DEFAULT 0,
    PROD_UNITCOST      float NOT NULL DEFAULT 0
)
go


ALTER TABLE TBLINV_PRODUCTS
    ADD PRIMARY KEY (PROD_CODE ASC)
go


CREATE TABLE TBLINV_PROJECT_PRODUCT (
    PP_PROJECT         uniqueidentifier NOT NULL,
    PP_PRODUCT         uniqueidentifier NOT NULL,
    PP_MODEL           uniqueidentifier NULL,
    PP_PROUCT_SOURCE   uniqueidentifier NULL,
    PR_CODE            uniqueidentifier NULL,
    PROD_CODE          uniqueidentifier NULL
)
go


CREATE TABLE TBLINV_PROJECTS (
    PR_CODE            uniqueidentifier NOT NULL,
    PR_NAME            varchar(50) NOT NULL,
    PR_DEFAULT_MODEL   uniqueidentifier NOT NULL,
    PR_DESC            varchar(255) NULL,
    MODDATE            datetime NULL,
    CREDATE            datetime NULL,
    MOD_CODE           uniqueidentifier NULL
)
```

```sql
go


ALTER TABLE TBLINV_PROJECTS
    ADD PRIMARY KEY (PR_CODE ASC)
go


CREATE TABLE TBLINV_STARTUP_INVENTORY (
    SI_PRODUCT        uniqueidentifier NOT NULL,
    SI_PROJECT        uniqueidentifier NOT NULL,
    SI_QUANTITY        float NOT NULL DEFAULT 0
)
go


CREATE TABLE TBLINV_STOK_ONCELIKLERI (
    ONCELIK            varchar(1) NOT NULL
)
go


ALTER TABLE TBLINV_STOK_ONCELIKLERI
    ADD PRIMARY KEY (ONCELIK ASC)
go


CREATE TABLE TEMP_INVENTORY (
    INV_PROJECT        uniqueidentifier NOT NULL,
    INV_MODEL        uniqueidentifier NOT NULL,
    INV_PERIOD        int NOT NULL,
    INV_PERIOD_TYPE    int NOT NULL,
    INV_PRODUCT        uniqueidentifier NOT NULL,
    INV_QUANTITY_ACTUAL  float NOT NULL,
    INV_QUANTITY_FORECAST float NOT NULL,
    PD_PRODUCT        uniqueidentifier NOT NULL,
    PD_PERIOD        int NOT NULL,
    PD_PERIOD_TYPE    smallint NOT NULL,
    PD_QUANTITY        float NOT NULL
)
go

CREATE VIEW dbo.VI_INV_FORMULATED_VALUES
AS
SELECT   dbo.TBLINV_PRODUCTS.PROD_CODE,
dbo.TBLINV_PRODUCTS.PROD_NAME,
dbo.TBLINV_PRODUCTS.PROD_PRICE,
         dbo.TBLINV_PRODUCTS.PROD_HOLDINGCOST,
dbo.TBLINV_PRODUCTS.PROD_SHORTAGECOST,
dbo.TBLINV_PRODUCTS.PROD_SUPPLYCOST,
```

```sql
                    dbo.TBLINV_PRODUCTS.PROD_UNITCOST,
ISNULL(dbo.TBLINV_INVENTORY.INV_QUANTITY_ACTUAL, 0) AS
INV_QUANTITY_ACTUAL,

ISNULL(dbo.TBLINV_INVENTORY.INV_QUANTITY_FORECAST, 0) AS
INV_QUANTITY_FORECAST, dbo.TBLINV_INVENTORY.INV_MODEL,
            dbo.TBLINV_INVENTORY.INV_PROJECT,
dbo.TBLINV_INVENTORY.INV_PERIOD
FROM        dbo.TBLINV_PRODUCT_DEMANDS INNER JOIN
            dbo.TBLINV_PRODUCTS ON
dbo.TBLINV_PRODUCT_DEMANDS.PD_PRODUCTS =
dbo.TBLINV_PRODUCTS.PROD_CODE LEFT OUTER JOIN
            dbo.TBLINV_PROJECT_PRODUCT INNER JOIN
            dbo.TBLINV_INVENTORY ON
dbo.TBLINV_PROJECT_PRODUCT.PP_PROJECT =
dbo.TBLINV_INVENTORY.INV_PROJECT AND
            dbo.TBLINV_PROJECT_PRODUCT.PP_PRODUCT =
dbo.TBLINV_INVENTORY.INV_PRODUCT AND
            dbo.TBLINV_PROJECT_PRODUCT.PP_MODEL =
dbo.TBLINV_INVENTORY.INV_MODEL ON
            dbo.TBLINV_PRODUCT_DEMANDS.PD_PERIOD =
dbo.TBLINV_INVENTORY.INV_PERIOD AND
            dbo.TBLINV_PRODUCTS.PROD_CODE =
dbo.TBLINV_INVENTORY.INV_PRODUCT
go




CREATE   PROC INV_DONEMLER_TABLOSUNU_YARAT AS
BEGIN

TRUNCATE TABLE TBLDONEMLER

DECLARE @i INT
SET @i = 0
WHILE @i < 52
BEGIN
     INSERT INTO TBLDONEMLER
     SELECT @i
     SET @i = @i + 1
END
END
go




CREATE  PROC INV_GECICI_ENVANTER_TABLOSUNU_YARAT AS
BEGIN
```

```
if exists (select * from dbo.sysobjects where id =
object_id(N'[dbo].[TEMP_INVENTORY]') and OBJECTPROPERTY(id,
N'IsUserTable') = 1)
drop table [dbo].[TEMP_INVENTORY]


SELECT * INTO TEMP_INVENTORY
FROM TBLINV_INVENTORY INV, TBLINV_PRODUCT_DEMANDS PD
WHERE INV_PRODUCT = PD_PRODUCT
AND INV_PERIOD = PD_PERIOD
END
Go
```

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Appendix – C

Sample Code of software Application

```
Option Explicit

Dim aParamsAvailable
Dim aFormula

Private Sub cmdDelete_Click()
    Dim aCode
    nReturn = MsgBox("Emin misiniz?", vbExclamation + vbYesNo)
    If nReturn = vbNo Then Exit Sub
    aCode = Array()
    ReDim aCode(0, 0)
    aCode(0, 0) = oINVModel.sUniqueIdentifier

    sSQL = "DELETE FROM TBLINV_MODELPARAMETERS WHERE
MOD_CODE = '" & oINVModel.sUniqueIdentifier & "'"
    WriteData sSQL

    sSQL = "DELETE FROM TBLINV_MODELS WHERE MOD_CODE = '" &
oINVModel.sUniqueIdentifier & "'"
    WriteData sSQL
    frmAddProject.ListModels
    MyFormUnload
End Sub

Private Sub Form_Load()
    Dim i As Integer
    Dim j As Integer
    Dim k As Integer
    Dim sFormula As String
    Dim aArray
    Dim sSignParameterCode As String
```

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```vb
    If IsArray(aFormula) Then Erase aFormula
    aFormula = ""
    txtConstant.Visible = False
    sSQL = "SELECT PAR_CODE, PAR_NAME, PAR_FIELD, PAR_CONSTANT,
PAR_PRODUCT_QUANTITY, PAR_ISSIGN "    sSQL = sSQL & " FROM
TBLINV_PARAMETERS "
    sSQL = sSQL & " ORDER BY PAR_CONSTANT, PAR_ISSIGN,
PAR_SIGNORDER, PAR_PRODUCT_QUANTITY, PAR_NAME"
    aParamsAvailable = GetData(sSQL)
    If IsArray(aParamsAvailable) Then
        lstParamsAvailable.Clear
        For i = 0 To UBound(aParamsAvailable, 2)
            If aParamsAvailable(5, i) = 0 Then
                lstParamsAvailable.AddItem aParamsAvailable(1, i)
            End If
        Next i
    End If
    cmdDelete.Visible = False
    If (oINVModel.sUniqueIdentifier <> "") Then
        cmdDelete.Visible = True
        txtProjectName.Text = oINVModel.sName
        txtDescription.Text = oINVModel.sDescription

        sSQL = " SELECT PAR_CODE, PAR_NAME, PAR_PRODUCT_QUANTITY,
PAR_CONSTANT, PAR_ISSIGN, PAR_SIGNORDER, MP_CONST_VALUE" &
vbCrLf
        sSQL = sSQL & " FROM TBLINV_MODELPARAMETERS MP,
TBLINV_PARAMETERS PAR " & vbCrLf
        sSQL = sSQL & " WHERE MP.MP_CODE = PAR_CODE " & vbCrLf
        sSQL = sSQL & "     AND MP.MOD_CODE = '" &
oINVModel.sUniqueIdentifier & "'" & vbCrLf
        sSQL = sSQL & " ORDER BY MP_SEQUENCE" & vbCrLf
        aArray = GetData(sSQL)
        If IsArray(aArray) Then
            sFormula = ""
            For i = 0 To UBound(aArray, 2)
                For j = 0 To lstParamsAvailable.ListCount - 1
                    If (aArray(0, i) = aParamsAvailable(0, j)) Then
                        lstParamsAvailable.ListIndex = j
                        Exit For
                    End If
                Next j
                If (CBool(aArray(3, i))) Then
                    sFormula = sFormula & SetFormula(CStr(aArray(6, i)), CBool(aArray(3,
i)), CInt(aArray(5, i))) & " "
                Else
                    sFormula = sFormula & SetFormula(CStr(aArray(1, i)), CBool(aArray(3,
i)), CInt(aArray(5, i))) & " "
                End If
            Next i
```

```
        SetFormulaCaption sFormula
      End If
    End If
End Sub

Private Sub cmdOK_Click()
    Dim i As Integer
    Dim j As Integer
    Dim sCode
    Dim aCode
    Dim sConstValue As String
    Dim sSignAfter As String

    If (txtProjectName.Text = "") Then
      MsgBox "Giriş gereklidir.", vbExclamation
      txtProjectName.SetFocus
      Exit Sub
    End If

    txtDescription.Text = ChangeApos(Replace(Replace(txtDescription.Text, vbCr, "
"), vbLf, " "))
    txtProjectName.Text = ChangeApos(txtProjectName.Text)

    If (oINVModel.sUniqueIdentifier <> "") Then
      aCode = Array()
      ReDim aCode(0, 0)
      aCode(0, 0) = oINVModel.sUniqueIdentifier

      sSQL = "DELETE FROM TBLINV_MODELPARAMETERS WHERE
MOD_CODE = '" & oINVModel.sUniqueIdentifier & "'"
      WriteData sSQL

      sSQL = "DELETE FROM TBLINV_MODELS WHERE MOD_CODE = '" &
oINVModel.sUniqueIdentifier & "'"
      WriteData sSQL
    Else
      aCode = GetUniqueID
    End If
    sCode = ""

'UBound0 - 0      : satır numarası
'UBound1 -    0  : alan adı
'UBound1 -    1  : Description
'UBound1 -    2  : Kod
'UBound1 -    3  : IsConstant
'UBound1 -    4  : Is QTY of Product
'UBound2 -        : "sabit sayılar" / "işaretler" topluluğu
```

```vb
      sSQL = "INSERT INTO TBLINV_MODELPARAMETERS ( MOD_CODE,
MP_CODE, MP_SEQUENCE, MP_CONST_VALUE )" & vbCrLf
   For i = 0 To UBound(aFormula, 2)
      If aFormula(2, i) Then
         sCode = sCode & " " & aFormula(3, i)
      Else
         sCode = sCode & " " & aFormula(1, i)
      End If
      sSQL = sSQL & " SELECT '" & aCode(0, 0) & "', '" & aFormula(0, i) & "', " & i
& ", '" & aFormula(3, i) & "'" & vbCrLf
         sSQL = sSQL & " UNION ALL"
   Next i
   sSQL = Mid(sSQL, 1, Len(sSQL) - Len(" UNION ALL"))
   WriteData sSQL

   sSQL = " INSERT INTO TBLINV_MODELS ( MOD_CODE, MOD_NAME,
MOD_DESC, MOD_FORMULA )"
   sSQL = sSQL & " SELECT '" & aCode(0, 0) & "', '" & txtProjectName.Text & "', '"
& txtDescription.Text & "', '" & sCode & "'"
   WriteData sSQL
   frmAddProject.ListModels CStr(aCode(0, 0))
   MyFormUnload
End Sub

Private Function SetFormula(sValue As String, bConstant As Boolean, Optional
iIndex As Integer = -1) As String
   Dim UBound1 As Integer
   Dim UBound2 As Integer
   Dim bFound As Boolean
   Dim i As Integer
   Dim j As Integer
   Dim aFormulaTemp
   Const CONST_UBOUND2 = 4

'UBound0 - 0       : satır numarası
'UBound1 -     0 : alan adı
'UBound1 -     1 : Description
'UBound1 -     2 : vt alan adı
'UBound1 -     3 : IsConstant
'UBound1 -     4 : IsQTY
'UBound2 -         : "sabit sayılar" / "işaretler" topluluğu

   If Not IsArray(aFormula) Then
      aFormula = Array()
      ReDim aFormula(3, 0)

      UBound1 = 3
      UBound2 = 0
   Else
      UBound1 = UBound(aFormula, 1)
```

```vb
    UBound2 = UBound(aFormula, 2) + 1

    ReDim Preserve aFormula(UBound1, UBound2)
  End If

  If (iIndex >= 0) Then
    aFormula(0, UBound2) = aParamsAvailable(0, lstParamsAvailable.ListCount + iIndex) ' kod
    aFormula(1, UBound2) = aParamsAvailable(2, lstParamsAvailable.ListCount + iIndex) ' vt alani
    aFormula(2, UBound2) = bConstant ' sabit mi
    aFormula(3, UBound2) = sValue   'sabitse değeri
  Else
    aFormula(0, UBound2) = aParamsAvailable(0, lstParamsAvailable.ListIndex) ' code
    aFormula(1, UBound2) = aParamsAvailable(2, lstParamsAvailable.ListIndex) ' code
    aFormula(2, UBound2) = bConstant ' sabit mi
    aFormula(3, UBound2) = sValue   'sabitse değeri
  End If

  SetFormula = sValue
End Function

Private Sub MyFormUnload()
  If IsArray(aFormula) Then Erase aFormula
  aFormula = ""
  Unload Me
End Sub

Private Sub cmdAddConstant_Click()
  Dim sValue As String
  sValue = SetFormula(txtConstant.Text, True)
  SetFormulaCaption sValue
End Sub


Private Sub cmdCancel_Click()
  MyFormUnload
End Sub

Private Sub cmdClear_Click()
  lblFormula.Caption = ""
  If IsArray(aFormula) Then Erase aFormula
  aFormula = ""
End Sub

Private Sub cmdSigns_Click(Index As Integer)
'   If lblFormula.Caption = "" Then Exit Sub
  Dim sValue As String
```

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```vb
    Select Case Index
        Case 0, 1, 2, 3, 4, 5 '+
            sValue = SetFormula(cmdSigns(Index).Caption, False, Index)
        Case 6 'u
            'SetFormula "^" & txtConstant.Text, Sign
            sValue = SetFormula("POWER(", False, Index)
        Case 7 'k
            sValue = SetFormula("SQRT(", False, Index)
    End Select
    SetFormulaCaption sValue
End Sub


Sub SetFormulaCaption(sFormula As String)
    lblFormula.Caption = lblFormula.Caption & " " & sFormula
End Sub


Private Sub Form_Unload(Cancel As Integer)
    MyFormUnload
End Sub


Private Sub lstParamsAvailable_Click()
    If lstParamsAvailable.ListIndex = lstParamsAvailable.ListCount - 1 Then
        txtConstant.Text = ""
        txtConstant.Visible = True
    Else
        txtConstant.Visible = False
    End If
End Sub


Private Sub lstParamsAvailable_DblClick()
    Dim sValue As String

    If (lstParamsAvailable.ListIndex = -1) Or (lstParamsAvailable.ListIndex =
lstParamsAvailable.ListCount - 1) Then
        txtConstant.SetFocus
        Exit Sub
    End If
    sValue = SetFormula(lstParamsAvailable.List(lstParamsAvailable.ListIndex),
False)
    SetFormulaCaption sValue
End Sub


Private Sub txtConstant_KeyPress(KeyAscii As Integer)
    If (KeyAscii = vbKeyReturn) Then
        If (txtConstant.Text = "") Then Exit Sub
        cmdAddConstant_Click
    End If
End Sub
```

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CURRICULUM VITAE

Boğaç ÖZGEN, was born in 5th January of 1978 in Erzurum as the only child of Nadire and Osman Şahin ÖZGEN who are the most important personalities in his life.

He completed his elementary school education in İzmir. He continued his education at Buca Anatolian High School for the secondary school. After moving to Ankara because of his father's assignment, he started to study in Gazi Anatolian High School. These years were the milestones of his life where he started to change it.

Until his graduation from Dokuz Eylül University, he resided in İzmir, where he first met his precious jewelry "Evrim Numanoğlu" in 1996. This meeting was the second milestone of his life. At the beginning of the 4th year in university he entered into the exited world of computers and computer science. This meeting was the key enabler of his professional life.

After graduation from the university, he moved to İstanbul. He started his first real-time job in CoreTech Information Technology Services Inc. While he continued his professional life, he decided to attend to a "Master of Science Program" at "Marmara University" which he re-learned all the subjects related to his under-graduate education.

He still works for Meteksan System and Computer Technologies Inc. as Senior Technical Business Intelligence Consultant and got married with Evrim NUMANOĞLU. They have no child yet.

T.C.
MARMARA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

KABUL VE ONAY BELGESİ

Implementation of Inventory Control on Manufacturing Industry

Boğaç ÖZGEN'in "Implementation of Inventory Control on Manufacturing Industry" isimli Lisansüstü tez çalışması, M.Ü. Fen Bilimleri Enstitüsü Yönetim Kurulu'nun 22/03/2006 tarih ve B.30.2.MAR.0.C1.00.00.sek/973 sayılı kararı ile oluşturulan jüri tarafından "Mühendislik Yönetimi" Anabilim Dalı "Mühendislik Yönetimi" Programında YÜKSEK LİSANS Tezi olarak Kabul edilmiştir.

Danışman   : Prof. Dr. Emin ARCA, Marmara Üniversitesi

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Tezin Savunulduğu Tarih : 30/03/2006

ONAY

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Prof. Dr. Adnan AYDIN
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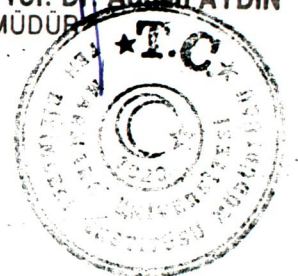
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