DESIGNING A PRODUCTION AND INVENTORY MANAGEMENT SOFTWARE FOR A MAKE-TO-ORDER COMPANY

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by

Elmas Alkan GENÇALP

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İZMİR

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We certify that we have read the thesis, entitled **"DESIGNING A PRODUCTION AND INVENTORY MANGEMENT SOFTWARE FOR A MAKE-TO-ORDER COMPANY"** completed by **ELMAS ALKAN GENÇALP** under supervision of PROF DR. ALP KUT and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Prof. Dr. Alp KUT

Supervisor

Doç.Dr. Yalçın ÇEBİ

Committee Member

Yrd.Doç.Dr. R. Cenk Erdur

Committee Member

Approved by the

Graduate School of Natural and Applied Sciences

Prof.Dr.Cahit Helvacı

Director

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E. Alkan GENÇALP

ABSTRACT

Importance of production planning , specially material planning is increasing day by day. Causes of this situation are cost of excess or lack of materials. If materials are not enough then this situation creates unsatisfactory customers because of shipping time lags. And excessive materials create handling costs. So Material Requirement Planning(MRP), which is module of Enterprises Resources Planning(ERP) package, is used widely in industry to obtain right part's required quantity at the right time. In this project, planning systems were analysed, specially MRP systems were examined deeply. At the application part system analysis of a textile company was done for developing computer based production and inventory management system. Database and Graphical User Interfaces'(GUI) were developed according to results of analysis.

ÖZET

Üretim planlamanın, özellikle de malzeme ihtiyaç planlamasının önemi gün geçtikte daha da artmaktadır. Bunun nedeni ise gereğinden fazla veya eksik enventerlerin yaratacağı maliyettir. Eksik envanter, yüklemenin gecikmesinden kaynaklanan müşteri memnuniyetsizliği, fazla envanter ise elde taşıma maliyeti oluşturacaktır. Bunlardan dolayı, KKP'nin(Kurumsal Kaynak Planlaması) bir parçası olan ve doğru malzemenin doğru zamanda doğru miktarda bulunmasını sağlayan MIP(Malzeme İhtiyaç Planlaması) sistemleri yaygın bir kullanım alanı bulmuştur. Bu çalışmada planlama faaliyetleri, özellikle de malzeme planlama faaliyetleri incelenmiş ve uygulama kısmı için bir tekstil işletmesinde bilgisayara dayalı üretim ve stok kontrol sistemi tasarımı için sistem analizi , veritabanı çalışması yapılmış ve grafiksel kullanıcı arayüzleri tasarlanmıştır.

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CHAPTER ONE
INTRODUCTION

1. Introduction

Todays, manufacturers face with many challenges at the increasing competitive marketplace these are improving quality, reducing costs and wastes and improving their competitive position. Aims of effective enterprise management can be categorized at the two categories. First one is customers' satisfaction related with the price, delivering, service and quality factors. Another one is producer's satisfaction with getting possible profitability and paying off of investment. Obtaining these satisfactions simultaneously shows that existence of effective enterprise management. But these aims can be realized simultaneously with execution of purchasing, production, marketing and finance operations with interactions. It is clear that this interaction can be obtained using management information software, which contains common database for all departments.

MRP (Material Requirement Planning), MRP II (Manufacturing Resource Planning) and ERP (Enterprise Resource Planning) softwares are used to achieve these aims.

MRP schedules time phased quantity of component and material requirements using a database, which consists of technical information like MPS (Master Production Schedule), BOM (Bill of materials), inventory and supplier/customer file records to meet the dependent and/or independent demands of customers. So interaction of purchasing and production planning departments can be obtained with MRP. Namely, MRP is a system that brings the right parts to the right place at the

right time. It also allows management to react quickly when large and various order are being placed.

However, MRP is used to improve scheduling and inventory management, it takes into consider only purchasing and planning departments. For this reason, at the 1980's MRP II had been developed to maximize utilization of the resources at their disposal. MRP II is a philosophy that attempts to incorporate the other relevant activities of a firm into the production planning process. At the Figure 1.1 flowchart of MRPII system can be seen.

And at the 1990's MRPII was expanded with engineering, human resources, project management, distribution, service, transportation, and supply chain management modules. ERP (Enterprises Resources Planning) is the name of this completely solution.

As a result, with effect of globalization, most important factors of competition are cost of the products and satisfaction of the customers. Cost of the products can be reduced by means of using resources effectively. Satisfaction of the customers can be increased with improving quality, service and delivery factors. Because of these points, companies, especially at the manufacturing industry uses computer based production and inventory control systems.

So content of the project is designing computer based production and inventory control software for a make-to-order company. As a previous work, I researched the production planning systems. Next chapter's content consists of this research. And chapter three constitutes system analysis and designing processes.

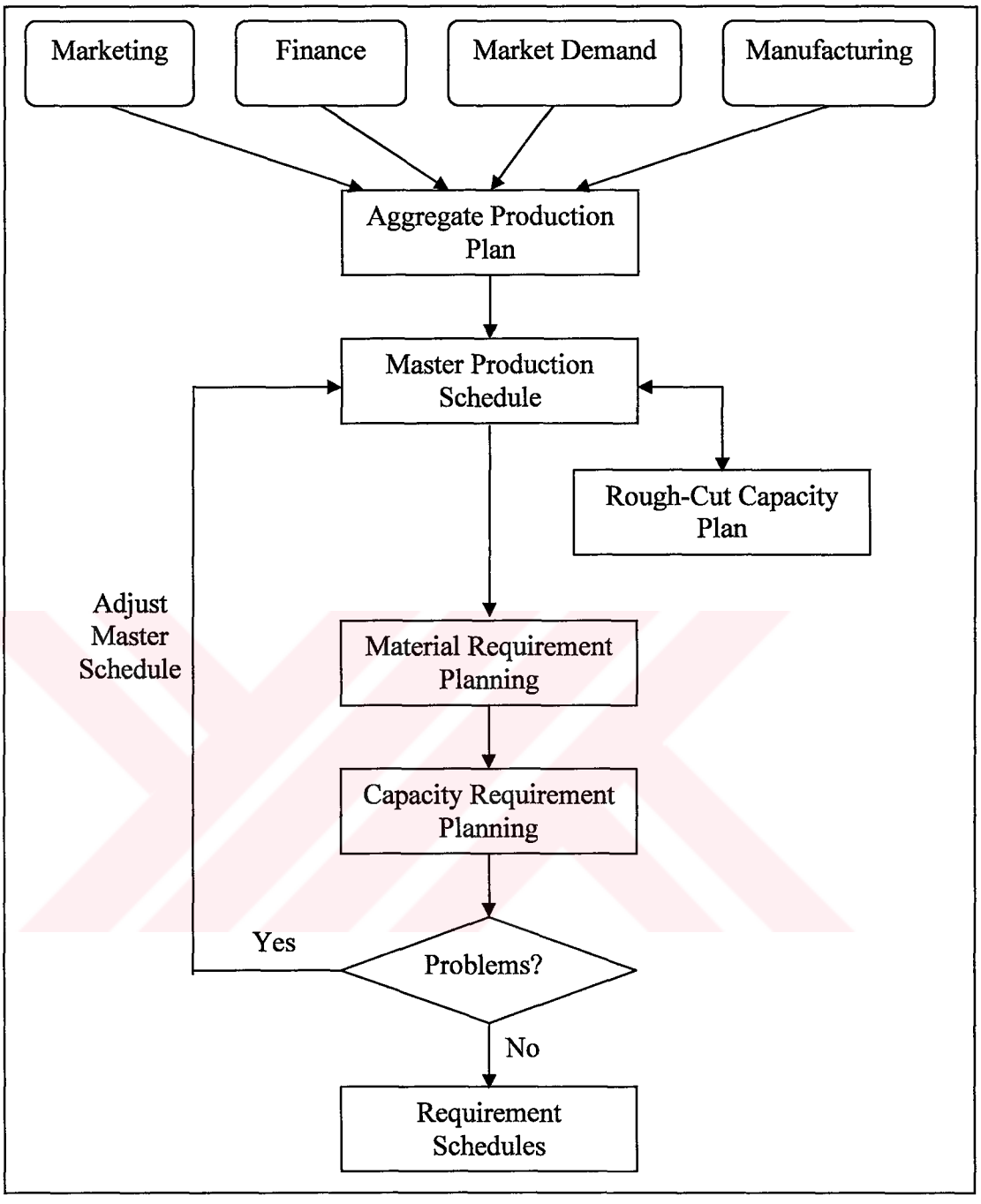

Figure 1.1 Overview of MRP II

CHAPTER TWO
PREVIOUS STUDY

2. Previous Study

This chapter includes theoretical part of the study. Before designing process, I researched the production planning systems. Because aim of the project is "Designing Computer Based Production and Inventory Control System". So giving these theoretical informations are useful for understanding the chapter three clearly.

Production Planning Systems were explained sequencely that from long range planning to short range planning. If we classified planning systems according to time horizon, Business Plans (long-range), Aggregate Plans (Intermediate Range), Master Production Schedule (Intermediate Range) and Material Requirement Planning (Short Range) are obtained. Figure 2.1 shows aims of these plans.

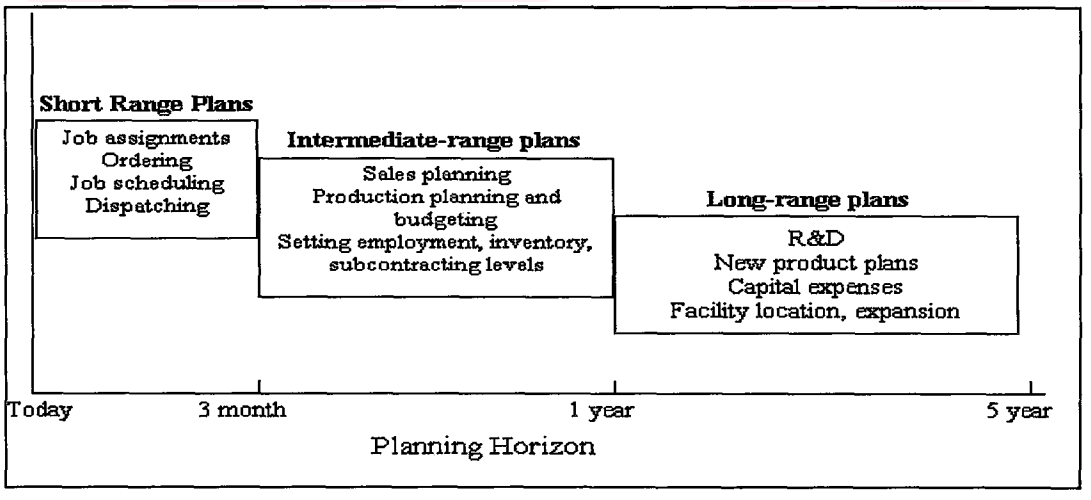

Figure 2.1 Time Phased Plans

Because of limited resources, these plans must be validated using capacity plans. Capacity Plans checks feasiblity of production plans according to required resources

that can be machines as a machine hours and/or employees as a labor. So Rough Cut Capacity Planning (RCCP) and Capacity Requirement Planning systems (CRP) are used. RCCP gets Master Production Schedule as an input and controls available aggregate resources versus required resources. CRP is more detailed plan than RCCP. Because its input is MRP's output.

Now I will explain these systems sequencely. Business Plan and Aggregate Production Plan will be explained in same heading.

2.1 Aggregate Production Planning

Intermediate range planning describes the rate of production considering sales forecast, factory capacity, inventory levels and the size of work force to reach some goals that objectives of minimizing cost and meeting demand. It seeks to find that combination of monthly work force levels and inventory levels that minimize total production-related costs through planning period. Intermediate range describes range of three months to one year. It is also known as aggregate planning. Steps of planning process can be seen in Figure 2.2.

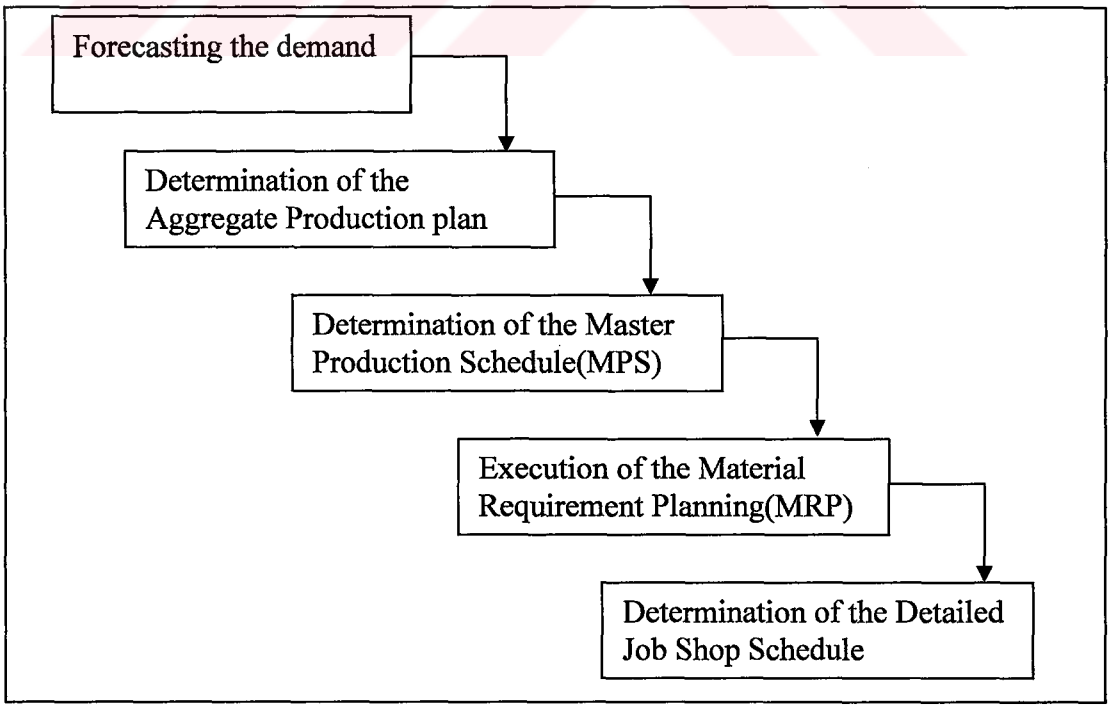

Figure 2.2 Steps of Planning Process

Aggregate plans translate annual and quarterly business plans into intermediate term production plans. Business plans establishes production and capacity strategies. Aggregate plans establish production capacities. So output of the business plan is used by the aggregate plan and the output of the aggregate plan used by the master production schedule. Master production schedule establishes schedules for specific products. This flow is illustrated in Figure 2.3.

In manufacturing organizations aggregate planning usually means determining the size of the work force, the rate of production and inventory level that are needed to implement a production plan. So aggregate plan determines workforce levels, overtime and inventory levels considering objectives of minimizing cost and meeting demand. Common measuring resource and output units are used with aggregate plans. Aggregate resources are like total number of workers, hours of machine time, tons of raw materials and aggregate outputs like gallons of paint in a paint factory, number of dresses, cases of beer in a brewery, hours of service delivered. In service organizations aggregate planning usually means scheduling staff to meet customers' service needs.

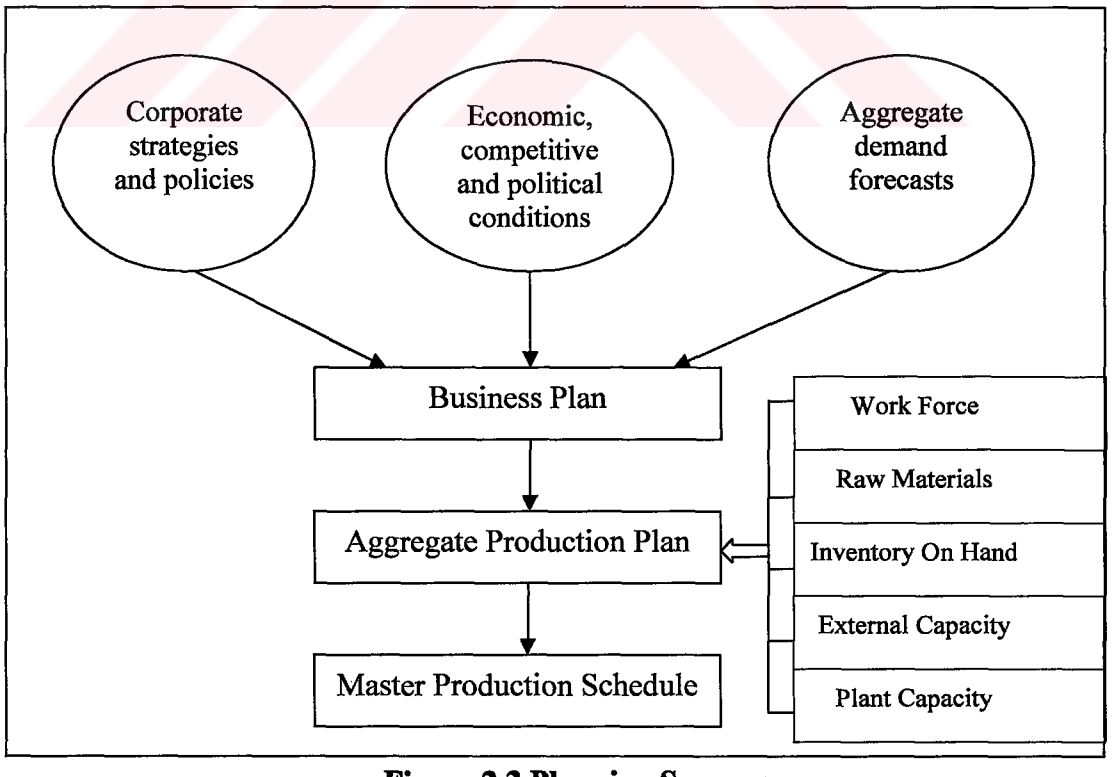

Figure 2.3 Planning Sequence

In aggregate planning, the operations planner makes decisions about intermediate-range capacity without getting into details of specific products, parts, or people.

2.1.1 Pure Strategies

Aggregate planning strategies involve the decisions about the inventory, production rate, manpower needs, capacity and other controllable variables. "When we vary any one of the variables at a time to cope with changes in product output rates, we use what are known as pure strategies". (Narasimhan et al.,1995, pp.256-257)

- **Changing Inventory Levels:** Managers can increase the inventory levels during the slack periods of demand to meet demands, which can be high, in the future.
- **Changing Workforce Levels:** To meet the demand exactly, manager can apply hiring or laying off production employees' strategies. But new employees require training. And productivity of these employees will be lower. A layoff causes lower worker morale and lower productivity. In a service sector part time workers can fill unskilled labor needs. Another solution is constant workforce and varies the working hours. But extreme work time causes lower productivity and absorbing idle time of workers in a slack demand periods is difficult task.
- **Subcontracting:** A firm can also acquire temporary capacity by subcontracting some work during peak demand periods.
- **Influencing Demand:** Firm can apply some strategies to increase demand in slack demand periods like promoting, discount. For example, airline industry offers weekend discounts and fares. And in the high demand periods firms apply backordering. Back orders are orders for goods or services that a firm accepts but is unable to fill at the moment.

2.1.2 Mixed Strategies

In an industry often mixing of pure strategies are used. Because pure strategies are often infeasible. So applying possible pure strategies together works best. Mixed strategies involve the combination of two or more controllable variables to set a feasible production plan. For example, a firm might use a combination of overtime, subcontracting, and inventory leveling as its strategy.

Manager constructs alternative plans and chooses one of them considering costs of the units. Cost components of aggregate production planning are: Hiring costs, lay off costs, overtime and undertime costs, inventory carrying costs, subcontracting costs, part time labor costs, stockout or backorder costs.

2.2 Master Production Schedule (MPS)

Master Production Schedule translates the aggregate plan into a short-term master plan for production. It is a series of time-phased quantities for each item that are produced by the company. So MPS indicates that how many items must be produced and when they must be produced. All other schedules in MRP are based on the MPS. Relationship of MPS with other planning activities can be seen in figure 2.4.

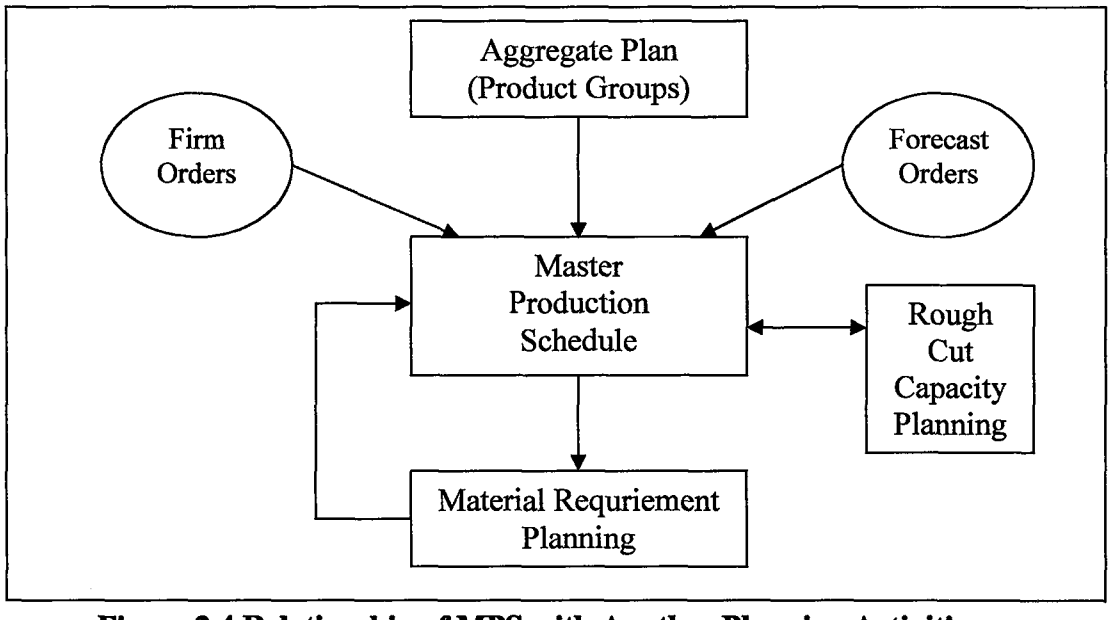

Figure 2.4 Relationship of MPS with Another Planning Activities

Aggregate plan and MPS should be consistent with each other. Because MPS is derived from aggregate production plan. The output of the aggregate planning process is usually a production schedule for family groups of the products. It tells a manufacturer production rate of the product groups. For example, it tells an auto manufacturer how many cars must be produced, but not how many should be two doors versus four doors or red versus green. The process of breaking the aggregate plan down into greater detail is called disaggregation. Linear Programming techniques can be used for disaggregation process. Table2.1 illustrates part of the MPS.

Table 2.1 Master Production Schedule Example

ITEM	WEEK NUMBER										
	1	2	3	4	5	6	7	8	9	10	11
Product A						100			100		100
Product B			60			60	120		60		
Product C					150					90	
Aggregate Plan	60				430				350		

This master schedule shows plans based on time blocks, or time "buckets", equal to one week. It indicates, for example, that the company plans to produce 100 unit of product A in week 6,100 in week 9 and 100 in week 11.

2.3 Rough Cut Capacity Planning (RCCP)

The master schedule is the primary information source for rough-cut capacity planning. When trial master production schedule is completed then it is checked against capacity constraints. This is called Rough Cut Capacity Planning (RCCP). So RCCP can be used to evaluate the feasibility of trial MPS and to plan how to make the needed capacity available before the time periods enter the time fence and execution must begin.

"Historical ratios are used to distribute a load of products across the various workstations (or work centers). The ratios gives the number of work hours needed in each station to produce one of each type of the product". (Meredith, 1992, p.395) If

a workstation is overloaded, additional capacity must be found or the MPS must be changed. If the work center's capacities are not overloaded (underloads are also checked), it is assumed that sufficient capacity exists to handle the master schedule and it is accepted for production.

2.4 Material Requirement Planning

Based on master schedule which is derived from a production plan, a material requirements planning (MRP) system creates schedules identifying the specific parts and materials required to produce end items, the exact numbers needed, and the dates when orders for these materials should be released and be received or completed within the production cycle. MRP's logic differs from classical inventory management systems.

2.4.1 Dependent and Independent Demand

Inventory management systems considers that items are independent and necessary items are calculated one by one whatever it is that end item or not. But in the MRP system, demand of end item is independent but its subassemblies and raw materials depend on their parent items demand.

"But sometimes an item appears to be dependent but its parent is unknown". (Schonberger, Knod, 1991, p.337) This situation occurs specially items, which are also used for service operations. Independent demands are also handled by MRP systems and they are often called time phased order point (TPOP). So dependent demands are calculated from its parent item but independent demands are forecasted items (TPOP). While MRP computation is done, the independent demand is merged with demands that are calculated by MRP. Managers usually keep safety stock on hand for independent demands because of probability of inaccurate forecast.

2.4.2 The Mechanics of the MRP

MRP is a production and inventory management system. So it gives both production and inventory information to make a plan. Figure 2.5 shows primary inputs and outputs of the MRP systems.

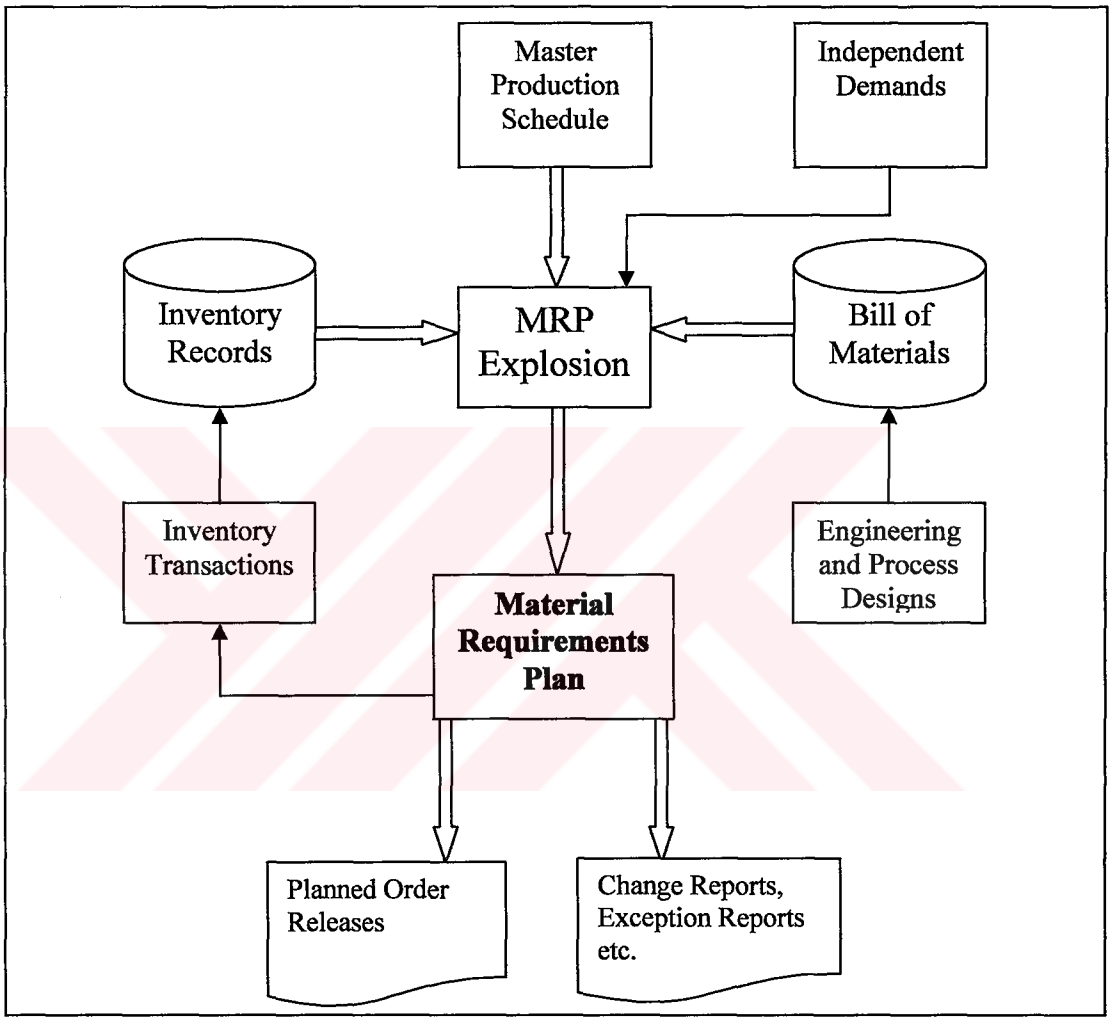

Figure 2.5 Schematic of MRP system

2.4.2.1 Inputs of the MRP

Primary inputs are:

1. The Master Production Schedule
2. The Bill of Materials File
3. The Inventory Master File

2.4.2.1.1 Master Production Schedule

As explained before it is derived from production plan and based on actual customer orders and predicted demand. It is time phased end items plan that indicates exactly when item will be produced to meet customers and forecasted demand.

2.4.2.1.2 The Bill of Materials (BOMs)

A bill-of-material (BOM) is a list of quantities of components, ingredients, and materials that are required to make a product. The BOM file is often called the product structure file or product tree, since it shows how a product is put together. "The MRP system accesses the Bill of Materials File to determine exactly what items, and in what quantities, are required to complete an order for a given item". (Meredith, 1992, p.459)

BOMs can be represented with three different ways. They are cross-classification chart, product structure tree and indented bill of material.

2.4.2.1.2.1 Cross-Classification Chart

It represents the relationships among parts using matrix. Table 2.2 shows end items 1's and 2's parts.

Table 2.2 Cross-Classification Chart

	Subassembly (SA)		**Part (P)**		**Raw Material(RM)**	
Item	***3***	***4***	***5***	***6***	***7***	***8***
1	1	2				
2	1	4				
3			2	4		
4			1	2		
5						3
6					2	

According table we calculate BOMs of Product1. So Product 1 requires one unit subassembly 3 and two units subassembly 4. Sub assembly 3 requires two units part 5 and four units part 6. Subassembly 4 requires one unit part 5 and two units part 6. Finally part 5 requires three units raw material 8 and part6 requires two units raw material 7.

2.4.2.1.2.2 Product Structure Tree

This technique is commonly used to show parts and quantities of items that are needed to produce one unit end item. In this technique level degrees are assigned to each part. Simple illustration of method can be seen in Figure 2.6.

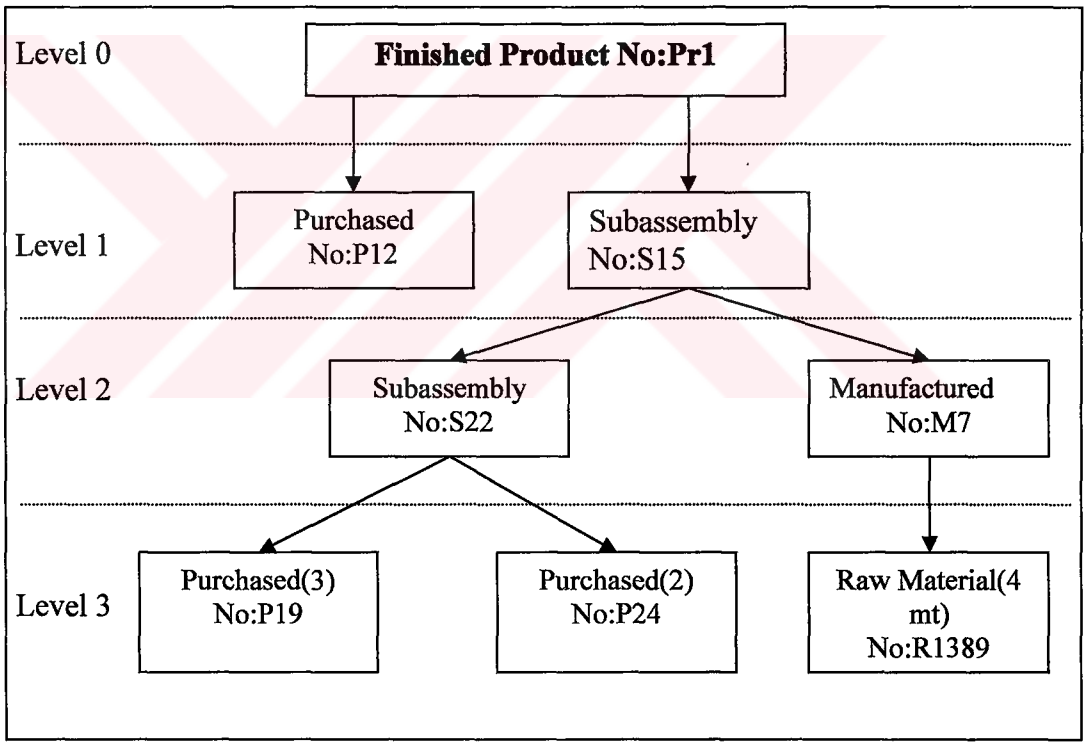

Figure 2.6 Product Structure Tree

This figure shows that product1 consist of one unit P12 and one unit S15. S15 consist of one unit S22 and one unit M7. S22 consist of three units P19 and two units P24. M7 consist of 4 meter R1389. So bill of materials of product1 can be seen in Table 2.3.

Table 2.3 Bill of Materials for a Three Level Product

Part Name	Level	Type	Quantity	Description	Source
P12	1	unit	1	...	Purchased
S15	1	unit	1	...	Manufactured
S22	2	unit	1	...	Manufactured
M7	2	unit	1	...	Manufactured
P19	3	unit	3	...	Purchased
P24	3	unit	2	...	Purchased
R1389	3	meter	4	...	Purchased

2.4.2.1.2.3 Indented Bill of Material

It is similar like other kind of bill of material structures that exhibits how much of what material is required. Additionally, it shows what order an end product is manufactured. To understand clearly we can look at Table 2.4 below.

Table 2.4 Indented Bill of Materials for Product1

Level	Quantity	Type	Part Number	Description
.1	1	unit	P12	...
.1	1	unit	S15	...
..2	1	unit	S22	...
...3	3	unit	P19	...
...3	2	unit	P24	...
..2	1	unit	M7	...
...3	4	meter	R1389	...

So we understand that Product1's subassemblies are P12 and S15. And P12 doesn't have subpart and S15's sub parts are S22 and M7. P19's and P24's parent item is S22. R1389's parent item is M7.

As a result the BOMs contain information about inputs of the end product, such as part numbers, descriptions, quantity needed for each part number, and the unit of measure. All items in the BOM must be uniquely numbered and identified.

2.4.2.1.3 The Inventory Master File

The inventory master file contains detailed information about each item. It is also called the item master file. It contains the part number, which is the unique item identifier, and other information such as lead time, standard cost, item description, list of vendors and lot size. And number of quantity on hand, on order and committed to use in various time periods information also handled by inventory master file.

After exploding the BOMs, MRP accesses the inventory master file to control needed item is available or not in a given time period. If enough item is available to meet the order needs, they are committed for use during the time period and the inventory master file is updated. If there are not sufficient items available then items are added to the planned order release report with lot sized quantity.

Basically, the job of the inventory master file is to keep data about the projected use and receipts of each item and to determine the amount of inventory that will be available in each time bucket. If the projected available inventory is not adequate to meet the requirement in a period, the MRP program will recommend that the item be ordered. Example of the item master file is at the Table 2.5 below.

Table 2.5 The Item Master File Table

Description		**Inventory Policy**	
Item Name		Lead Time	
Item No		Annual Demand	
Item Type		Holding Cost	
Value Class(A,B,C)		Ordering/Setup Cost	
Vendor		Safety Stock	
Unit price/cost		Reorder Point	
Lowest Level Code		Economic Ord. Qty.	
		Min/Max Ord. Qty	
Physical Inventory		**Usage**	
On Hand		Year to Date Usage	
Location		Month to Date Usage	
On Order		Year to Date receipts	
Allocated		Mont to Date Receipts	
Last Count Date		Last Receipt Date	

The time allowed to complete the job from start to finish is known as the lead time. The lead time may be either the time required from the beginning of the purchase to the receipt (an ordering lead time) or the time to process the finished product from the raw materials (a manufacturing lead time). The MRP system can use these items to help the purchasing department. Field definitions of the item master file are below.

Item No: Unique no of the item

Item Type: Manufacturing or purchasing item

Value Class: Class of the item after using ABC analysis technique

Lowest Level Code: Lowest level of the item in the BOM file

Year to date usage: Quantity of used item for beginning of the year

Month to date usage: Quantity of used item for beginning of the month

Year to date receipt: Quantity of received item for beginning of the year

Month to date receipt: Quantity of received item for beginning of the month

Last receipt date: Date of the last received lot

Until now I explained MRP systems' inputs. Next step is outputs of the MRP. Basically during the MRP computation purchasing and manufacturing requirements are computed based on inputs of master production schedule, bill of materials and item master file. Flowchart of this process is illustrated in Figure 2.7.

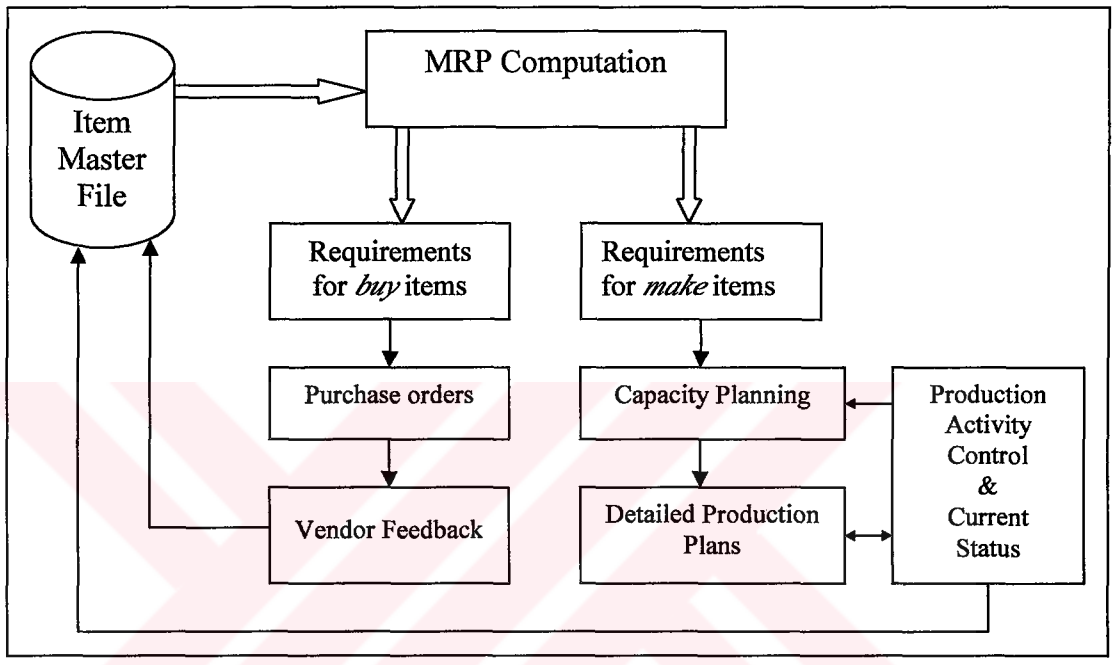

Figure 2.7 Basically outputs of The MRP

2.4.2.2 Outputs of the MRP

A variety of reports can be constructed by a MRP program. The primary reports can be grouped into five general categories.

- *Open Order Releases Report* indicates the quantity of each item to order in the current time period
- *Planned Order Releases Report* (shown by the inventory master file for each item) indicates the quantity and timing of orders to be released in future periods
- *Revision Notices* indicates changes in quantity that should be made on open orders.

- *Reschedule notices* indicates which order's due dates need to be changed and the dates to which they should be changed
- *Order Action Notices* indicates any open orders that should be cancelled or suspended because there is no longer a net requirement within the planning horizon.

MRP can also provide reports that can be used to determine feasible delivery dates for customer orders. When a potential customer order is entered into the master schedule for evaluation, the system backs up by the lead times and checks inventory availability at each level of the production process to see if sufficient lead time and materials are available to fill the order on time. After capacity requirements planning, the system will provide additional evaluation of whether the customer's requested delivery date is feasible or not. The company can evaluate alternative delivery dates and then select a reasonable date.

Secondary reports can be obtained from the system to indicate errors. Such messages indicate a wide variety of conditions such as alphabetic information in a numeric field, non-existent part numbers or transaction codes, a number of digits too great for a field size, or indicated dates for a requirement that is outside the planning horizon. This type of information is helpful in guarding against erroneous inputs.

2.4.3 MRP Lot Sizing

"In conjunction with scheduling orders to be released (i.e., the "when to order" decision), the second major inventory management question "how many to order," must also be answered." (Meredith, 1992, p.465) Appropriate lot size is calculated considering setup cost with inventory holding costs.

Another important topic is related with lot sizing is the time allowed to complete the job from start to finish is known as the lead time. The lead time may be either the time required from the beginning of the purchase to the receipt (an ordering lead time) or the time to process the finished product from the raw materials (a

manufacturing lead time). There is several lot sizing methods. Most used methods are described below.

2.4.3.1 Lot-for-Lot Method (L-4-L)

This method is commonly used because of its simple applicable. Net requirement is ordered considering the lead time of it. Consequently, there is no holding cost in this method and the average cost per period is determined by the setup cost for that period. An example can be seen in Table 2.6.

Table 2.6 Lot for Lot Method

Lead Time: 2 week	**Item:S12**			
Lot Size:L-4-L	**Description: Seat subassembly**			
Week	1	2	3	4
Planned Order Receipt	0	0	40	50
Planned Order Release	40	50		

Third week 40, fourth week 50 unit of S12 part is required. Considering the lead time, orders are opened two weeks before. And order size is equal to what quantity is needed.

2.4.3.2 Fixed Order Quantity (FOQ)

This method commonly used items that have higher ordering/setup cost. Determined lot size is distributed through time periods considering the net requirements.

Appropriate lot size is determined by the production planner. So an example below, it is 100 unit. And third and forth periods' requirements are 90 units (40+50). 100 units are ordered to handle these periods' requirements.

Table 2.7 Fixed Order Quantity

Lead Time: 2 week	**Item:S12**			
Lot Size:100	**Description: Seat subassembly**			
Week	1	2	3	4
Planned Order Receipt	0	0	40	50
Planned Order Release	100			

2.4.3.3 Economic Order Quantity (EOQ)

This method is used classical inventory management systems, which suppose item's demand is independent. But this method can also be applied to the MRP systems. There may be well defined order or setup costs and handling costs. Formula of this method:

$$EOQ=\sqrt{2.d.S/h}$$

Where *d:Annual demand, S:setup/order cost, h: handling cost of an unit*

2.4.3.4 Fixed Period Order Method

In this method order interval is identified by the planning and purchasing departments. So order quantity is determined considering this order interval. Consider that order period is three week and the lead time is equal to one week. With this constraints second, third and fourth periods requirements are merged and ordered first week.

2.4.3.5 Wagner Within Algorithm

This method uses dynamic programming technique to find the optimal lot size. Complexity of dynamic programming, it is hard to implement this method to the MRP systems. This method finds optimal lot sizes by evaluating all possible ways of ordering to meet the master schedule.

2.4.3.6 Part Period Balancing

"This method provides a more systematic solution procedure. Part period balancing attempts to equate the cost of placing a single order with the cost of holding the inventory produced by that order since, the optimal order quantity is that quantity for which order cost equals holding cost." (Meredith, 1992, p.465) Suppose that planning horizon is three weeks. And the lead time is one week. There are three possibilities for first ordering lot size with part period balancing method.

- Order only requirement of first week (week 1)
- Order first and second weeks requirements together (week 1,2)
- Order all weeks requirements (week1, 2,3)

We must choose one of these order choices above for first ordering. Optimal choices are that which's cumulative carrying cost near the setup cost.

2.4.4 MRP Types

Continuous changing in manufacturing industry is inescapable. After MRP computes requirements, changes can occur because of design, scheduling, production processes and demands changing. MRP systems handle these changes by means of recomputing the resource plan.

There are two methods for recomputing the plan, regeneration (or a regenerative calculation) and net change.

2.4.4.1 Regeneration

Regenerative systems periodically reprocess the entire Master Production Schedule. Old MPS is destroyed and new MPS is recalculated completely. Namely, "The old plan is discarted each time planning is run. A new plan is developed using

the status of the on-hand balance, allocations, master production schedule and scheduled receipts at the time of the regeneration."(Landvater, Gray, 1989,p.21)

This method is status driven that replanning calculation is done for all items regardless of whether they changed or not. Regenerative systems are run weekly because of they have serious computer run time problems however companies want to run regeneration less frequently than weekly.

2.4.4.2 Net Change

Net change planning recalculates only changed items. So this method is change driven. "These changes may include changes to the on-hand balance, gross requirements, allocations, changes due to unanticipated scrap, changes in ordering rules and lead times." (Landvater, Gray, 1989,p.21)

Netchanges systems are run frequently may be run every hour, every day or several times a week. There are two types of net change method, batch net change and continuous net change.

Batch net change system identifies changed items and runs MRP for all these changed items. Continuous net change system replans changed item without delay. Continuous net change systems can also work batch net change and regenerative method. But it is not possible that to run regenerative systems as other MRP types or a batch net change system as a continuous net change system.

2.4.5 MRP Explosion

MRP computes requirements of materials using MPS, BOMs and inventory status file. Some terms' definitions are :

Gross Requirements: "How many each item is needed to produce the ordered quantity of the end product."(Schonberger, Knod, 1991, p.338)

Scheduled Receipts: These items ordered before and available at this period.

Projected On Hand: Expected on-hand inventory at end of period

Planned Receipts: Net requirements adjusted for lot-sizing

$$Net\ Req. = \{\text{Grooss Req.+ Allocated}\} - \{\text{Scheduled Receipts+ Projected On Hand}\}$$

Planned Order Releases: Planned order receipts offset by lead time.

MRP explosion identifies the calculation of items requirements from beginning to end of the product structure tree. To understand this process clearly I will explain this process with assistance of example. Consider that end item A is made with two unit subassembly B and one unit subassembly C. Lead times of these materials are respectively 1, 1 and 2 week. Master Production Schedule can be seen below.

Table 2.8 Master Production Schedule of One Item

Week	1	2	3	4	5	6
Product A	0	80	40	0	10	15

Suppose that firm purchase or produce materials using lot-for-lot method. And At the beginning of time period we have 40, 100 and 50 unit of A, B and C items respectively. So MRP computation produces table 2.9's values.

Now, we examine some points of example below. At the first period projected on hand for A item is 110. Formula is *{on hand(t=0)=40}+{*scheduled *receipt(t=1)=70}-{gross req.(t=0)=0}*. And net requirement is equal to 10 at period 5. Because at this period gross requirement is 10 and there is no scheduled receipt and projected on hand. And this requirement is ordered one week before because lead time is equal to one week. Formal name of this operation is planned order release. So planned order releases are multiplied with precesors of parent item considering what unit is needed to constitute parent item. This operation result is gross requirements of the successors. These computations continue as well as last level of product tree.

Table 2.9 MRP Explosion Example

Item: A Description: End Item On Hand: 40	Lot Size: Lot-for-Lot Lead Time: 1 week					
	1	2	3	4	5	6
Gross Requirements	0	80	30	0	10	15
Scheduled Receipts	70					
Projected On Hand	110	30	0			
Planned Receipts					10	15
Planned Order Releases				10	15	
Item: B Description: Subassembly On Hand: 100	Lot Size: Lot-for-Lot Lead Time: 1 week					
	1	2	3	4	5	6
Gross Requirements		75		20	30	
Scheduled Receipts						
Projected On Hand	100	25	25	5	0	
Planned Receipts					25	
Planned Order Releases				25		
Item: C Description: Subassembly On Hand: 50	Lot Size: Lot-for-Lot Lead Time: 2 week					
	1	2	3	4	5	6
Gross Requirements		30		10	15	
Scheduled Receipts						
Projected On Hand	50	20	20	10	0	
Planned Receipts					5	
Planned Order Releases			5			

2.5 Manufacturing Resources Planning

The scope of MRP has been expanded in recent years to integrate MRP with the order processing, billing, shop floor scheduling, and personnel and machine utilization activities of the company. These newer systems, called *manufacturing resources planning* or *MRP II*, contain the classical MRP scheduling function as their centerpiece. However, MRP II systems may include modules that collects sales and customer order data and generates an MPS for future end product requirements (e.g.,

using a forecasting model). In addition, an MRP II system may convert information from the material requirements plans into specific work schedules for departments and machines, evaluate department workloads and capacity conditions, generate shipping documents and customer invoices, and produce management reports on production and financial performance. Typically, these systems have a feedback mechanism (called closed-loop MRP systems) so that if department, machine, or personnel capacity limits are exceeded, the material requirements plans and corresponding production schedules are revised to stay within capacity limits.

So, with MRP II system, capacity requirement planning is needed for controlling whether MRP schedules are feasible or not.

2.6 Capacity Requirements Planning (CRP)

Basic definition of the capacity requirement planning is the process of establishing, measuring and adjusting limits or levels of capacity. It is the process of determining how much resources are required to accomplish the tasks of production. The integration of capacity requirements, master scheduling and MRP is often called a closed loop MRP system. Closing the planning loop in MRP systems involves checking production plans against available resources. Therefore capacity is checked throughout the process and if the proposed plans are not achievable at any level, they are revised. This relation is illustrated in Figure 2.8.

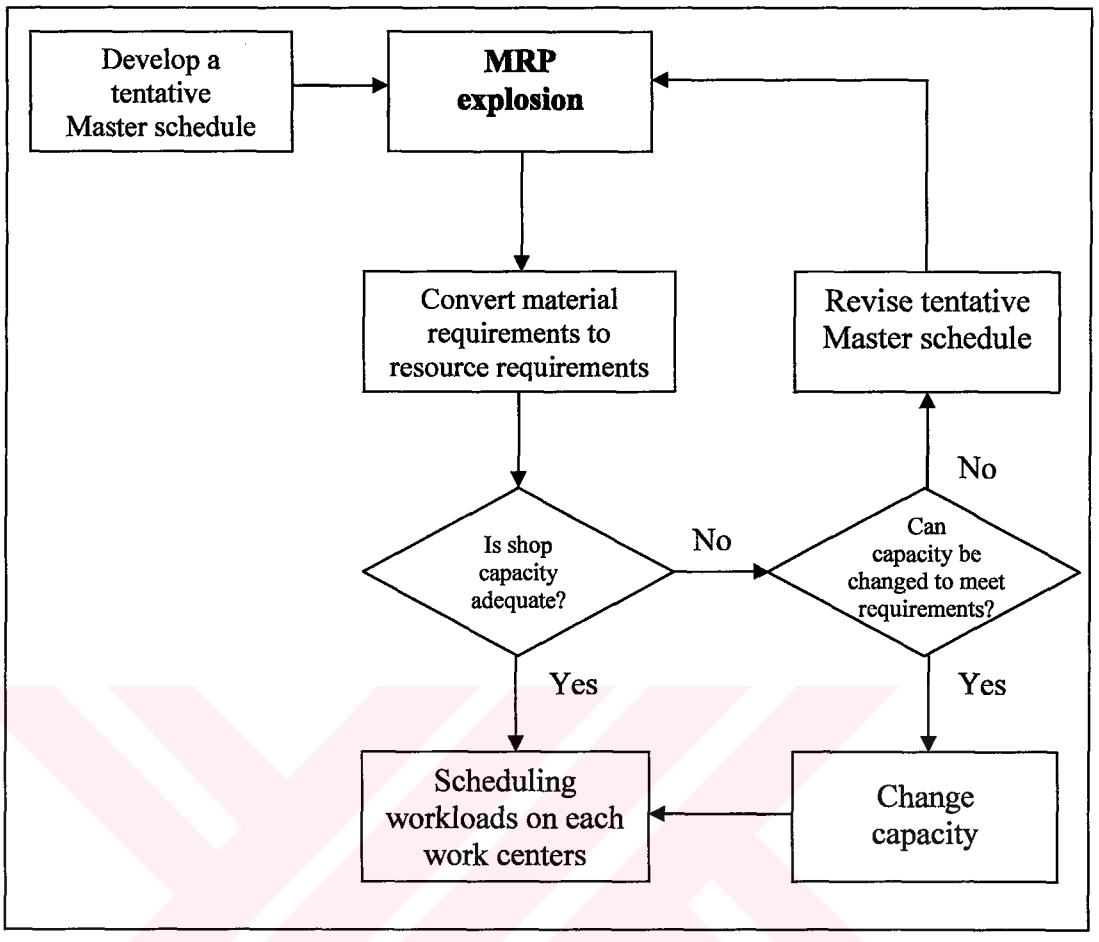

Figure 2.8 Closed loop MRP

Material requirements planning (MRP) takes the requirement dates for each MPS item and calculates the quantities of each sub-assembly, manufactured component and purchased item required to meet that program. The logic of CRP is that it receives all planned orders, firm planned orders and scheduled receipts from MRP and then breaks each down into individual operations. For each operation, the order quantity is multiplied by the run time standard hours stated on the route sheet and added to the set-up time. So required hours for per work center and per operation can be calculated. This is done for each manufacturing order operation. Finally calculated required capacity hour compared with available capacity hour of the work center. Normally this information is taken in a summarized form, either as a histogram or as a percentage load report. The percentage load report shows diagrammatically the percentage loading for a work center by time period.

To illustrate CRP calculations, suppose that the planned order releases and workloads of machine are as follows.

Table 2.10 An Example of Workload of Workcenter

Time Period	**1**	**2**	**3**	**4**
Planned Order Release (unit)	20	0	25	25
Work Loads (hour)	12	30	0	10

Assume that the component requires 1.10 hours per unit of labor in a particular work center and 1,5 hours of setup time. And capacity of machine is 30 hour/period.

(20 units)*(1,10 hours/unit)+1,5 hours=23,5 hours (for first period)

(25 units)*(1,10 hours/unit)+1,5 hours=29 hours (for third and fourth periods)

And if existing and required hours are accumulated then total workloads are obtained. Results can be seen in Table 2.11.

Table 2.11 Total Workload of the workcenter

Time Period	**1**	**2**	**3**	**4**
Total Work Loads(hour)	35,5	30	29	39

Such information is usually provided in a load report, as illustrated in Figure 2.9. If sufficient capacity is not available, then decisions must be made regarding overtime, transfer of personnel between departments, subcontracting and so on. The master production schedule may also have to be revised in order to meet available capacity.

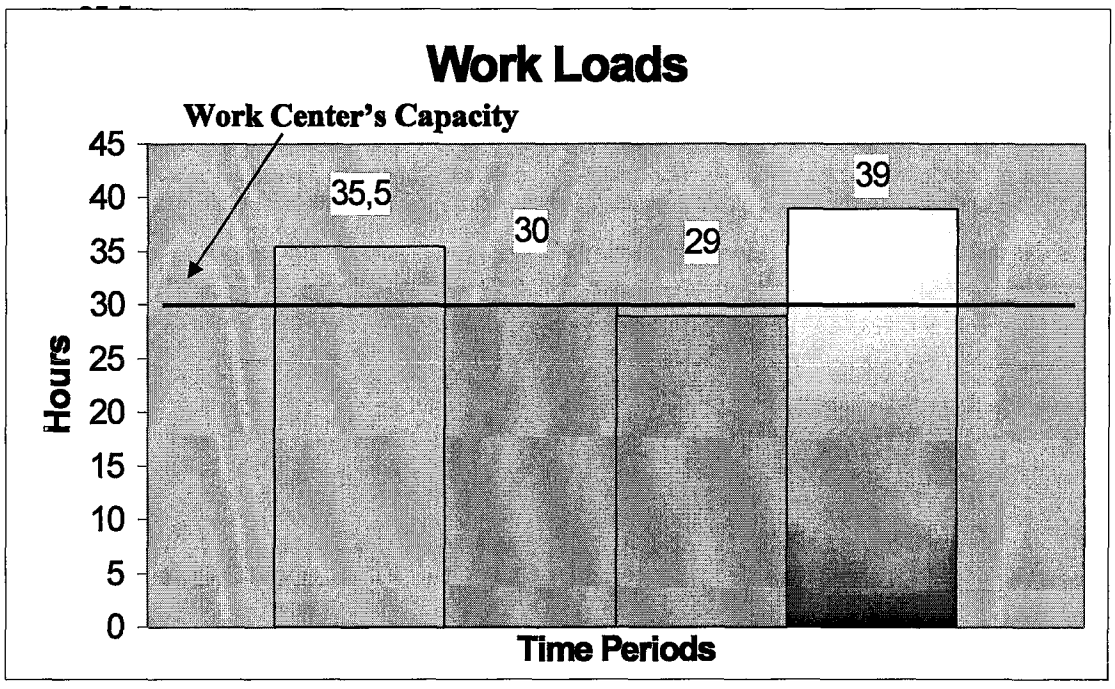

Figure 2.9 A Sample Load Report

Areas of the first and the forth time periods,which locate over the work center's capacity line, show that 30 hour work load limit is exceeded.

CHAPTER THREE
MATERIAL-METHOD

3. Material-Method

This chapter contains designing "Computer Based Production and Inventory Control System" for a make-to-order textile company that applies Just-in-Time (J.I.T) policy for inventory management. Firstly current system of the company will be examined. After that new system will be proposed versus current system and designed software will be explained module by module. This software contains a database and GUIs (graphical user interface). In addition, MS Sql Server 7.0 and Delphi 5.0 tools are used through designing process.

3.1 Current System

Company's customers are mostly from Germany. When demands are taken they are processed considering due dates and priorities. Company had been bought a software package, which is AS/400 in 1990s for planning operations. But because of some reasons, some of them are usefulness of programme because of became of text based, complex menus and slow computation and company's organizational decisions, this package is not used productively. For example, if planner wants to know that raw material entered to the warehouse, inventory cards are controlled. MS Office Applications, especially Excel, are used for planning computations.

When a new order is demanded by customer, to generate a purchasing form of this order, all demanded quantities, bill of material values of demanded products and loss values are inserted to the excel sheet. And then required quantities are calculated using excel formulas. Input dates of the materials are given by the planning engineer

according to due date of the party and capacity constraints. And then these values are copied and pasted to the purchasing form. All unique values are given manually. For example, order no and purchasing no must be unique and this number is given by the planning engineer controlling previous number.

After that purchasing person materialize the purchasing operation. Vendors of the materials are known by the purchasing person and they are also holded in the excel sheet. Negotiations are made with vendors and orders are opened to the appropriate vendors according to delivery date and cost factors.

Warehouse transactions are holded in the inventory cards. So when planner wants to know that the needed material entered or not to the warehouse, manually inventory cards are controlled. If material enters to the warehouse or gets out to the production floor then this transaction is written to the inventory card of the materials. This controlling process so hard because a hundred of inventory cards exist. Other problem is that, may be transaction is not written to the inventory card because of forgetfulness.

As a result, mostly operations are made over papers. And there are not computer records of them. Common database does not exist for marketing, planning, purchasing and warehouse departments.

So this study consists of system analysing and designing database and GUI (Graphical User Interface) of taking customer orders, computing material requirements and tracing production status of orders for improving the current system.

3.2 Proposed System

As I mentioned previous parts, inputs of the MRP are MPS, BOMs and inventory status file. But in this situation MPS is not important. Because company produces products when customers demand. So MPS is done by the customers. And

forecasting is not important because of make-to-order type production and Just in Time policy for inventory management. So MPS is equal to customers' demand that is known when customer faxes the orders. Namely, purchasing and production operations are done order based. But BOM of the products and inventory status file of the materials are important for MRP computing.

Flowing of a system that is designed by me is :

- Pre Conversation of customer representative with customer's contact person.
- Customer sends fax about orders' size and color quantities, due dates and other specifications.
- Customer representative records this fax information to the database. They are:
    - Order Information
        - Customer Order Number
        - Customer ID
        - Demanded Model
        - Order Date
        - Due Date
        - Size set
        - Other Information about orders
    - Quantities of each color of the model
- Planning engineer checks opened orders according to their shipping dates and needed production capacities. Appropriate orders are selected for computing material requirement.
- Planning Engineer gets latest bill-of-material values from model department and updates values.
- Material Requirements are computed by planning engineer. And needed dates are determined considering shipping date of the order and capacity constraints. This report is sent to the purchasing department.

- Vendors of the materials and the lead times of each vendor exist in the database. Purchasing employee makes a contact with vendors and opens orders with assistance of the database records. And then enters to the database that materials' coming dates to the warehouse.
- Warehouse transactions are inserted online to the database.
- Planning Engineer controls materials' status from warehouse and allocates materials to the related order number which are entered the database before by customer representative.

Flowchart of the model can be seen in figure 3.1 below. So we can see that for entering orders to the system, firstly, owner of the demanded order, color of the demanded order, ordered model and the variants of the demanded model must be recorded.

Model department determines the variants' raw materials and the needed quantities for one unit. If these raw materials are not recorded to the inventory records then definitions of these materials are completed firstly. And then bill of material of the model's variants are prepared.

After that demands are inserted to the database by the customer representative. Planner daily controls open orders and selects orders for starting to the production according to their due dates and orders' needed capacity requirements.

Next step is computing material requirements of the order and determining the input dates to the warehouse. So purchasing form is generated and this form is sent to the purchasing department. Purchasing person opens orders according to their input dates to the warehouse. Lead times of the raw materials are known by means of MatVendors table. So appropriate vendors are selected.

Warehouse person enters transactions of the raw materials when transaction occured. Suppose that planner controls the needed material's existence in the warehouse and see that it had entered to the warehouse. And takes this material to

the production. So warehouse person creates transaction about this situation that is allocation. If raw material comes from the vendor to the warehouse and then warehouse person creates transaction that is input to the warehouse. After that planner updates status of the order that is in progress. After shipping, order status of the order is updated to completed.

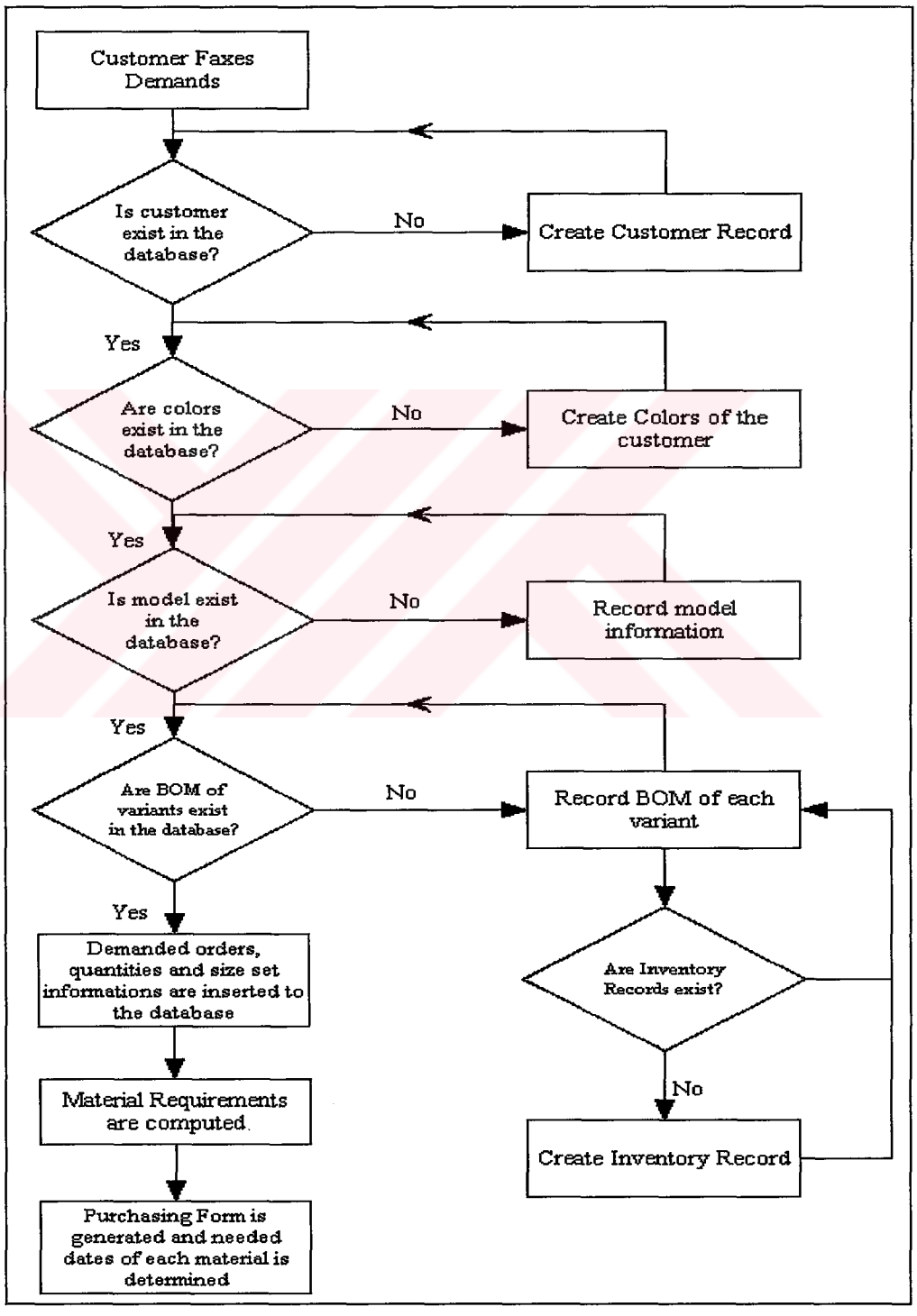

Figure 3.1 Flow Chart of the Proposed System

To materialize this model, I designed three essential modules of production and activity control system. They are:

- Order Module
- Material Requirements Module
- Warehouse Module

Before explanation of these modules I will explain database of the model.

3.3 Designed Database

"The heart of a computer-based production and inventory control system is its database."(Smith, 1989, p. 35) In order to plan activities, the database must include extensive information about customers, products, materials of the end items and their current inventories. Tables of the database are explained above briefly;

Customer: Customers of the company are holded in this table.
Color: Colors of the customers are holded in this table.
Ord: Order informations are recorded to this table.
SizeQuant: Quantities of demanded orders are recorded to this table according to colors and size sets.
Model: Until now demanded models by customers are holded in Model table.
BOM: Raw materials and needed quantities of Models are holded in BOM table.
MaterialOperations: Properties of cloth materials are holded in this table.
InventoryID: Information of raw materials is holded in this table.
InventoryTransactions: Warehouse transactions are inserted to this table.
Vendors: All suppliers are recorded to this table.
MatVendors: Raw materials' suppliers are holded in this table.

Now modules of a system will be explained.

3.4 Order Module

Aim of this module is that storing color and size quantity information of the orders. I designed a screen to handle these operations. This screen can be seen in Figure 3.2 below. Ord (Order), Customer, Color and BOM (Bill of material) tables are used during creating order. Sql script of Ord table is;

```
CREATE TABLE [dbo].[Ord] (
[CustOrdNo] [int] NOT NULL ,
[CustIni] [char] (10) NOT NULL ,
[OrdNo] [int] NOT NULL ,
[Model] [char] (10) NOT NULL ,
[OrdDate] [datetime] NOT NULL ,
[DueDate] [datetime] NOT NULL ,
[Notes] [text] NULL
) ON [PRIMARY] TEXTIMAGE_ON [PRIMARY]
GO
ALTER TABLE [dbo].[Ord] WITH NOCHECK ADD
CONSTRAINT [PK_Order] PRIMARY KEY  NONCLUSTERED
(
[OrdNo]
)  ON [PRIMARY]
GO
CREATE  INDEX [IX_Order] ON [dbo].[Ord]([Model]) ON [PRIMARY]
GO
```

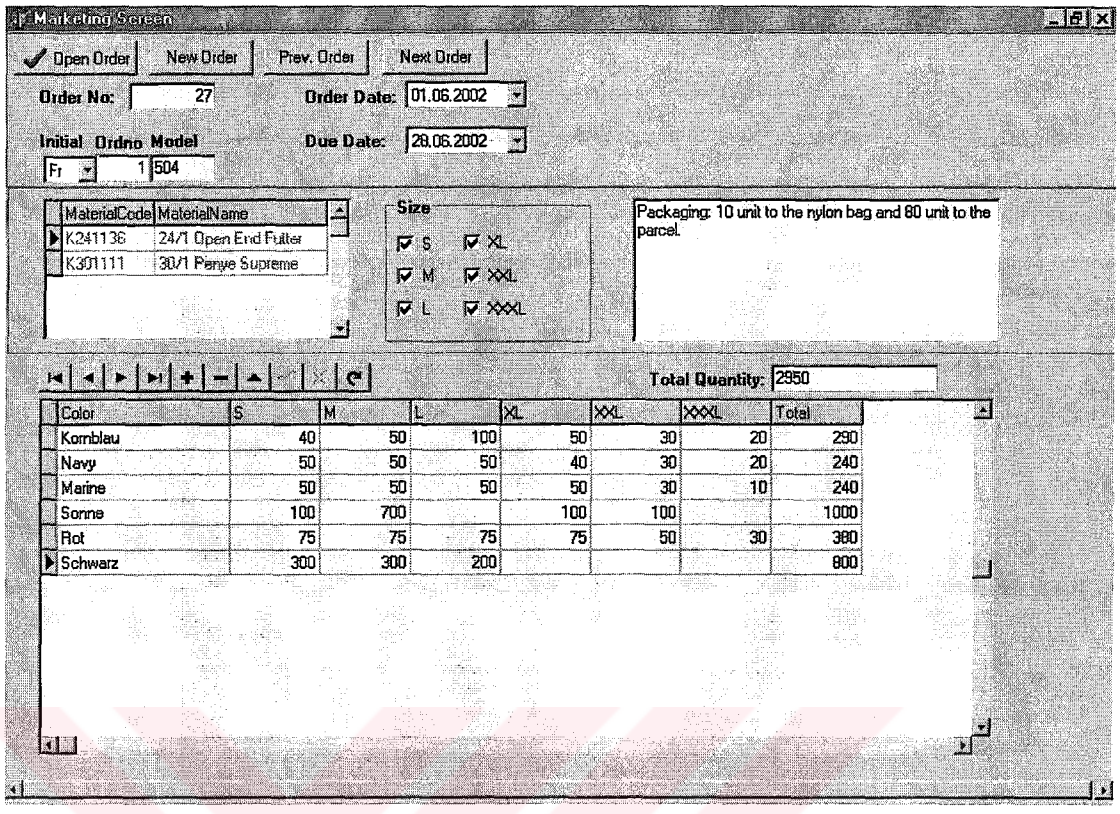

Figure 3.2 Order Screen

Field Descriptions are:

Order No: Order number of the customer. Customer controls status of the production using this number. So customer representative learns about the production using this number. Location of these fields is *Ord->CustOrdNo*(Ord table's CustOrdNo field).

Initial: Initial of the customer. This value is gotten from customer table using dblookupcombobox. Location of this field is *Customer->CustInitial.*

Ordno: This value represents the company's status that how many orders are demanded to us by customers. It is autoinc number and generated automatically using sql code. Location of this field is *Ord->OrdNo.*

Order Date: It is customer's demand date. Location of these fields is *Ord->OrdDate.*

Due Date: It is shipping date of order's. Location of these fields is *Ord->DueDate.*

Model: Model number of the order. Entered value is compared with the model table. If this value is not recorded Model table before, first this model must be defined using Bill-of-Material screen. Location of these fields is *Ord->Model.*

Material Code & Material Name: After inserting the model number these values are gotten from bill-of-material table. Cloth raw materials are seen at the grid component. It is useful for the planner's first preview about the needed materials. Location of these fields are sequencely *BOM->MaterialCode, BOM->MaterialName.*

Size: Customer representative selects sizes that customer demanded using these check boxes. And related columns are been visible at the quantity grid, which locates at the bottom of the screen.

Memo: Specially packaging info and other variant informations are entered to this memo area. Location of this field is *Ord->Notes.*

First customer's order number is inserted in *Order No* editbox. Then initial of the customer selected using combobox. When user selects initial of the customer, *Ordno* value is created automatically and then user inputs the demanded model in to the *Model* field. Union of the initial, ordno and model, create information that is used for purchasing operations and tracing status of the order. Orderdate value automatically takes system date and shipping date is entered in to the *DueDate* field using datetimepicker component. Union of demanded sizes of variants are selected using check boxes and other information is written in to the memo area. After inserting these required values, open order button is clicked and order is opened and values are stored to the **Ord** (order) table. Next step is inserting the color and quantities of each size set. Quantity informations of the order are stored in the **SizeQuant** (size and quantity) table. It is detail table of Ord table.

When size set is selected, related columns are opened at the quantity grid, which locates at the bottom of the screen. For example, if S, M and L sizes are selected only these sizes locate at the quantity grid. I made it with using onClick event of check boxes. Columns descriptions of quantity grid is:

Color: It represents color of the product. Color values are gotten from color table using dblookupcombobox and inserted to the columns picklist. Location of this field is *Color->ColorID.*

Sizes (S, M, L, XL, XXL, XXXL): After choosing color, quantities of sizes are inserted. Location of these fields are *SizeQuant->S... SizeQuant->XXXL.*

Total: It is total of each color's quantity. It is calculated field so its value is not stored at the any table.

Total Quantity: This is total quantity of all colors' and sizes'. It is calculated field so its value is not stored at the any table.

After completing quantity information, post button is clicked from dbnavigator. Besides of grid's values Ordno value is inserted to the SizeQuant table. Sizequant is a detail table of Ord table joining over Ordno field. Because Ordno field is unique at the Ord table but there may be many same Ordno value, if the customer demands at least two colors of the model, in sizequant table.

We can create another new order clicking "New Order" button. "Prior Order" and "Next Order" buttons are used for editing or checking old orders.

Relationships of Ord table can be seen in figure 3.3. Customer, SizeQuant and Color tables will be described now but Model and BOM tables will be described while explaining Material Requirement module.

I designed a Customer and Color screens as an interface of Customer and Color tables. So inserting, editing and navigating operations of these tables are done with these interfaces.

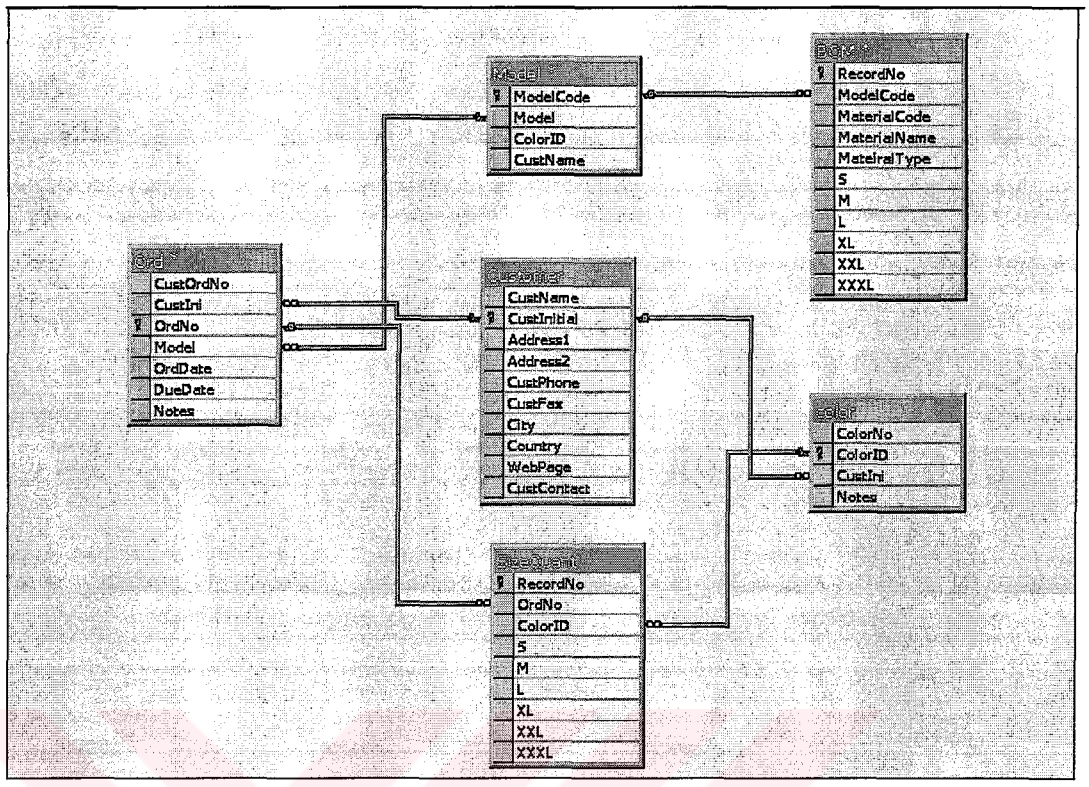

Figure 3.3 Relationships of Ord table

We can see that customer initials are gotten from Customer table and model informations is checked from Model table. And Ordno value joins Ord and Sizequant tables.

3.4.1 Customer Screen

I designed an interface of the customer table for inserting and editing customer informations. This screen can be seen in figure in 3.4. Sql script of Customer table is;

```
CREATE TABLE [dbo].[Customer] (
    [CustName] [char] (30) NOT NULL ,
    [CustInitial] [char] (10) NOT NULL ,
    [Address1] [char] (25) NULL ,
    [Address2] [char] (25) NULL ,
    [CustPhone] [char] (20) NULL ,
    [CustFax] [char] (20) NULL ,
```

```
    [City] [char] (20) NULL ,
    [Country] [char] (20) NULL ,
    [WebPage] [char] (25) NULL ,
    [CustContact] [char] (30) NULL
) ON [PRIMARY]
GO
ALTER TABLE [dbo].[Customer] WITH NOCHECK ADD
CONSTRAINT [PK_Customer] PRIMARY KEY  NONCLUSTERED
    (
        [CustInitial]
    ) ON [PRIMARY]
GO
CREATE  INDEX [IX_Customer] ON [dbo].[Customer]([CustName]) ON
[PRIMARY]
GO
```

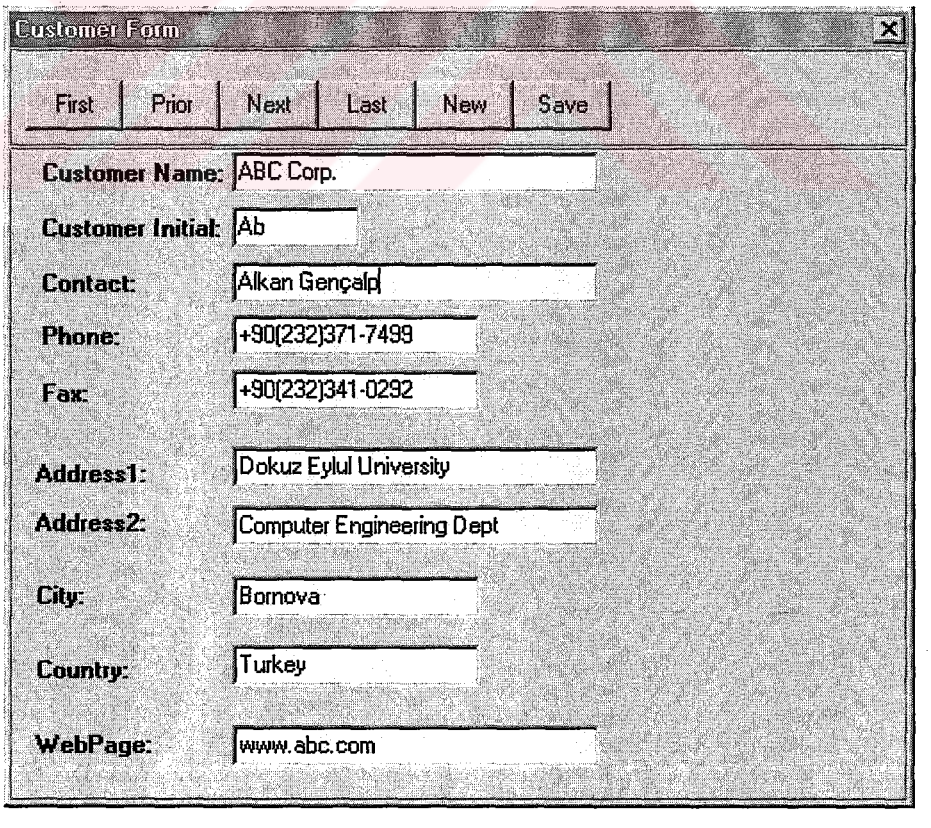

Figure 3.4 Customer Screen

If demands come from a new customer, information of the customer is inserted firstly. They are name, initial, contact, phone, fax, address, location and web page informations of the customer. Customer table's fields are used for several operations. For example, creating orders, creating models. And colors are grouped by CustName (Customer Name) field.

3.4.2 Color Screen

I designed a color screen in order to hold color information of the customers. Customers can demand many colors of their models. For example, customer can demand only one model but can demand ten different colors of this model. We can see illustration of this in figure 3.2 above. At this screen customer demands six variants of 504 model. They are Kornbalu, Navy, Marine, Sonne, Rot and Schwarz. These colors are gotten from color according to customer. Because colors are related with the customers. At the my example Kornbalu, Navy, Marine, Sonne, Rot and Schwarz colors are belong to Ford company.

Sql script of the color table is;

```
CREATE TABLE [dbo].[color] (
    [ColorNo] [int] NOT NULL ,
    [ColorID] [char] (20) NOT NULL ,
    [CusName] [char] (30) NOT NULL ,
    [Notes] [text] NULL
) ON [PRIMARY] TEXTIMAGE_ON [PRIMARY]
GO
ALTER TABLE [dbo].[color] WITH NOCHECK ADD
    CONSTRAINT [PK_color] PRIMARY KEY  NONCLUSTERED
    (
        [ColorNo]
    )  ON [PRIMARY]
GO
```

```
CREATE  INDEX [IX_color_1] ON [dbo].[color]([ColorID]) ON [PRIMARY]
GO
```

Color screen can be seen in figure 3.5. Field descriptions of the color table;

ColorNo: It is an autoinc number and generated automatically using sql query. This value is used for generating modelcode, which will be described BOM (Bill-of-material) table. This field is read only at the color screen.

ColorID: Name of the color. It is specially used while entering demanded quantities and also used generating variants of models that will be described BOM (Bill-of-material) table.

Customer: This field describes that owner of the color. This value is gotten from customer table using dblookupcombobox.

Notes: If extra information is available about color, this memo area is used.

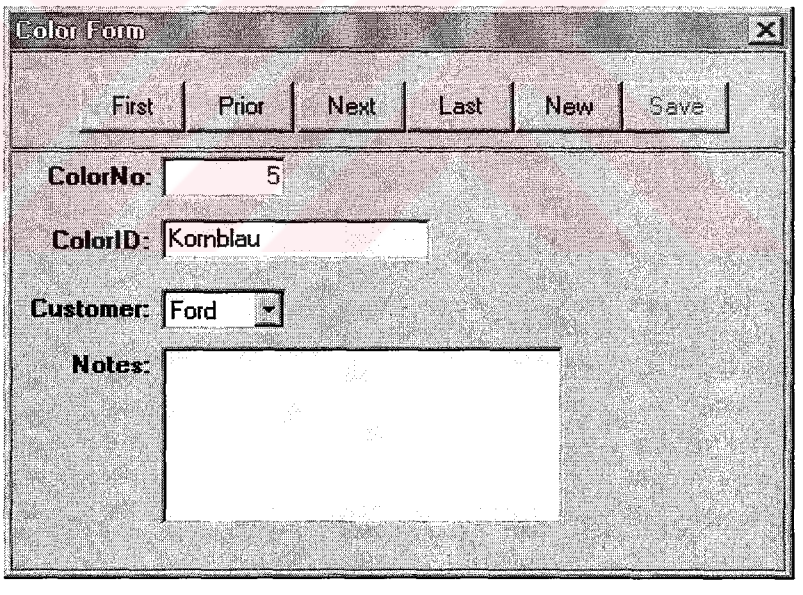

Figure 3.5 Color Screen

First, prior, next and last buttons are used to navigate at the color table. New button inserts a new record and save button saves edit boxes values to the color table.

3.5 Material Requirement Module

Major inputs of the MRP are Master Production Schedule, Bill of Materials and Inventory Status Files, which are explained detailed at the second chapter of the study. Because of the company's production type that is make-to-order and the inventory handling type that is Just in Time, specially for A and B class items, material requirements are determined order based. So in this situation most important input of the material computation is Bill of Materials for this company that defines raw materials of the master product. Bill of Material records of each product are needed to compute material requirements. I designed a user friendly screen to create and edit raw materials of each model's variant. This screen includes two table's fields. They are Model and BOM (bill of material) tables. I designed that Model table is master table and the BOM table is detail table of the Model table. Model table contains model information and the BOM table contains related model's raw materials and required quantities of each size. These tables joined over ModelCode field, which describes model and variant information. So ModelCode is unique at the Model table but infinite at the BOM table because each raw material of the model has a ModelCode of the model. Snapshot of this screen can be seen below in figure 3.6.

Brief description of creating bill of material is like that. First model, customer and the variant informations are inserted. Model's color is called variant of the model in textile terminology. And then "Create Model" button is clicked which locates at the top of the screen. ModelCode value is generated automatically by the program using Model and Variant values after clicking the button.

And then raw materials and quantities of each raw material of the variant are recorded. So at the topside of the screen model information is created and at the bottom side of the screen, which consists dbgrid, raw materials and quantities of each size is defined. Material codes and material names are gotten from InventoryID (Inventory Records) table. If material is cloth then properties of the material is defined by clicking "Define Material Opt." button.

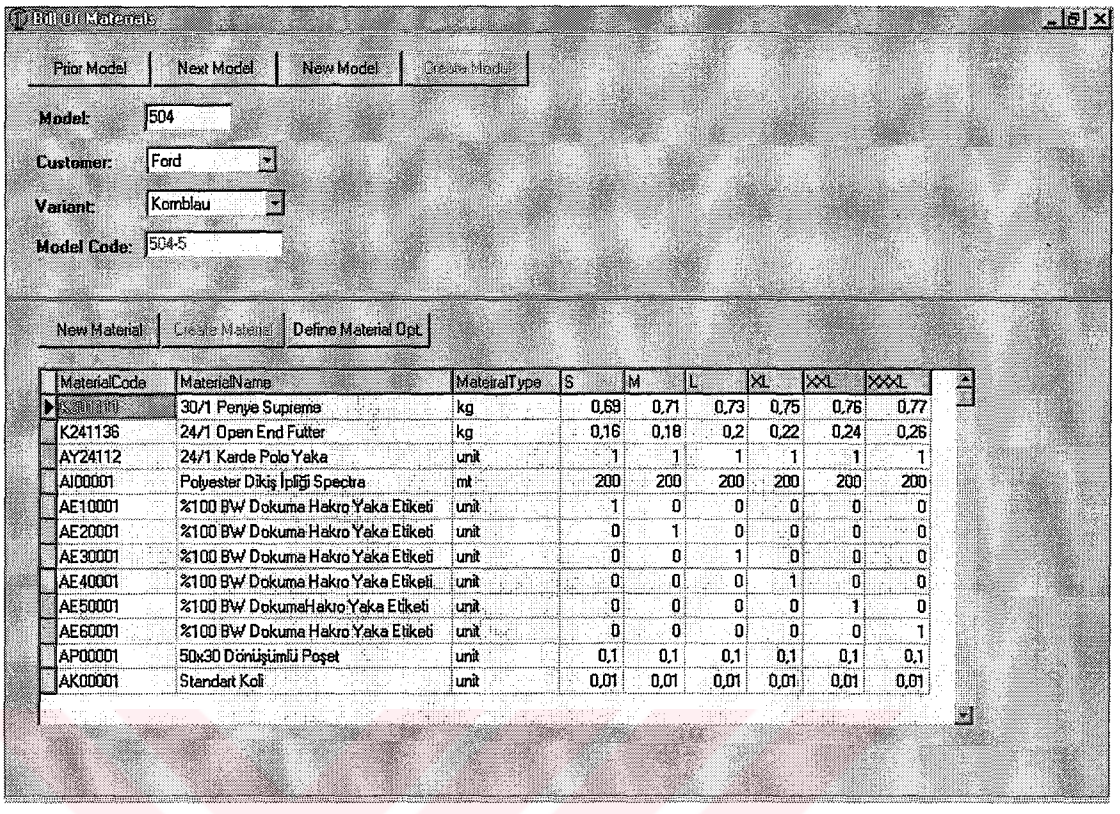

Figure 3.6 Bill of Materials Screen

Now I will explain sources of this screen they are Model, BOM and MaterialOperatins tables, sequencely.

3.5.1 Model Table

Model informations are recorded to this table. Sql script of Model table is below;

```
CREATE TABLE [dbo].[Model] (
    [ModelCode] [char] (10) NOT NULL ,
    [Model] [char] (10) NOT NULL ,
    [ColorID] [char] (20) NOT NULL ,
    [CustName] [char] (30) NOT NULL
) ON [PRIMARY]
GO
ALTER TABLE [dbo].[Model] WITH NOCHECK ADD
    CONSTRAINT [PK_Model] PRIMARY KEY  NONCLUSTERED
```

```
(
        [ModelCode]
) ON [PRIMARY]
GO
```

Field definitions of the screen, which are related with model table;

Model: This field defines main definition of the product. But color property is not included this info. Raw materials are generated considering color of the model.
Customer: Owner of the model is entered to this field. Customer name is gotten from customer table. Dblookupcombobox is used to get customer names.
Variant: Color of the model is called variant of the model in textile terminology. So model's color is recorded to this field. Only related colors are listed using dblookupcombobox from color table according to customer name.
Model Code: Model Code is generated when user clicks Create Model button. Model Code is concatenation of the model and the variant fields. For example, if user selects Kornblau color at the Variant edit box, this color's colorno is gotten from color table and concatenated with Model like 504-5. 504 defines model number and 5 defines colorno of the Kornblau. This value also inserted to the BOM table. Because master-detail relation is set up using this field.

Upper side buttons of the Bill of Material screen are used to navigate, insert and post operations at the model table.

3.5.2 BOM (Bill of Material) table

Dbgrid of the Bill of Materials Screen is, which locates at the bottom of the screen, an interface of the BOM table. As mentioned before Model and the BOM tables are master-detail tables in my design. So they joined over ModelCode field. When user starts to create a raw material by clicking *New Material* button, ModelCode of the active model is inserted to the BOM table. And then raw material

and quantity values inserted to the table when user clicks to the *Create Material* button. Each record has an unique number, which is holded at the RecordNo field.

Sql script of the BOM table is below;

```
CREATE TABLE [dbo].[BOM] (
    [RecordNo] [int] NOT NULL ,
    [ModelCode] [char] (10) NOT NULL ,
    [MaterialCode] [char] (15) NOT NULL ,
    [MaterialName] [char] (40) NOT NULL ,
    [MateiralType] [char] (10) NOT NULL ,
    [S] [float] NULL ,
    [M] [float] NULL ,
    [L] [float] NULL ,
    [XL] [float] NULL ,
    [XXL] [float] NULL ,
    [XXXL] [float] NULL
) ON [PRIMARY]
GO
ALTER TABLE [dbo].[BOM] WITH NOCHECK ADD
    CONSTRAINT [PK_BOM_1] PRIMARY KEY  NONCLUSTERED
    (
        [RecordNo]
    )  ON [PRIMARY]
GO
 CREATE    INDEX  [IX_BOM]  ON  [dbo].[BOM]([MaterialCode])  ON
[PRIMARY]
GO
```

Column definitions of the Bill of material grid is below;

MaterialCode: It is code of the raw material and gotten from InventoryID table, which will be explained while explaining the inventory screen. Material codes are added to the columns pick list. So user easily selects required code using combobox in the MaterialCode column of the grid.

MaterialName: It is name of the raw material and gotten from InventoryID table, which will be explained while explaining the inventory screen. After user selects the material code and exits this column, onExit event is triggered and Material name of the material code is automatically selected.

Material Type: This column describes the type of the material's quantity. This field can contain only three different values. They are kg, unit and meter. If raw material is cloth, type can be kg or if raw material is thread, type can be meter or if raw material is accessory, except of thread, type can be unit. Accessories can be sticker, washing instruction, nylon bag, package and collar label.

Sizes (S, M, L, XL, XXL, XXXL): these fields are used to hold raw material's quantity of each size for one unit. Using these fields and order quantities, material requirements are calculated.

Relationship of BOM table with other tables can be seen in figure 3.7.

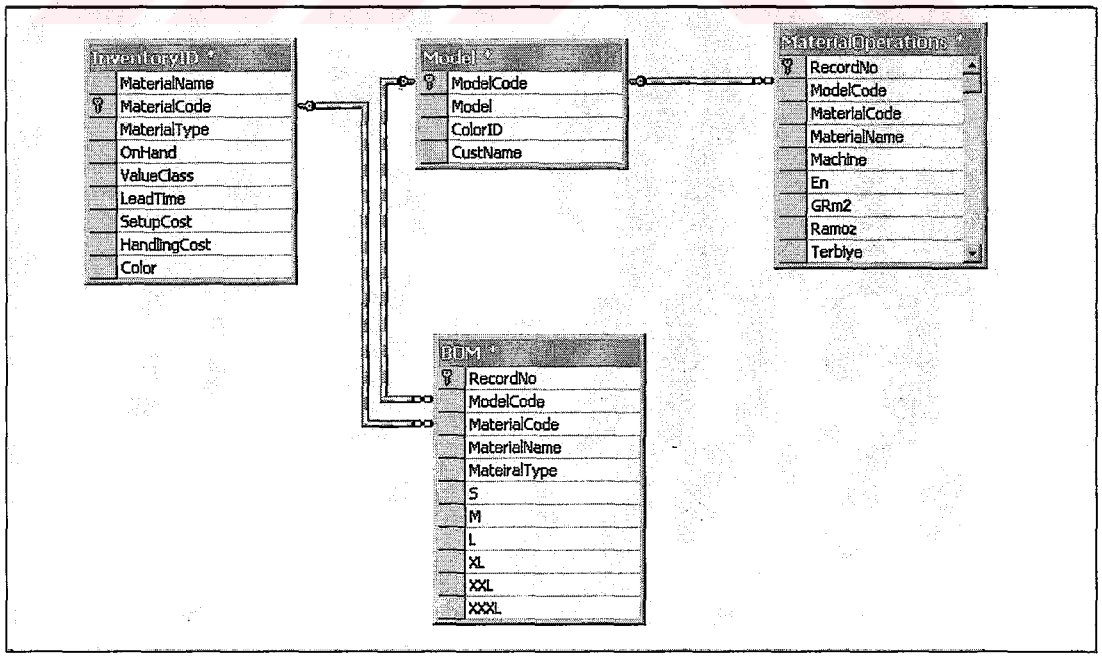

Figure 3.7 Relationship of BOM table with other tables

As we saw in figure 3.7 MaterialCode is primary key for InventoryID table. And this table joins with BOM table over MaterialCode field. Because models can have same materials and raw material informations are holded in the BOM table. And ModelCode is primary key for Model table. So Model and BOM tables join with ModelCode field. ModelCode is not unique for BOM table, because each raw material record also has ModelCode information of end product.

3.5.3 MaterialOperations Table

Clothes can have some operations. These operations are identifies variant's properties. Clothes are sewed according to clothes machine type and purchasing department opens orders according to these operations and these kind materials are demanded from vendors. Operations are described below;

Machine: This property identifies that cloth will be sewed at this kind of machine. So planner reserves related machines to the production. Sewing operation can be done at the 32" 28E, 30" 28E, 26" 28E machines.

Width: Model department identifies the width of the cloth batch. This value is demanded from vendors.

GRm2: Model department analyses optimum height of the cloth that tries minimum cloth loss. And multiplies this height with width and obtains area of the cloth. Consider that two units S sized product requires 3 m^2 cloths and 1 m^2 cloth's weight is 200 gr. So 600 gr cloths is required to produce two unit S sized products. Consequently 300 gr cloths are required to produce each S sized product and this value is inserted BOM table as mentioned before.

Ramoz: This property is demanded from vendors. If this property is needed cloth is processed over Ramoz operation by vendor.

Sanfor: This property is related with cutting process. Sanfor can be Open Width Sanfor or Bottle Width Sanfor. This property is demanded from vendors too.

Sardon: This property is demanded from vendors. If this property is needed cloth is processed over Şardon operation by vendor.

Press: If cloth of model requires this property that is demanded from vendors and %5 press loss added to the material requirement.

Embroidery: If cloth of model requires this property that is demanded from vendors and %5 embroidery loss added to the material requirement.

MeterEmbroidery: If cloth of model requires this property that is demanded from vendors and %5 meterembroidery loss added to the material requirement.

After inserting raw material to the BOM table then this raw material is inserted also MaterialOperaions table if it is cloth. So after posting to the BOM table, AfterPost event is triggered and controls that material is cloth or not by checking type of the material. If type is 'kg' then this item's ModelCode, MaterialCode and Material Name fields also inserted to the MaterailOperations table. Sql script of this table is below;

```
CREATE TABLE [dbo].[MaterialOperations] (
    [RecordNo] [int] NOT NULL ,
    [ModelCode] [char] (10) NOT NULL ,
    [MaterialCode] [char] (15) NOT NULL ,
    [MaterialName] [char] (40) NOT NULL ,
    [Machine] [char] (10) NULL ,
    [En] [char] (10) NULL ,
    [GRm2] [char] (10) NULL ,
    [Ramoz] [char] (10) NULL ,
    [Sanfor] [char] (10) NULL ,
    [Sardon] [char] (10) NULL ,
    [Press] [char] (10) NULL ,
    [Embroidery] [char] (10) NULL ,
    [MeterEmbroidery] [char] (10) NULL
) ON [PRIMARY]GO
ALTER TABLE [dbo].[MaterialOperations]  WITH NOCHECK ADD
    CONSTRAINT [PK_ MaterialOperations _1] PRIMARY KEY
    NONCLUSTERED
```

```
    (
        [RecordNo]
    ) ON [PRIMARY]
GO
```

I designed a screen that user inserts material operations. When user clicks "Define Material Opt." button at the Bill of Materials screen then Material Operations screen is been visible. MaterialOperations table is detail table of BOM table and they joined over ModelCode field. This screen can be seen in figure 3.8.

At the upper side of the screen related model informations are listed. These values are gotten from model table. And clothes of this variant are listed at the bottom side of the screen in the dbgrid component. And user edits these clothes' properties they are machine type, width of material, Gr/m² value, whether Ramoz, Sardon, Press, Embroidery, MeterEmbroidery operations are needed or not and Sanfor type.

Standard properties are added to the pick list of the columns. Machine types can be 32" 28E, 30" 28E or 26" 28E. Ramoz, Sardon, Press, Embroidery and MeterEmbroidery can have two value that are existent or non existent. And Sanfor type can be Open Width Sanfor or Bottle Width Sanfor.

Existence of Press, Embroidery and MeterEmbroidery properties also important for computing material requirement. Because each one has loss ratio that is %5.

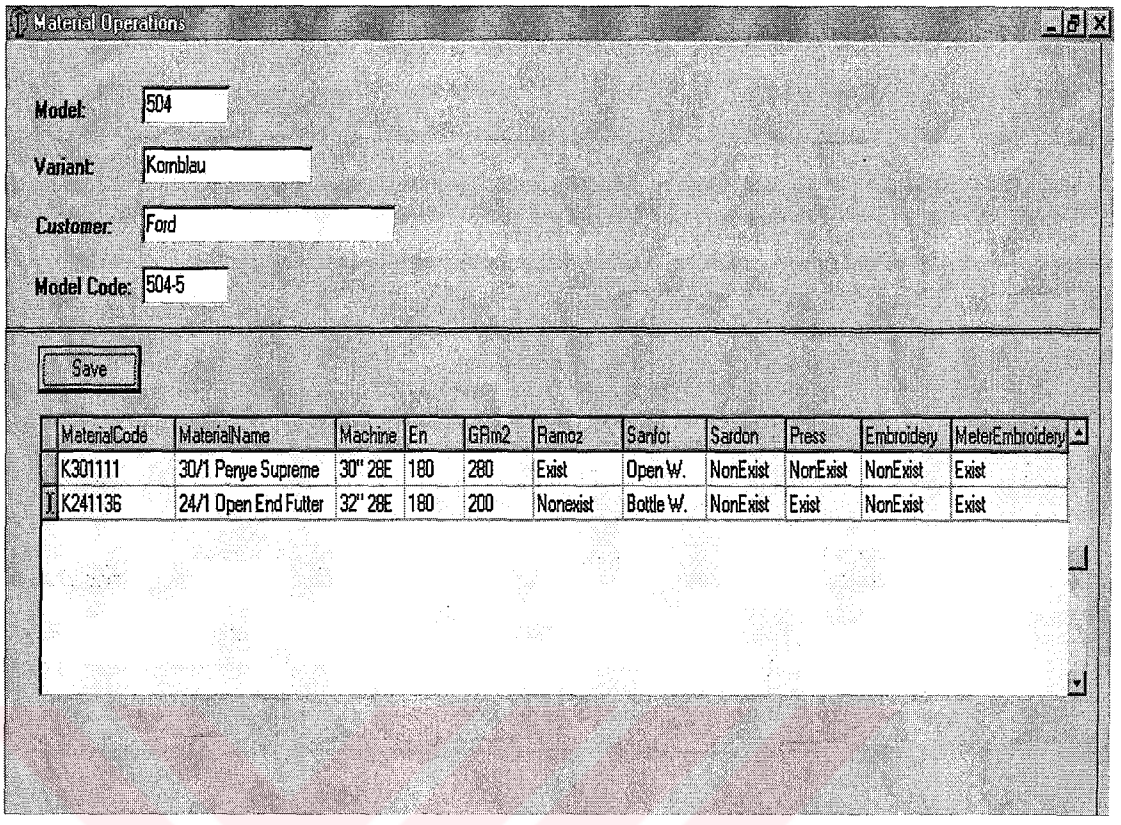

Figure 3.8 Material Operations Screen

3.5.4 Determining Material Requirements

Brief description of the process is that planner updates bill of material of model and materializes the computing process, which is variant based. Steps of process are listed below.

- Opened orders are controlled which are not in production floor and one of them is selected taking into consideration due dates and the priorities.
- Bill of materials of the demanded variants are updated if it is necessary.
- Variant based material requirements of order are computed.
- Warehouse input dates are determined.
- This report is used for purchasing operation.

Loss ratios are used at the computing process. %10 loss ratio is used for all materials. If press, embroidery, meterembroidery properties is needed for cloth

materials then additional %5 loss ratios are added to the cloth requirements. Planner selects order using orders screen, which is illustrated in figure 3.9 below.

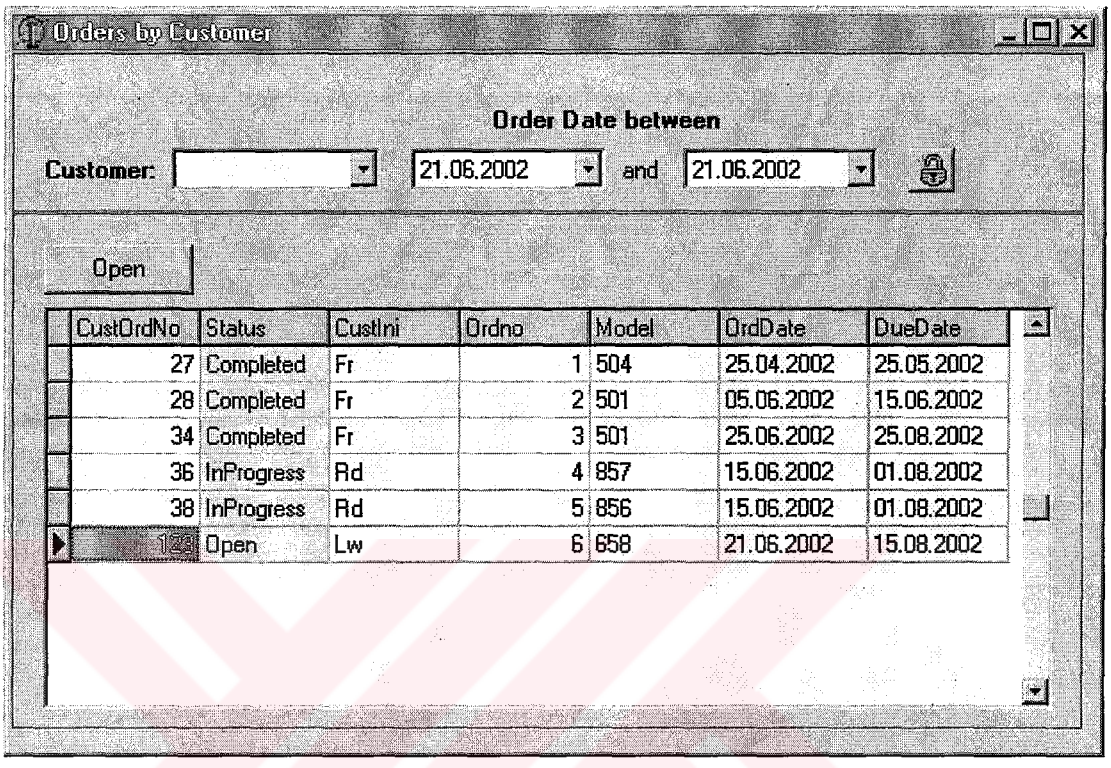

Figure 3.9 Orders Screen

This screen's datas are gotten from Ord table, which was inserted by customer representative using Marketing screen that is illustrated in figure 3.2. So planner selects an order for determining requirements. At the first open, all orders are listed. Planner can filter using customer and order date constraints, which locate at the upper side of the screen. Then clicks bitbutton and filters the orders.

When customer representative opens new orders, *open* value is inserted automatically to the Ord table's status field. Then planner changes status of order that can be *completed* or *inprogress*. Completed's mean is that order is shipped and inprogress' mean is that order is still in production floor. Planner selects order from dbgrid then clicks Open button. Then demanded quantities of variants and bill of materials are listed at another screen with master-detail relation. Figure 3.10 shows snapshot of material requirement computation screen.

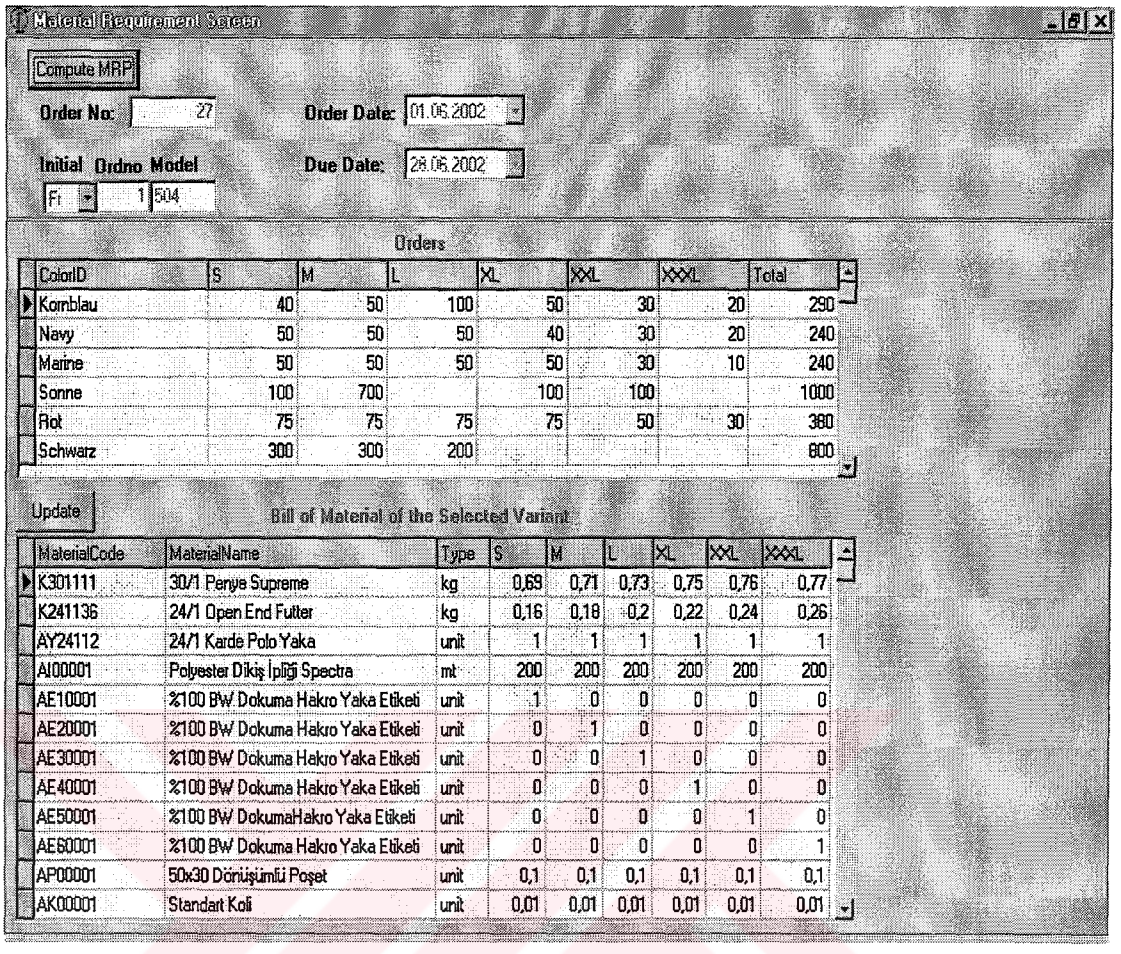

Figure 3.10 Material Requirement Screen

At the top of the screen, editboxes show order information, which was selected by the planner at the previous screen. And at the middle of the screen demanded values of the model is listed in dbgrid component. When user selects any color in other mean variant then related bill of material values are listed at the below in dbgrid. If necessary, planner updates a value of bill of material then clicks "Update" button to post changes to the BOM table.

When compute MRP button is clicked which locates at the top of the screen, material requirements report is generated for all demanded variants of the model. Computation process is listed below;

- Demanded quantity of each size is multiplied with its bill of material value.

- %10 loss ratio added for each size set.
- Obtained values are accumulated. So total requirement of raw material is obtained.
- Cloth materials' material operations properties are added to the report and %5 loss ratios are added for each existence of Press, Embroidery and MeterEmbroidery properties.
- Variant based report generated which consists total requirements of each material.
- Planner determine input dates of materials to the warehouse according to due date of the order and the capacity requirements.

Material computing formula is ;

$$\sum_{i=S}^{XXXL}\sum_{j=0}^{3}\{\textbf{(Demanded Quantity[i].value x BOM[i]. value x 1.1)} + \textbf{(A[j] x Demanded Quantity[i].value x BOM[i]. value x 0.05)}\}$$

**A[i]={Press, Embroidery, MeterEmbroidery}*

This report is called Purchasing Form and sent from planning department to the purchasing department. Purchasing personnel contacts vendors and purchases materials obeying necessary input dates to the warehouse. So he/she opens warehouse screen and finds related material from the database. Vendors of material, cost of unit and lead time also appeared in this screen that will be explained Inventory Control module. So easily selects proper vendor and opens order. This process is done for all of the demanded materials of planning department. Snapshot of Purchasing form can be seen in figure 3.11.

Purchasing Form

Model:	504	Cust. Order No:	27
Order Date:	25.05.2002	Order No:	1
Variant:	Kornblau	OrderCode:	FR001504

Mat. Code	Material Name	ColorID	Type	Quantity	Needed Date	Machine	En	Gr/m2	Sanfor	Ramoz	Sardon
K301111	30/1 Penye Supreme	Kornblau	kg	211,8	01.06.2002	30"22E	204	300	O.W	*	
K241136	24/1 Open End Futter	Marine	kg	58,8	01.06.2002	30"16E	174	280	B.W		*
AY24112	24/1 Karde Polo Yaka	Kornblau	unit	290	15.06.2002	47x11					
AI00001	Polyester Dikiş İpliği Spectra	Marine	meter	58000	03.06.2002						
AE10001	%100 BW Dokuma Hakın Yaka Etiketi	S	unit	40	20.06.2002						
AE20001	%100 BW Dokuma Hakın Yaka Etiketi	M	unit	50	20.06.2002						
AE30001	%100 BW Dokuma Hakın Yaka Etiketi	L	unit	100	20.06.2002						
AE40001	%100 BW Dokuma Hakın Yaka Etiketi	XL	unit	60	20.06.2002						
AE50001	%100 BW Dokuma Hakın Yaka Etiketi	XXL	unit	30	20.06.2002						
AE60001	%100 BW Dokuma Hakın Yaka Etiketi	XXXL	unit	20	20.06.2002						
AP00001	50x30 Dönüşümlü Poşet		unit	29	25.06.2002						
AK00001	Standart Koli		unit	2,9	25.06.2002						

Figure3.11 Purchasing Form

If we examine the purchasing form we see that Model, Order Date, Variant, Customer Order No, Order No and Order Code informations locates at the top of the report. Details of the report are result of the Material Requirement computation. So required materials, their needed quantities and other purchasing informations are listed.

A form illustrated above is generated for all variants. And coordination of planning and purchasing departments about demanded materials is handled by variant and ordercode. Ordercode consists of Initial of the customer, orderno and demanded model like FR001504. FR is initial of ford, 001 is orderno and 504 is demanded model by Ford. And planner reserves materials to the production using Inventory Control screen which is explained before.

Two additional types of this form can be used for purchasing operations. First one is cloth based purchasing form. This one is contains only clothes of all demanded variants. Accessories are not included to this form. Another type contains only accessories. Purchasing department purchases materials more structural by means of dividing purchasing operations to two categories.

3.6 Inventory Control Module

I created four tables, which are used at the inventory control module. These tables are;

- **Vendors:** Vendors' name, phone, fax, website and location informations are recorded to this table.
- **MatVendors:** Relationship of raw material and vendor are formed using this table. Material data is gotten from InventoryID table and vendor data is gotten from Vendors table.
- **InventoryID:** Raw materials' informations are recorded to this table.
- **InventoryTransactions:** Warehouse transactions are holded in this table. Two types of transactions are available which are input and allocation.

Relationships of these tables can be seen in figure 3.12 at the relationship diagram. We can see that MaterialCode is primary key for InventoryID table. And Model, InventoryTransactions and BOM tables join using MaterialCode with InventoryID table.

MatVendors table gets its Vendor field values from Vendors table. These tables join using VendorName field. So VendorName is primary key for Vendors table. One-to-many relation is created using VendorName field between MatVendors and Vendors tables.

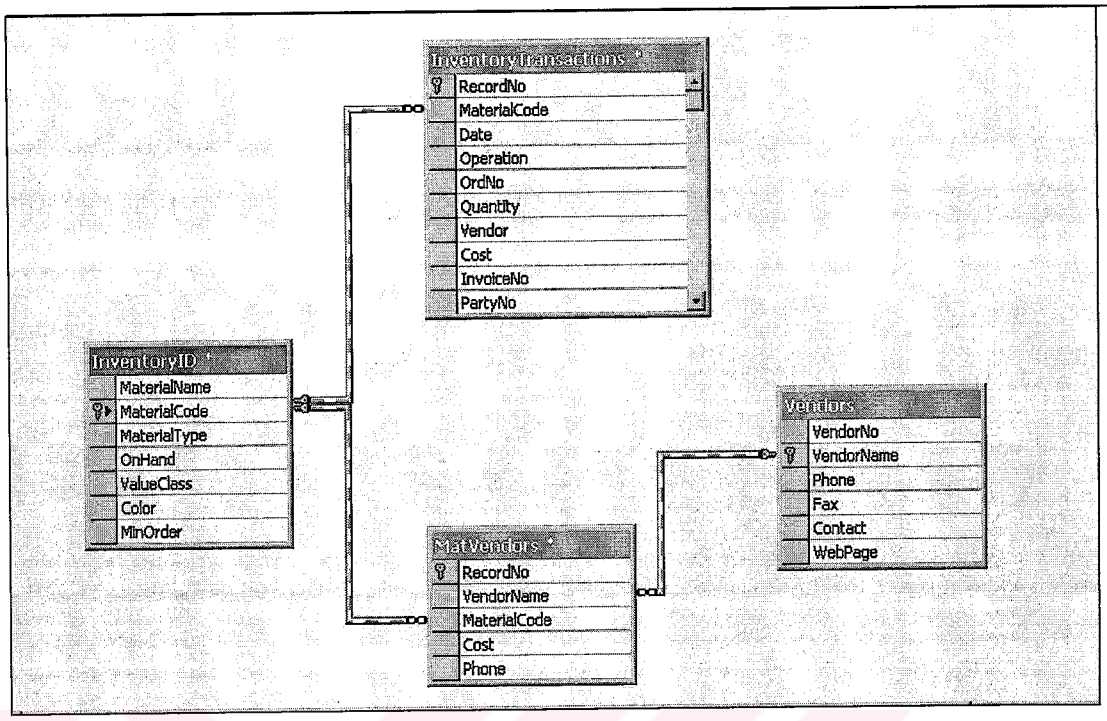

Figure 3.12 Relationship of Inventory Control Module Tables

3.6.1 Vendors Screen

I designed Vendors screen that is an interface of Vendors table. So purchasing personnel inserts and edits available vendors using this screen. Vendors of the materials are assigned using this table's records. Snapshot of screen can be seen in Figure 3.13.

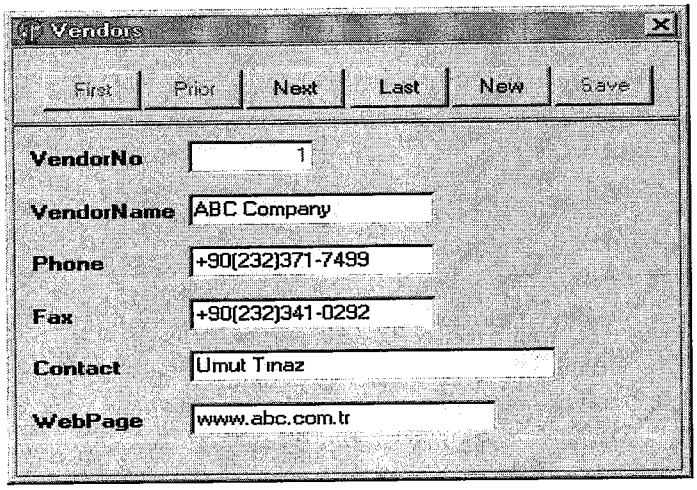

Figure 3.13 Vendors Screen

Name, Phone, Fax, Contact and Web Page informations of Vendors are holded in this table. Vendorno field is an autoinc field and generated using sql code. Buttons, which locate at the top of the screen, are used to navigate, save and insert operations at the Vendors table. Sql code of the table is below;

```
CREATE TABLE [dbo].[Vendors] (
    [VendorNo] [int] NOT NULL ,
    [VendorName] [char] (25) NOT NULL ,
    [Phone] [char] (20) NULL ,
    [Fax] [char] (20) NULL ,
    [Contact] [char] (30) NULL ,
    [WebPage] [char] (25) NULL
) ON [PRIMARY]
GO
ALTER TABLE [dbo].[Vendors] WITH NOCHECK ADD
    CONSTRAINT [PK_Vendors] PRIMARY KEY  NONCLUSTERED
    (
        [VendorName]
    )  ON [PRIMARY]
GO
 CREATE  INDEX [IX_Vendors] ON [dbo].[Vendors]([VendorNo]) ON
 [PRIMARY]
GO
```

3.6.2 Inventory Records Screen

I designed a screen to record and preview Material records, vendors of materials and transactions of materials. This screen is an interface of three tables that are InventoryID, InventoryTransactions and MatVendors (Vendors of material) tables. At the figure 3.14 we can see snapshot of this screen.

InventoryTransaction and MatVendors tables are detail tables of InventoryID table. So user can see each material's transactions and vendors of this material. Upper side of screen consists of InventoryID table's fields in dbeditboxes and MatVendors table's fields in dbgrid component. And bottom side of the screen includes InventoryTransactions table's fields in dbgrid component.

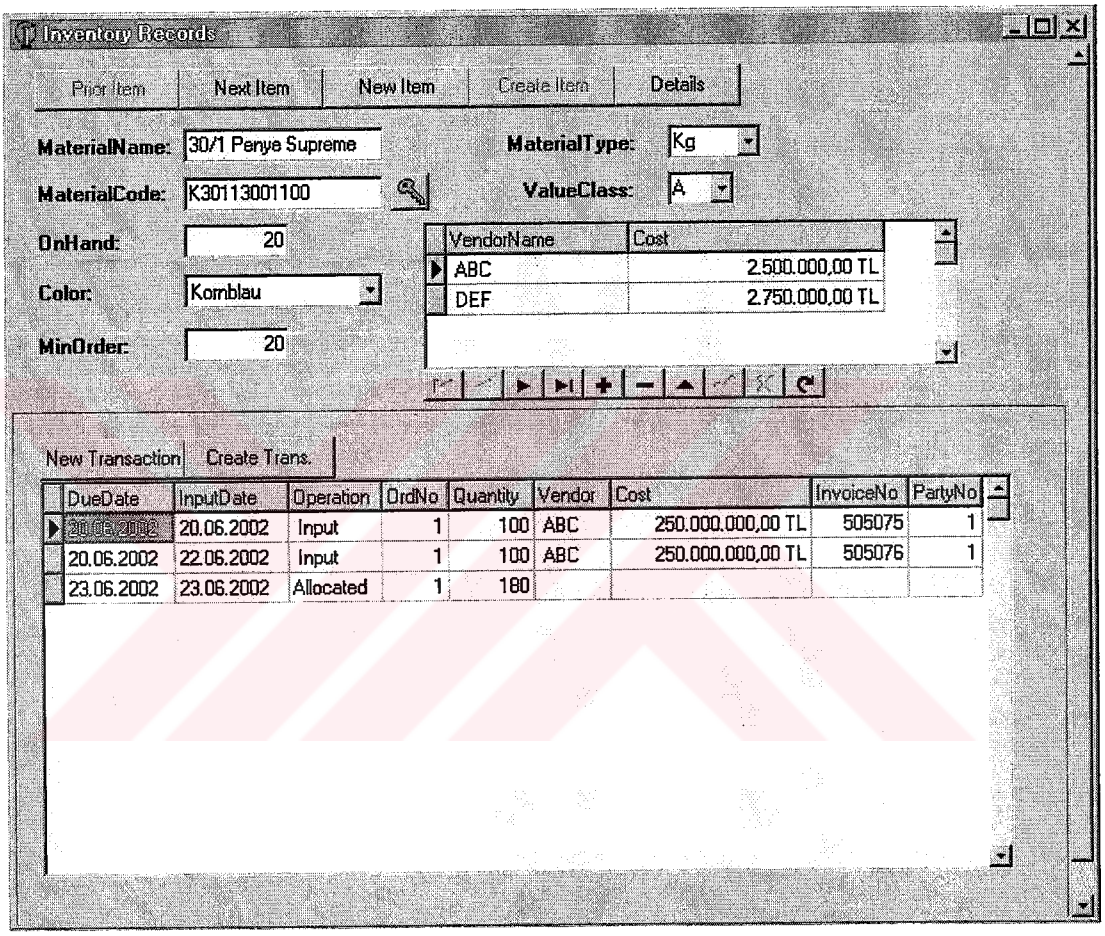

Figure 3.14 Inventory Records Screen

Now I will explain InventoryID, InventoryTransactions and MatVendors tables sequencely.

3.6.2.1 InventoryID table

"Prior Item", "Next Item" buttons are used to navigate through InventoryID table. "New Item" and "Create Item" buttons are used to insert and post operations. Details button shows materials properties in memo field.

If user enters material code and clicks bitbutton, which locates near by MaterialCode then InventoryID table locates this code. And related vendors and transactions also updated because of master-detail relation of InventoryID table and InventoryTransactions, MatVendors tables. Sql script and field definitions are below.

```
CREATE TABLE [dbo].[InventoryID] (
    [MaterialName] [char] (40) NOT NULL ,
    [MaterialCode] [char] (15) NOT NULL ,
    [MaterialType] [char] (10) NOT NULL ,
    [OnHand] [float] NULL ,
    [ValueClass] [char] (1) NULL ,
    [Color] [char] (20) NULL ,
    [MinOrder] [int] NULL ,
    [Properties] [text] NULL
) ON [PRIMARY]
GO
ALTER TABLE [dbo].[InventoryID] WITH NOCHECK ADD
    CONSTRAINT [PK_InventoryID] PRIMARY KEY  NONCLUSTERED
    (
        [MaterialCode]
    )  ON [PRIMARY]
GO
 CREATE  INDEX [IX_InventoryID] ON [dbo].[InventoryID]([MaterialName])
 ON [PRIMARY]
GO
```

Field definitions, which are seen in Inventory Records screen, are below;

Material Name: Name of the material.

MaterialCode: Unique code of the material. Basicly two different MaterialCodes exist. They are clothes and accessories. So codes of clothes begin with "K" and codes of accessories begin with "A". Clothes get their codes according to their thread thickness, color, quality, knitting type and properties like Ramoz, Sardon and Sanfor.

OnHand: Available quantity of the material that can be used for any production. This value is available, especially C class items like buttons because of Just in Time Policy of the company in inventory operations.

Color: Color of the material. This value is gotten from color table with dblookupcombobox component.

MinOrder: Minimum order quantity of the material.

Material Type: If raw material is cloth type can be kg or if raw material is thread type can be meter or if raw material is accessory type can be unit. So combobox is used to hold these three values.

ValueClass: Class of the material. This value is obtained by ABC analysis results. So A, B and C values are added to items of combobox.

Properties: For example, sizes of packages, raw material of the button and similar informations are holded in this field.

3.6.2.2 MatVendors Table (Vendors of material)

This table holds vendors of materials, unit costs and lead time of materials. As explained before it is detail table of InventoryID table. An interface of this table can be seen in figure 3.14, which locates under the ValueClass field. This grid shows vendor's name, cost and lead time of the material. So purchasing person easily selects convenient vendor according to cost and date constraints.

After inserting the material information, purchasing person enters vendor information using dbgrid. So material's code also inserted to the MatVendors table

and other information is inputted by person that is VendorName, Vendor's selling cost of unit and lead time of the material. Unit of the lead times is week.

Dbnavigator are used for table operations that is locates at the bottom of the grid. Create code of the table is below;

```
CREATE TABLE [dbo].[MatVendors] (
    [RecordNo] [int] NOT NULL ,
    [VendorName] [char] (25) NOT NULL ,
    [MaterialCode] [char] (15) NOT NULL ,
    [Cost] [money] NULL ,
    [LeadTime] [smallint] NULL
) ON [PRIMARY]
GO
ALTER TABLE [dbo].[MatVendors] WITH NOCHECK ADD
    CONSTRAINT [PK_MatVendors] PRIMARY KEY  NONCLUSTERED
    (
        [RecordNo]
    )  ON [PRIMARY]
GO
 CREATE  INDEX [IX_MatVendors] ON [dbo].[MatVendors]([VendorName],
[MaterialCode]) ON [PRIMARY]
GO
 CREATE  INDEX [IX_MatVendors_1] ON [dbo].[MatVendors]([Cost]) ON
[PRIMARY]
GO
```

3.6.2.3 InventoryTransactions table

Material transactions are recorded to this table. As I mentioned before this table is detail table of InventorID table. These tables joined with MaterialCode field. So if user creates a new transaction, MaterialCode of active InventoryID table record is

written to the InventoryTransaction table's MaterialCode field. And then other informations are inserted. Sql code of table is showed below;

```
CREATE TABLE [dbo].[InventoryTransaction] (
    [RecordNo] [int] NOT NULL ,
    [MaterialCode] [char] (15) NOT NULL ,
    [DueDate] [datetime] NOT NULL ,
    [InputDate] [datetime] NOT NULL ,
    [Operation] [char] (10) NOT NULL ,
    [OrdNo] [int] NULL ,
    [Quantity] [float] NULL ,
    [Vendor] [char] (10) NULL ,
    [Cost] [money] NULL ,
    [InvoiceNo] [int] NULL ,
    [PartyNo] [int] NULL
) ON [PRIMARY]
GO
ALTER TABLE [dbo].[InventoryTrs] WITH NOCHECK ADD
    CONSTRAINT [PK_InventoryTrs] PRIMARY KEY  NONCLUSTERED
    (
        [RecordNo]
    )  ON [PRIMARY]
GO
 CREATE  INDEX [IX_InventoryTrs] ON [dbo].[InventoryTrs]([InputDate],
 [OrdNo]) ON [PRIMARY]
GO
```

Figure 3.15 shows an interface of InventoryTransaction table, which is quoted from Inventory Records screen that is showed in figure 3.14. "New Transaction" and "Create Trans." buttons are used for inserting and posting operations to the InventoryTransactions table respectively.

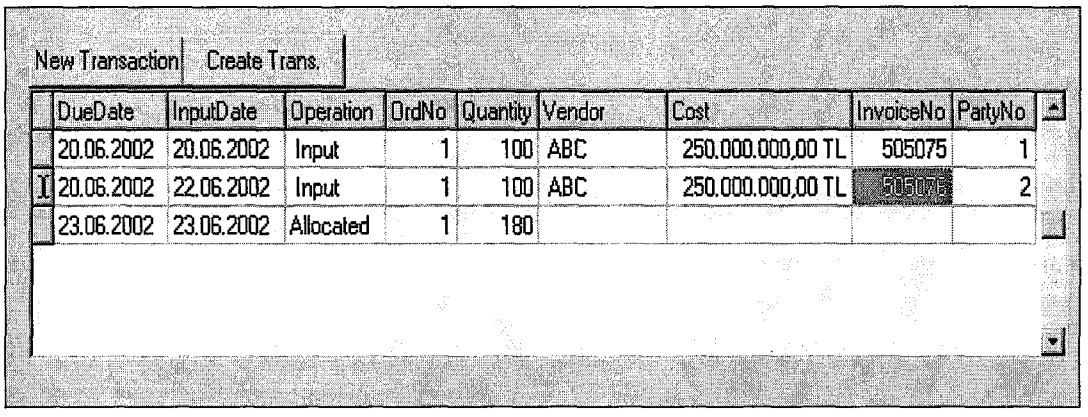

Figure 3.15 Interface of InventoryTransaction table

Field definitions of this table are below;

DueDate: Planning engineer determines input date of the material to the company's warehouse considering capacity limits and duedate of the order.

InputDate: Real input date of the material to the warehouse. So lead times of the vendors are updated or reasons of the time laggings are interrogated by comparing DueDate and InputDate values.

Operation: If the material comes from the vendor then the operation is Input. Another situation that if material is reserved to the production then operation is Allocation. So Input and Allocation values are added to the column's picklist.

OrdNo: Order number of the purchasing operation. This value is equal to OrdNo that is generated while entering customer's demands.

Quantity: Inputted or allocated quantity of the material.

Vendor: Vendor of the material.

Cost: Total cost of the material that is obtained multiplying vendor's unit sale cost and quantity value.

InvoiceNo: Invoice no of the entered material.

PartyNo (Lot no): Especially at the cloth purchasings, ordered quantity doesn't comes at one time. So same order can have several party (lot) inputs. This field is used to handle this process. Suppose that we ordered 200 kg cloth but 100 kg of that comes one day and other 100 kg comes another day. So order had come at two parties or lots.

3.7 Comparison of the Old System with My Design

Until now, I explained designed software's database structure and interfaces. We can see that, this software is used for marketing, planning, purchasing and warehouse departments' interactions. Block diagram of the system can be seen in figure 3.16 at the next page. Meanings of the numbers that locate over the arrows are explained below.

- 1= Fax of the customers that includes demands.
- 2=Demands of the customers are inserted to the database for planning activities.
- 3=Informations of the products are gotten from model department. If necessary, bill of materials are updated.
- 4=Purchasing form is generated
- 5=Material orders are opened.
- 6=Materials are delivered.
- 7=Materials get out from warehouse to the production floor.
- 8=Completed products enter to the warehouse.
- 9=Shipment of the customers' orders are done

Now, I will compare current status with new status that is designed by me. First old system will be explained.

MS Excel programme is used for computing material requirements and creating purchasing form. So there is no any updated database about orders, customers, vendors and materials. Ordered products are existed in the fax page that is faxed by customers. And these values are gotten and inserted to the excel sheet to compute required materials. Materials of the products are also inserted to the sheet. And computing is done. After that, input dates of the materials to the warehouse are determined. These values are copied and pasted to the purchasing form and this form is sent to the purchasing department. Purchasing person contacts with vendors and opens orders.

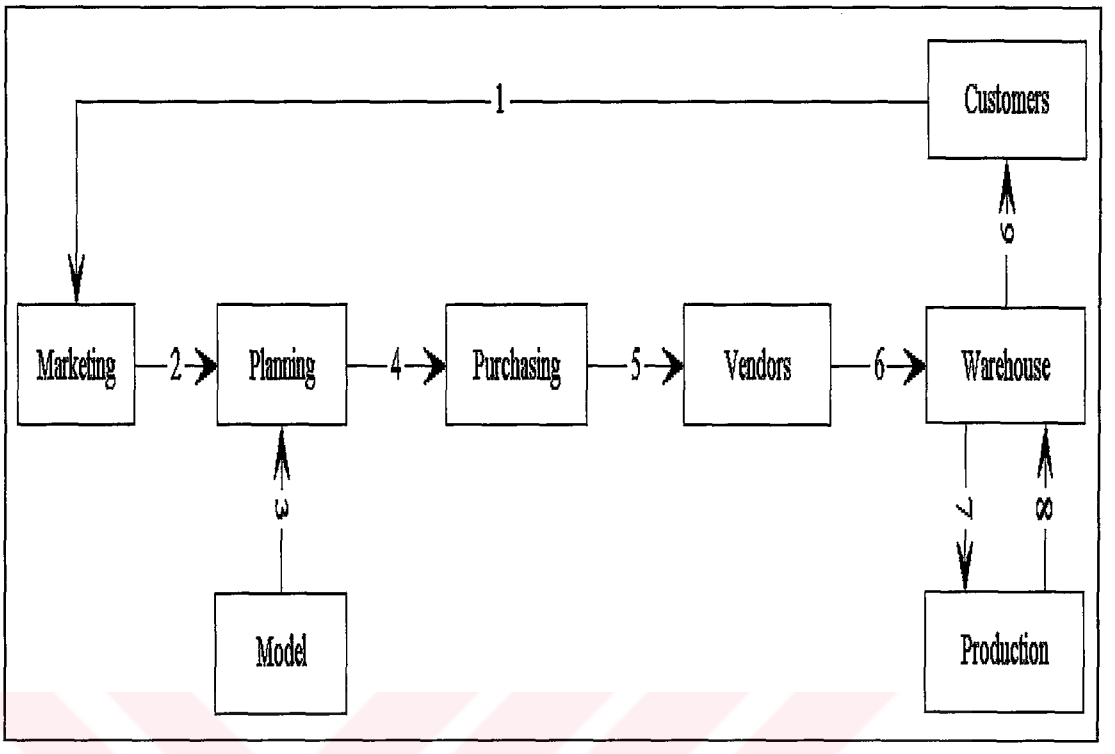

Figure 3.16 Information Flow Chart Between Departments Of The Company

But in my design automation of these processes were obtained. Because after getting fax page these orders are inserted to the database in assistance of user friendly screen and new order is opened that shows that, there is a demand and must be shipped until due date of it. So planner controls that, are there any opened orders and selects them for computing needed materials of them and starting the production. And purchasing form is generated. Input date of the each material to the warehouse is determined according to capacity and shipping date constraints. Then purchasing form is sent to the purchasing department. Purchasing person contacts with vendors for purchasing materials. And finds these materials and controls vendors of them from the inventory module. Cost and lead time informations are also exists. So proper vendors are selected and orders are opened. In addition, status of the orders, that can be open, in progress or completed, can be followed at the new system. And agreed input dates of the materials are inserted to the Inventory Management module. When material enters to the warehouse transaction is updated and real input date is inserted to the record. So lead times of vendors are controlled that are reliable or not.

Some superiorities of new system are;

- Users use this program easily because of visual environment.

- Until now, opened orders are holded at the database. But at the old system opened orders takes part at the fax pages.

- All materials' records that are used by end products are holded in assistance of inventory control module. And transactions of them are recorded online. Vendors of the materials, lead times and unit costs are also holded by means of inventory control module. But at the old system inventory transactions are written to the inventory cards. And statuses of the materials are controlled from inventory cards manually.

- Material Operations of the clothes inserted to the purchasing form automatically. But at the old system, material operations are added to the form manually.

- Loss ratios are added automatically while MRP computing process. Because operations of the clothes are defined at the materials operations screen. So whether material has a press, embroidery or meter embroidery operations are controlled from MaterialOperations table.

Consequently, in my design customers, orders, products, inventories, and vendors are gathered in one database. Users do their works in assistance of this database records and graphical interfaces.

CHAPTER FOUR
CONCLUSION

4. Conclusion

In this study, I researched the production planning systems according to time horizons that long range, intermediate range and short range planning horizons. So I explained Aggregate Production Planning as long range decision making strategy, which is derived from Business Plan. And then I examined Master Production Schedule (MPS) as intermediate range plan that gets Aggregate Production Plan as an input. Finally I explained Material Requirement Planning (MRP) detailed as short range planning. MRP uses MPS as an input and computes needed material requirement. We can understand that all planning horizons are an important to the enterprises because each one is related with each other.

Huge part of the theoretical side of the study is MRP systems. Inputs and outputs of the MRP are explained and MRP computation is sampled with assistance of figures and tables. And Capacity Requirement Planning, which is used for MRP results' validation, explained briefly.

Application part constitutes main aim of the study. At the application part system analysis of a textile company was done for developing computer-based production and inventory control system. This company produces various typed shirts and applies make–to–order policy for production and Just-in-Time policy for inventory management. So order and inventory management is so important to the company.

I explained flowing of the system that includes order management, inventory management and computing material requirement. And database was designed for all

planning related production process from taking orders to completing production process. Because heart of computer-based production and inventory control system is its database. Graphical User Interfaces (GUI) were designed for all needed operations that database operations are done with these interfaces.

As a result I believe that this study can be a reference who wants to learn about MRP systems and these systems working logic. And application part can be used by the company as a guide for order, inventory and MRP modules of ERP project.

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