ASSUMPTION UNIVERSITY (ABAC) BANGKOK
มหาวิทยาลัยอัสสัมชัญ

INVENTORY MANAGEMENT AT VALENTINE DRINKING WATER COMPANY

by

Mr. Nutapong Asavalahaphun

A Final Report of the Three - Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
Assumption University

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Project Title	Inventory Management at Valentine Drinking Water Company
Name	Mr. Nutapong Asavalahaphun
Project Advisor	Dr Chamnong Jungthirapanich
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The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

Approval Committee:

(Dr. Chamnong Ju t panich)
Dean and Advisor

(Prof.Dr. Srisakdi Charmonman)
Chairman

(Asst.Prof.Dr. Boonmark Sirinaovakul)
Member

(Dr. Prapon Phasukyud)
Member

(Assoc.Prof. Somchai Thayarn ong)
MUA Representative

November 2000

ABSTRACT

This project specifies the characteristics of Valentine Drinking Water Company, which includes the inventory management, ways to improve the inventory system and strategies. Inventory management and control is a key activity area within the business logistics process.

The overview of inventory management and just-in-time tactics (JIT), master production schedule (MPS), material requirements planning (MRP) and management of maintenance, repair and operating (MRO) will give the reader get more understanding of the inventory subject.

Valentine Drinking Water Company used to use basic order quantity model technique, which the delivering system is being done once a week, which the safety stock never happens. It may cause the lacking of products.

Cost of inventory system is not occurred from only the safety stock. This project will show factors of inventory cost and show how to find the total annual cost, reorder point, optimum order quantity, expected number of orders and expected time between orders by using MPS, MRP and inventory models techniques. Comparing cost of the existing system and the proposed system of each product shows that the cost of the proposed system is better than the existing system. The duration of reorder point of the proposed system is longer than the existing system. This makes the order quantity larger than the existing system. Furthermore, it also makes higher holding cost but more lower ordering cost.

Safety stock is used in the proposed system, which can solve the lack of products problem. The author will recommend further work for readers who are interested in this inventory subject that theories in this project are sufficient to analysis for some organizations that their inventories are not complicated.

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I. INTRODUCTION

Redesigning the inventory processes can have a significant impact on a manufacturer's profitability. It is important to always look at the various types of inventory and understand how they work. There are five main factors that involve with the inventory system: pipelines, economies of scale, overstock, dead stock, and safety stock. In a meantime, it is critical to understand to find ways to improve customer service while reducing levels of inventory throughout the logistic processes.

Valentine Drinking Water Company is a company using a unique system which is like running the family business. However, it has been operated systematically for a long time. The current system that the company is using is based on inventory models called EOQ.

The Inventory System of Valentine Drinking Water Company allows you to understand the concept of internal and external inventory management of the company itself. For example, excess costs of carrying inventory need to be eliminated whenever possible. The final goal of the company is to analyze and to improve the existing inventory system at Valentine Drinking Water Company by using appropriate inventory management techniques. In order to succeed the goal, it must compose of three main objectives: to reduce cost of inventory, to increase customer's satisfaction, and to make it easy in managing the inventory system. In addition, there is calculation of accommodation costs in the inventory's analysis.

This project scope is aimed to study the inventory management of Valentine Drinking Water Company. Old inventory system should be considered and developed to the new system that will be analyzed. The scopes of this project are to gather the past sales data and analyze demand pattern of a Valentine Drinking Water Company.

II. LITERATURE REVIEW

This chapter proposes the inventory management & just-in-time tactics, master production schedule (MPS), material requirements planning (MRP) and management of maintenance, repair and operating (MRO). Each topic provides concept and method to differentiate itself from others. In addition, formulas are also provided for the calculation and figures are shown to help better understanding.

2.1 Inventory Management and Just-In-Time Tactics

Inventory is one of the most expensive assets of many companies, representing as much as 40% of total invested capital. Operations managers have long recognized that good inventory control is crucial. On one hand, a firm can try to reduce costs by reducing on-hand inventory levels. On the other hand, customers become dissatisfied when frequent inventory outages (called stockouts) occur. Thus, companies must strike a balance between inventory investment and customer service levels. As you would expect, cost minimization is a major factor in obtaining this delicate balance.

Inventory is any stored resource that is used to satisfy a current or future need. Raw materials, work-in-process and finished goods are examples of inventory.

All organizations have some type of inventory planning and control system. A bank has methods to control its inventory of cash. A hospital has methods used to control blood supplies and pharmaceuticals. Government agencies, schools, and, of course, virtually every manufacturing and production organization are concerned with inventory planning and control.

In cases of physical products, the organization must determine whether or not to produce goods or to purchase them. Then operations managers determine the inventory necessary to service that demand. We discuss inventory management. Two basic questions we need to answer are how much to order and when to order.

2.1.1 Functions of Inventory

Inventory can serve several important functions that add flexibility to the operation of a firm. Three uses of inventory are (a) the decoupling function, (b) a hedge against price changes and inflation, and (c) quantity discounts.

(a) The Decoupling Function

The major function of inventory is to decouple production and distribution processes. When the supply or demand for an inventory item is irregular, maintaining inventory may be a good decision. For example, if product demand is high only during, the summer, the firm may want to make sure that inventory is adequate to meet this high demand. This might require production in the winter, in which case the inventory level would build up during the winter to be used during the summer. This decouples production from demand and avoids the cost of shortages and stockouts. Similarly, if a firm's supplies fluctuate, raw material inventories may be necessary for decoupling input from the transformation process. Production processes may also fluctuate within the firm. When two related processes are not synchronized, inventory can separate (decouple) the two processes, allowing each to operate at its own pace.

(b) A Hedge Against Inflation

Inventory can be a hedge against price changes and inflation. Placing cash reserves in the bank might enable the firm to obtain a good return. On the other hand, the value of inventory may increase even more. Thus, inventory may be a better investment. Of course, the cost and the risk of holding or carrying inventory must be considered. As a matter of policy, most firms do not allow operations personnel to speculate in this manner.

(c) Quantity Discounts

Another use of inventory is to take advantage of quantity discounts. Many suppliers offer discounts for large orders. Purchasing in larger quantities can substantially reduce the cost of products. There are, however, disadvantages of buying in larger quantities. Higher costs due to storage, spoilage, damaged stock, theft, and insurance will be incurred. By investing in more inventories, less cash will be available to invest elsewhere.

2.1.2 Just-In-Time Inventory

Inventories in production and distribution systems often exist "just in case" something goes wrong, that is, just in case some variation from the production plan occurs. In such a concept, inventory exists between all segments of production and distribution. We suggest that good inventory tactics require not "just-in-case," but "just-in-time" (JIT) inventory. Just-in-time inventory is the minimum inventory necessary to keep a perfect system running. With just-in-time inventory, the exact amount of good items arrive, at-the -moment they are needed, not a minute before or a minute after the units are required. Let us examine this idea.

To achieve just-in-time inventory, managers reduce variability caused by both internal and external factors. If inventory exists because of variability in the process, then managers eliminate the variability. Inventory hides variability a polite word for problems. If managers can get rid of the variability, they need very little inventory. What causes variability? Most variability is caused by tolerating waste or by poor management. Some of the reasons variability occurs are:

(a) employees, machines, and suppliers produce units that do not conform to standards, are late, or are not the proper quantity;

(b) engineering drawings or specifications are inaccurate;

(c) production personnel try to produce before drawings or specifications are complete;

(d) customer demands are unknown.

The variability described above may require that a firm maintains various types of inventories. These include raw material inventory, work-in-process inventory, maintenance/repair/operating supply (MRO) inventory, and finished goods inventory.

Raw material inventories can be used to decouple suppliers from the production Process. However, the preferred approach is to eliminate supplier variability in quality, quantity, or delivery time. Some work-in-process inventory may exist because of the time it takes for a product to be made (call cycle time). Reducing the cycle time reduces inventory. Most of the time a product is "being made," it is in fact sitting idle. Actual work time or "run" time is a small portion of the material flow time, perhaps as low as 5%.

MRO inventories exist because need and timing for some maintenance and repair of equipment is unknown. While the demand for some MRO inventories is a function of maintenance schedules, other MRO demands must be forecasted. Similarly, finished goods may be inventoried because customer demands for a given time period may not be known.

For the above reasons, inventory exists. The just-in-case approach to inventory management deals with variability by "decoupling" the various stages of the process. Decoupling is accomplished by increasing inventory until inventory is adequate to allow for all of the variability. If variability is large, management ends up with huge amounts of inventory.

To achieve just-in-time inventory, management must begin by reducing inventory. Reducing inventory uncovers the rocks that represent the variability and problems currently being tolerated. With reduced inventory, management chips away at the exposed problems until the stream is clear, and then makes additional cuts in inventory, chipping away at the next level of exposed problems. Ultimately there will be virtually no inventory and no problems (variability).

Perhaps the manager who said, "Inventory is the root of operations management evil" was not far from the truth. If inventory is not evil, it tends to hide the evil at great cost.

(1) Just-in-Time Production

Just-in-time production has come to mean elimination of waste, synchronized manufacture, and little inventory. The key to JIT is producing small lot sizes to standards. Reducing the size of batches can be a major help in reducing inventory and inventory costs. When inventory usage is constant, the average inventory level is the sum of the maximum inventory plus the minimum inventory divided by two. Expressing the average inventory level algebraically, we have:

Average inventory level = (Maximum inventory + Minimum inventory)/2

The average inventory drops as the inventory reorder quantity drops because the maximum inventory level drops. Moreover, as noted earlier, the smaller the lot size (batch), the fewer problems are hidden. Only when problems are identified can they be solved and the organization become more efficient. We therefore want to decrease total inventory and attendant lot sizes. One of the ways to achieve small lot sizes is to move inventory through the shop only as needed rather than pushing it on to the next workstation, whether they are ready for it or not. When inventory is moved only as needed, it is referred to as a pull system and the ideal lot size is one.

(2) The Revolution Against Waste

Just-in-time (JIT) implies a sweeping reorganization of work and society. The JIT factory attacks four types of waste: inventories, changeovers, defects, and human resources. The war against waste begins and ends with factory layout. The long production lines and huge "economic lots" of the Industrial Revolution, with goods passing through monumental, single-operation machines, are gone. Now each work cell, arranged in a U-shape, contains several small machines performing different operations. The cells produce goods a unit at a time, and produce them only after a customer buys them.

Inventory is waste. It wastes space because it takes up storage room. It wastes money because it has to be financed. It wastes time because it has to be transported. Nothing is wasted that can be sold; so produce nothing that cannot be sold.

Defects are waste. When workers produce units one at a time, they can test each product or component at each production stage. Machines in work cells with "human-touch" functions sense defects and stop automatically when they occur. An entire production line can stop when someone finds a defect. Before JIT, defective products were replaced from inventory. In a JIT factory there are no such buffers. Getting it right the first time is all-important. Waste removal thus has a by-product: quality.

(3) Holding, Ordering, and Setup Costs

(a) Holding Costs

Holding costs are the costs associated with holding or "carrying" inventory over time. Therefore holding costs also include costs related to storage, such as insurance, extra staffing, interest, and so on. Many firms find it difficult to evaluate inventory-holding costs realistically. Consequently, inventory-holding costs are typically understated.

(b) Ordering Costs

Small order quantity requires, as we shall see shortly, a low ordering cost for each order. Ordering cost includes costs of supplies, forms, order processing, clerical support, and so forth. When orders are being manufactured, ordering costs also exist, but they are known as setup costs.

(c) Setup Costs

Setup cost is the cost to prepare a machine or process for manufacturing an order. The operations manager, prior to determining when to order or how much to order, should endeavor to reduce ordering costs. This may be done by efficient procedures such as electronic ordering and payment and by reducing setup costs. In many environments setup cost is highly correlated with setup time. Whatever the setup time, it is probably longer than innovative managers should accept. Setups usually require a substantial amount of work prior to an operation actually being accomplished at the work center. Much of the preparation required by a setup can be done prior to shutting down the machine or process.

Machines and processes that traditionally have taken hours to set up are now being set up in less than a minute by the more imaginative world-class manufacturers. Reducing setup times is an excellent way to contribute to a reduction in inventory investment and to improve productivity.

2.1.3 Inventory Models

(1) Independent versus Dependent Demand

Inventory control models assume that demand for an item is either independent of or dependent on the demand for other items. For example, the demand for refrigerators is usually independent of the demand for toaster ovens. Many inventory problems, however, are interrelated; the demand for one item is dependent on the demand for another item. Consider a manufacturer of small power lawn mowers. The demand for lawn mower wheels and spark plugs is dependent on the demand for lawn mowers. Four wheels and one spark plug are needed for each finished lawn mower. Usually when the demand for different items is dependent, the relationship between the items is known and consistent. Thus, management schedules production based on the demand for the final products and computes the requirements for components.

(2) Types of Inventory Models

Inventory models that assist in answering two important questions that apply to each item in stock:

(a) when to place an order for an item;

(b) how much of an item to order.

We will consider four independent demand models:

(a) economic order quantity (EOQ) model;

(b) production order quantity model;

(c) back order inventory model;

(d) quantity discount model.

The Basic Economic Order Quantity (EOQ) Model

The economic order quantity (EOQ) is one of the oldest and most commonly known inventory control techniques. EOQ is still used by a large number of organizations today. This technique is relatively easy to use, but it does make a number of assumptions. The more important assumptions are:

(a) Demand is known and constant;

(b) Lead time is known and constant;

(c) Receipt of inventory is instantaneous. In other words, the inventory from an order arrives in one batch, at one time;

(d) Quantity discounts are not possible;

(e) The only variable costs are setup cost and holding or carrying cost;

(1) Stockouts (shortages) can be completely avoided, if orders are placed at the right time.

With these assumptions, the graph of inventory usage over time has a sawtooth shape as shown in Figure 2.1. In Figure 2.1, Q represents the amount that is ordered. If this amount is 500 dresses, all 500 dresses arrive at one time when an order is received. Thus, the inventory level jumps from 0 to 500 dresses. In general, an inventory level increases from 0 to Q units when an order arrives.

Because demand is constant over time, inventory drops at a unifoiiii rate over time. (Refer to the sloped line in Figure 2.1) When the inventory level reaches 0, the new order is placed and received, and the inventory level again jumps to Q units (represented by the vertical lines). This process continues indefinitely over time.

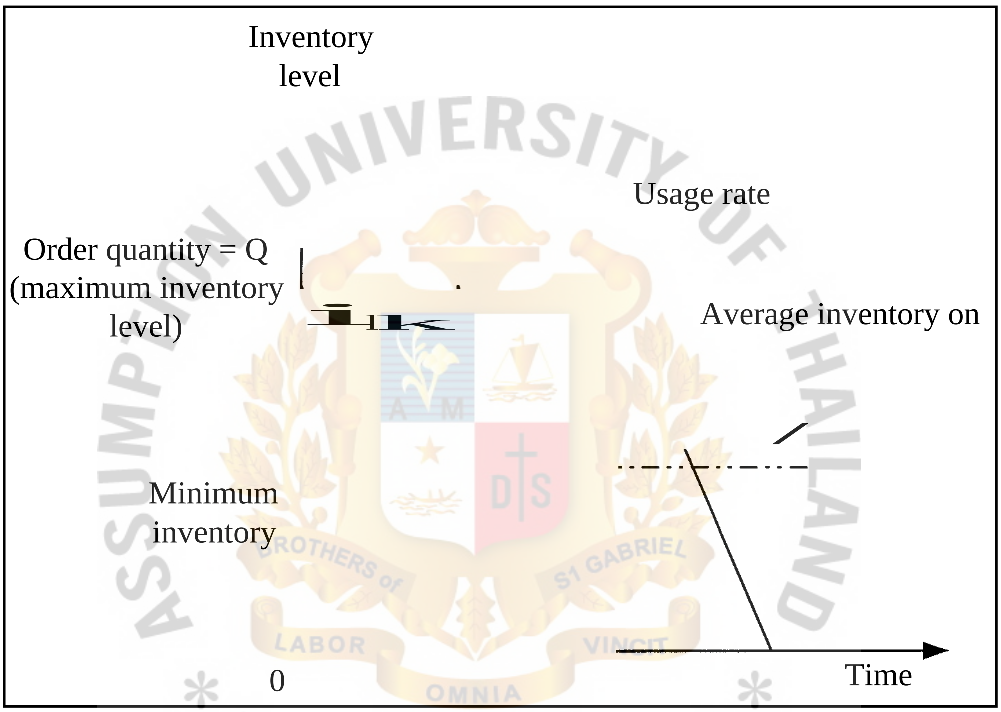

Figure 2.1. Inventory Usage Over Time (Heizer and Render 1993).

(4) Inventory Costs

The objective of most inventory models is to minimize the total costs. With the assumptions just given, the significant costs are the setup (or ordering) cost and the holding (or carrying) cost. All other costs, such as the cost of the inventory itself, are constant. Thus, if we minimize the sum of the setup and holding costs, we will also be minimizing the total costs. To help you visualize this, in Figure 2.2 we graph total costs as a function of the order quantity, Q. The optimal order size, Q*, will be the quantity that minimizes the total costs. As the quantity ordered increases, the total number of orders placed per year will decrease. Thus, as the quantity ordered increases, the annual setup or ordering cost will decrease. But as the order quantity increases, the holding cost will increase due to larger average inventories that are maintained.

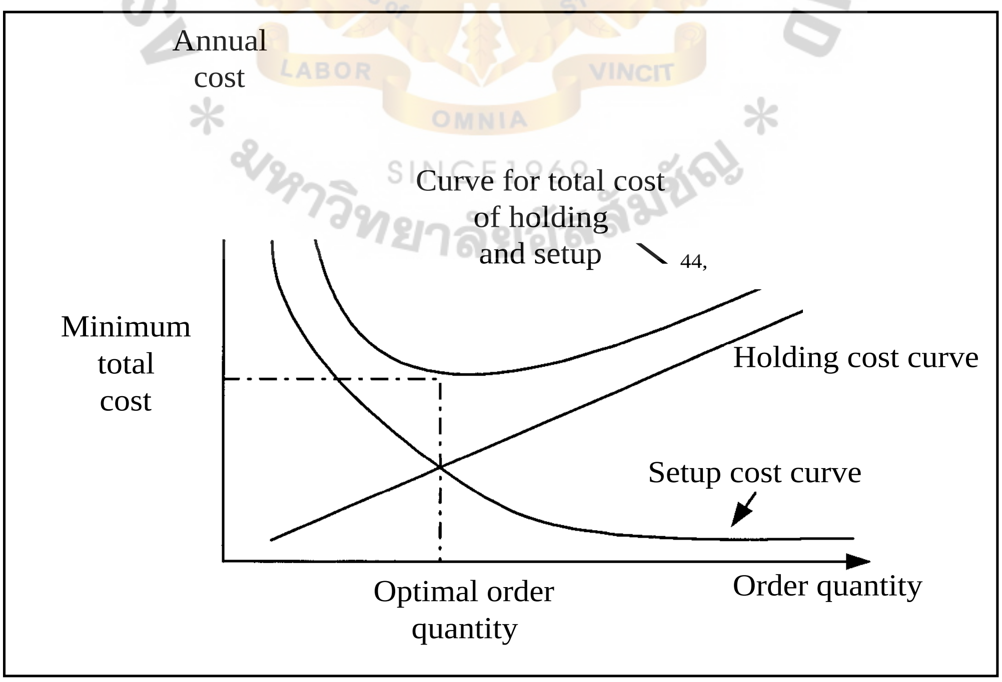

Figure 2.2. Total Cost as a Function of Order Quantity (Heizer and Render 1993).

You should note that in Figure 2.2 the optimal order quantity occurred at the point where the ordering cost curve and the carrying cost curve intersected. This was not by chance. With the EOQ model the optimal order quantity will occur at a point where the total setup cost is equal to the total holding cost. We use this fact to develop equations that solve directly for Q*. The necessary steps are:

(a) Develop an expression for setup or ordering cost;

(b) Develop an expression for holding cost;

(c) Set Setup cost equal to holding cost;

(d) Solve the equation for tile best order quantity.

Using the following variables we can determine setup and holding costs and solve for Q*:

Number of pieces per order

Q* = Optimum number of pieces per order (EOQ)

Annual demand in units for the inventory item

Setup or ordering cost for each order

Holding or carrying cost per unit per year

Annual ordering cost = (No. of orders placed/yr.)*

(Setup or order cost/order)

(Annual demand/No. units in each order)*

(Setup or ordering cost/order)

(D/Q)*S

Annual holding cost – (Average inventory level)*

(Holding cost/unit/year)

- (Order quantity/2)*(Holding cost/unit/year)

- (Q/2)*H

Optimal order quantity is found when annual setup cost equals annual holding cost, namely,

(D/Q)*S = (Q/2)*H

To solve for Q*, simply cross-multiply terms and isolate Q on the left of the equals sign.

2DS – Q^2H

Q^2 – (2DS)/H

Q* – V(2DS)/E1

Now that we have derived equations for the optimal order quantity, Q*, it is possible to solve inventory problems directly.

We can also determine the expected number of orders placed during the year (N) and the expected time between orders (T) as follows:

Expected number of orders

Demand/Order quantity

= D/Q*

Expected time between orders

= Number of working days in a year/N

As mentioned earlier in this section, the total annual inventory cost is the sum of the setup and holding costs:

Total annual cost Setup cost + Holding cost

In terms of the variables in the model, we can express the total cost TC as:

TC (D/Q)/S + (Q/2)H

(5) Reorder Points

Now that we have decided how much to order, we shall look at the second inventory question, when to order. Simple inventory models assume that receipt of an order is instantaneous. In other words, they assume that a firm will wait until its inventory level for a particular item reaches zero before placing an order, and that it will receive the items immediately. However, the time between the placement and receipt of an order, called the lead time or delivery time, can be as short as a few hours to as long as months. Thus, the when-to-order decision is usually expressed in terms of a reorder point, the inventory level at which an order should be placed. See Figure 2.3.

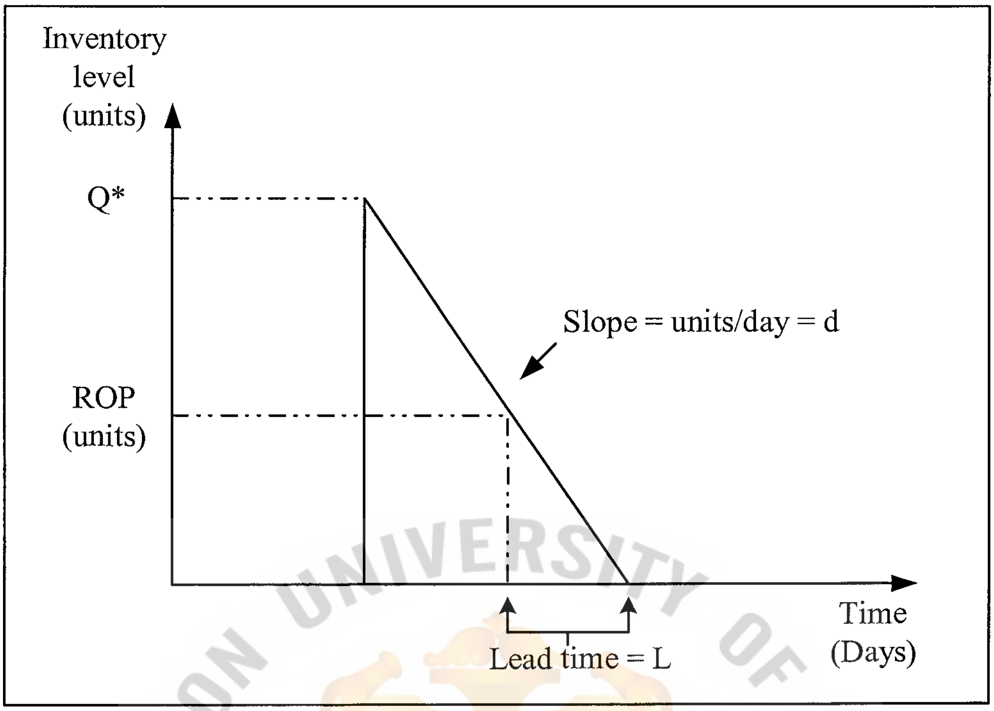

Figure 2.3. The Reorder Point (ROP) Curve (Heizer and Render 1993).

The reorder point (ROP) is given as:

ROP = (Demand per day)(Lead time for a new order in days)

$= d * L$

This equation for ROP assumes that demand is uniform and constant. When this is not the case, extra stock, often called safety stock, should be added.

The demand per day, d, is found by dividing the annual demand, D, by the number of working days in a year:

d = D / Number of working days in a year

2.1.4 Inventory Accuracy and Importance

An Inventory system is not just a record of how many are in stock, but it is an integral part of the information system. Inaccuracies here spread, purchasing may not be triggered, production may start when components are not available.

Accurate inventory balances are essential if not fundamental to an effective planning system. Without accurate data, it's the old "garbage in, garbage out".

For many companies annual, semi-annual, or even monthly physical inventories are used to keep inventory accurate. Between physicals, the inventory immediately gets out of whack once again. This is the most costly, inefficient way to retain inventory accuracy. Complete physical inventories are notoriously inaccurate because too many items are counted all at once by people who wish they were somewhere else rather than counting parts on the weekend. Secondly, you usually have to freeze production or be down for a period of time while the physical checking takes place, which is costly.

Far better is to have a perpetually accurate inventory. This can be accomplished by the following three methods: cycle counting, maintaining accurate bills of materials, and adherence to procedures.

Frequent, small physical counts are by far preferable to complete physicals. Small physicals are highly accurate and can be done regularly throughout the year, sometimes eliminating the need for an annual physical.

Accurate bills of material are essential. Many companies have sloppy bills of material, or have one bill of material in engineering and another one in manufacturing. An effective planning system requires one, common bill of material for each manufactured item and it must be completely accurate. Many work order systems relieve inventory through kit issues or "back flushing" when the work order is completed, both of which relieve inventory by complete sets of the bill of material. If the bill of material is inaccurate, inventory will be relieved inaccurately.

Some items have an inherent scrap factor that varies slightly with each production run. This is common with sheet metal and plastics. You should define the quantity required in the bill of material as accurately as you can, but schedule periodic cycle counts of these materials to adjust for scrap variance.

Finally, you must train everyone in the company to adhere to procedures. Parts cannot be pulled from stock without recording the transaction on pick lists or material tickets. Bills of material must be faithfully updated for engineering changes. It must be stressed to employees that sloppy paperwork fouls up the system and won't be tolerated (Cybor Communications Limited 1998a).

Inventory record errors are costly. No computer system, be it old or new, will work properly if the transactions are not entered correctly.

The costs of poor inventory record accuracy is not always apparent to management. Consider the following results, all of which increase production costs and reduce profits:

(a) unanticipated stockouts;

(b) decreased production efficiency;

(c) higher investment in safety stocks;

(d) requirement for staging of items to determine availability or shortages;

(e) invalid data for inventory replenishment system;

(f) more obsolete and excess inventory.

Some of these costs can be quantified. Others are intangible, but nevertheless do exist and can be substantial.

At any rate, it is important to have inventory records which are accurate. Most experts agree that this accuracy must be at least 95% and even higher for critical or high unit value items.

The key to accurate records is the implementation of a sound cycle counting system. To install a new cycle counting system or review the effectiveness of an existing system, there are sixteen steps. These are:

(a) Education and training of company personnel in the concept and techniques of cycle counting.

(b) Assignment of responsibility for cycle counting, including the reconciliation of records and correction of the causes of error.

(c) Segmentation of inventory, conduct of a Distribution by Value (ABC -- Pareto) Analysis and coding of all inventory records.

(d) Establishment of the initial phase of cycle counting and establishment of a control sample.

(e) Establishment of a system for measuring inventory record accuracy.

(f) Selection of methods for scheduling items to be cycle counted.

(g) Establishment of a procedure for conducting location audits.

(h) Development and implementation of techniques of counting.

(i) Procedure for cycle counting.

(j) Procedure for cut-off control.

(k) Procedure for reconciliation of cycle counts with inventory records.

(1) Detection and correction of conditions causing errors.

(m) Procedure for making inventory adjustments.

(n) Review of the effectiveness of cycle counting system by the outside auditor.

(o) Elimination of annual physical inventory.

(p) Reduction of number of cycle counts.

A high degree of inventory record accuracy does not necessarily require the employment of full-time cycle counters. Companies have achieved great results by stores personnel doing cycle counts and inventory analysts reconciling the physical count with the record.

The key, of course, is to identify the cause of the error and correct it. The major effort is in instilling the principles of record accuracy in the users (i.e. the people who report and record the inventory transactions). This is a combination of education and on-the-job training. It usually requires only a few hours of management effort each month to achieve significant improvements in inventory record accuracy.

Good inventory policies are meaningless if management does not know what inventory is on hand. Accuracy of records is a critical ingredient in production and inventory systems. Record accuracy allows organizations to move away from being sure "some of everything" is in inventory to focusing on only those items that are needed. Only when an organization can determine accurately what it has on hand can it make precise decisions about ordering, scheduling and shipping.

To ensure accuracy, incoming and outgoing record keeping must be good, as must be stockroom security. A well-organized stockroom will have limited access, good housekeeping, and storage areas that hold fixed amounts of inventory. Bins, shelf space, and parts will be labeled accurately (Jordan 2000).

2.2 Master Production Schedule

A master production schedule (MPS) specifies what is to be made and when. The schedule must be in accordance with a production plan. Tile production plan sets the Overall level of output in broad terms (for example, product families, standard hours, or dollar volume). Such plans include a variety of inputs, including financial plans, customer demand, engineering capabilities, labor availability, inventory fluctuations, supplier performance, and other considerations. Each contributes in it's own way to the production plan, as shown in Figure 2.4, which shows the planning process from the production plan to execution. Each of the lower-level plans must be feasible. When it is not, feedback to the next higher level is used to make the necessary adjustment. One of the major strengths of MRP is its ability-to-determine Precisely the feasibility of a schedule within capacity constraints. This planning process can yield excellent results. The production plan sets the upper and lower bounds on the master production schedule. From this production planning process the master production schedule is developed.

The master production schedule tells us what is required to satisfy demand and meet the production plan. This schedule establishes what items to make and when. Managers must adhere to the plan for a reasonable length of time (usually a major portion of the production cycle). Many organizations establish a master production schedule and then "fix" the near-term portion of the plan. The fixed portion of the schedule is then referred to as the "fixed," "firm," or "frozen" schedule. Only changes beyond the fixed schedule are permitted. The schedule then becomes it rolling production schedule. For example, a fixed seven-week plan has an additional week added to it as each week is completed, so there is always a seven-week fixed schedule. Note - that the master production schedule is a statement of production, not a forecast of demand. It shows the units that are to be produced. The master schedule can be expressed in terms of:

(a) an end item in a continuous (make-to-stock) company;

(b) a customer order in a job shop (make-to-order) company;

(c) modules in a repetitive (assemble-to-stock) company.

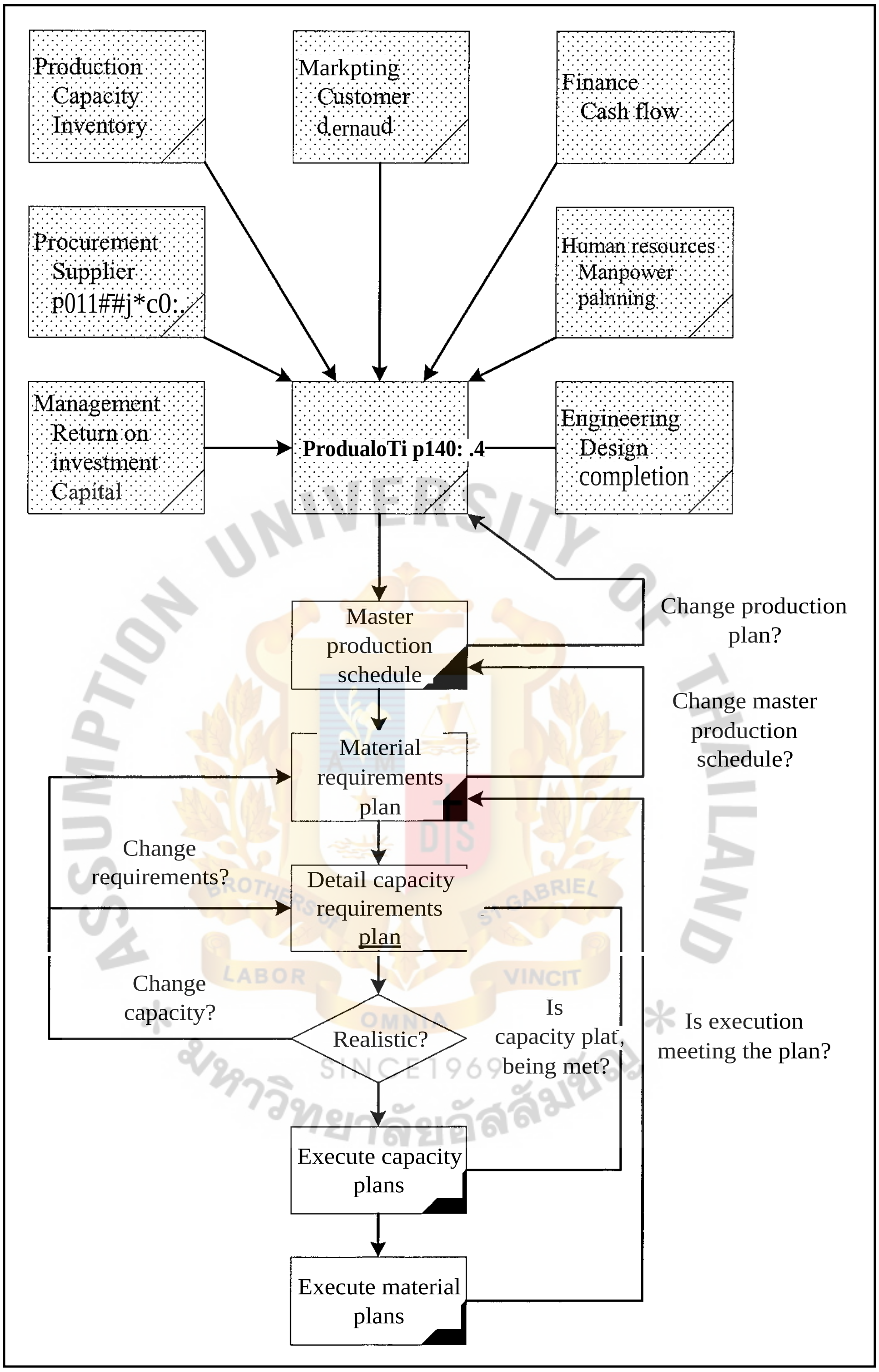

Figure 2.4. The Planning Process (Heizer and Render 1993).

2.2.1 Benefits of MPS

Improve customer service levels with an increase in one-time deliveries. Lower inventory investment by timely acquisition of material. Better coordination of company resources through corporate wide visibility of information. Improve management teamwork through better planning and execution. Reconciliation of supply and demand to create a more productive work flow.

To schedule works orders you must organize your factory into work centers and define your labor and plant operations with routings (Bill of Material). Each operation is specified in the routing to occur within a specific work center. While you can enter time standards for each operation, more important for scheduling is that you accurately list each operation in proper sequence and assign them to the correct work center. Typically these work centers revolve around a plant item or production area.

Besides using routings and work centers you must be prepared to collect and report labor to the computer if shop scheduling is to be performed. It's the only way the system knows what has been completed and what remains to be done where. This use of routings and the tracking of labor comprises what is often referred to as a "shop floor control" system.

Setting up routings and collecting labor is a big job and requires daily dedication. Most job shops understand the importance of collecting labor for job costing purposes to compare actual performance with estimated costs, and often do so even with manual systems.

Many small companies who have product lines and build to stock do not feel it is worth the effort to create routings and collect labor. When companies are small, when products are fairly easy to assemble, and when pinpoint delivery schedules are not required, this is a very legitimate way of operating.

Even with light manufacturing, work orders should be used to at least establish a start date and due date so that purchasing has a target for which to get materials on hand and so that some sense of priority can be given to work orders. With each of these routings may typically revolve around a plant machine. This machine will need to be set to provide the tolerance / specifications of the product and optimal production. In some operations this machine requires specific setup, scrap results from inexperienced operators or new staff. What if the key person with all of the knowledge about the machine leaves, do you pay an arm and a leg for a replacement, or do you employ someone less skilled. The key to this is storing machine setup with the bill of material. This enables exact instructions to be provided to the works center when the job comes up - which in turn results in less scrap (Cybor Communications Limited 19980.

2.2.2 Features of MPS

(a) supports forecast maintenance and forecast analysis;

(b) provides for profile maintenance;

(c) supports multiple planning policies;

(d) provides for planning policies;

(e) supports consumable and non-consumable forecasts;

(0 integrated with MRP;

(g) supports multi-level;

(h) master scheduling;

(i) provides critical path and cumulative lead time analysis;

(j) provides an available to promise;

(k) supports rough cut capacity planning;

(1) forecasts can be consumed by sales order processing;

(m) net change.

2.2.3 Objectives of MPS

Master production scheduling is one of the most important functions of medium term production planning. On this planning level, the actual economical objectives are determined which define the basic conditions for following planning tasks (as material requirements planning, capacity planning, or job sequencing). A good master production schedule (MPS) is the basis for the reliable determination of delivery dates of customer orders, the efficient utilization of resources, and the alignment of operative activities with strategic objectives of the enterprise.

Though MPS is the basis for many of the following planning decisions, the function is often badly supported in traditional manufacturing planning and control systems. The MPS is only roughly matched with available capacities (on the level of the final product), and a substantial part of the planning task is shifted to detailed capacity planning and finite scheduling. Due to the lack of information and the limited decision scopes of short term planning levels, an optimization of the schedule in terms of cost and profit criterions is here no longer implementable.

Moreover the coordination of master production scheduling and the actual manufacturing situation is presently not available, as feedbacks are not foreseen in the straight forward proceeding of existing MRP-II-concepts.

A further problem of existing MRP-systems is the inadequate decision support, resulting from the lack of relevant aggregated planning information and the insufficient presentation of the information base. Alpha-numeric user-interfaces complicate the info' nation retrieval process as they do not support any graphical presentation and organization of data (Adelsherger 1998).

2.2.4 Finite vs Infinite Scheduling

Most scheduling systems will assign due dates for each operation. Some assign overall start dates and due dates. You can then get daily dispatch reports by work center that show all the operations waiting to be performed and their due dates for completion. You will often hear the terms finite and infinite scheduling bandied about by manufacturing software companies. With finite scheduling the system looks at available plant capacity and schedules or reschedules an order accordingly. If the plant is at high capacity, orders will take longer to complete, if the plant is at low capacity, orders will get through more quickly.

The problem with most scheduling systems is that it's another theory that doesn't hold up in the daily world we all have to cope with. When most of us accept a customer's due date, it isn't scientifically determined. We accept the date to get the order, and then we somehow get the job done by using overtime, temps, or whatever it takes to meet the date. Unexpected rush orders materialize, machines break down, employees don't show up, any number of things happen like this every day. Capacity changes all the time as orders get changed, rescheduled, canceled, as we hire people, use more overtime, add machines, etc.

Once you take an order and quote a customer a due date, you tend to be stuck with that date. Do you want that supply date changing every time the scheduling program is run? No. Therefore you end up locking most of your orders into the schedule anyway. What fits capacity one day doesn't stay within capacity as conditions quickly change.

Infinite scheduling, is another approach for day to day operations. You give the system a start date and a due date and it assigns due dates to each operation based on each operation's production time. Essentially, each operation's due date is a milestone that must be met on time if the overall due date is going to be met.

Some operations need to schedule jobs in a particular order, like a paint/print process - why stop the machine for a color change when the next job could be the same color.

Essentially what is needed is a mixture or finite and infinite scheduling that allows for process changes and locking of start dates and times, together with the flexibility of infinite automatic scheduling based on each operations production time. Then "what if' type queries can be tried on the overall production schedules with the highlighting of passed due dates. To quote a customer a realistic delivery date requires a real time production schedule with a production lead time to give the production manager a buffer to work with to facilitate the optimizing of labor and plant resources. Once you and the customer have agreed on a date, though, the obligation is generally on you to do what it takes to meet your commitment (Cybor Communications Limited 1998a).

2.3 Material Requirements Planning

It is a time phased priority-planning technique that calculates material requirements and schedules supply to meet changing demand across all products and parts in one or more plants (http://www.netmation.com/socs/bb03.htm, 2000).

Basically, material requirements planning (MRP) is a calculation method geared toward determining how much of which raw materials are required and roughly when they should be ordered to fulfill a set of product orders. MRP generally consists of 4 steps:

(a) Bill of Materials Explosion - looking backward from each product, determine which intermediates and raw materials are required, and in what quantities;

(b) Netting - compare the above quantities against current inventory levels;

(c) Lot Sizing - determine how the needed materials will be purchased or produced;

(d) Start Date Determination - based on cycle time information, determine when each order should start production.

Materials planning involves getting the materials on hand when needed for production. In a perfect world this would be easy but most companies rely on expediting to accomplish this, which is the least efficient and normally very costly.

Some companies use a minimum stock level and reorder point to order and schedule materials. With reorder point planning a reorder level is established for each item, usually based on usage, the lead time it takes to get the material in, and some safety stock to cover unexpected swings in usage. It all seems very logical and theoretically protects against shortages.

The biggest problem with reorder point planning is that it typically doesn't get maintained at regular enough intervals and can lead to higher stocking levels when it is not really necessary. Whenever a finished good, subassembly, or component gets delayed (which happens all the time for a variety of reasons), many supporting schedules must also be delayed. If a job is pushed out a month or two because one component does not turn up on time, all of the other components needed for the same job are not needed until the rescheduled date, nor are the other sub assemblies needed and can be rescheduled. Imagine this on a 10 level bill of materials.

The other problem with reorder point planning is that it only works for very short term planning with simple bills of material. Most companies today, even job shops, have to plan months ahead for many orders (especially as blanket orders from customers are becoming more common), at which point reorder point planning is less than optimal.

The only way to plan material requirements in a manner that provides an optimal inventory level and allows for real time changes to forecasted demands would be through a material requirements planning (MRP) program.

Which method is better, MRP (material requirements planning) or JIT (just-in-time). Well they are both essentially the same, Just-in-time production is MRP with a very narrow windows. MRP can be driven to minimize stock holdings.

Small manufacturers have hidden from MRP software, feeling that it is too expensive or requires experts to run it correctly. This was true at one time, but is no longer the case. Advances in PC hardware and the availability of inexpensive PC-based MRP software now makes MRP software affordable for virtually any sized company.

There is no need to cloak MRP in a shroud of mystery. Over the years MRP has acquired an aura about it that scares many companies from ever trying it. Or, some people mistakenly think MRP doesn't fit job shops. If you think of MRP as a materials ordering and scheduling system, it brings it down to earth for what it really is. MRP simply puts in a computer program the very same processes that have to be performed in any manufacturing system.

Some MRP systems get very complex, but MRP in its purest form is very simple. Demand for materials is created by existing sales orders, work orders, and by entering forecasts. The MRP program compares the demand for materials with available inventory and suggests purchase orders and work orders where shortages are projected. These new orders are offset by the lead times needed to purchase or manufacture the items.

As new work orders are suggested by the program, additional material requirements are created for the components needed by these new work orders, creating additional suggested work orders and purchase orders. The process continues down through all levels of the bills of materials. This process is often referred to as an MRP "explosion."

MRP does more than just suggest what to buy or make. Equally important is its scheduling function. Whenever changes occur to required dates at any level, be it a customer order, a work order, or a purchased component, the MRP program reschedules all dates of all items affected by that change. On existing work orders and purchase orders, MRP suggests when to expedite items that are arriving too late, or when to delay items that are arriving too early.

The end result when running MRP is an order action report that tells you four basic things: what to buy and when to buy it, what to make and when to make it, what orders should be expedited, and what orders should be delayed (de-expedited). It's that simple. MRP can plan, schedule, and reschedule materials as far into the future as necessary.

Even job shops with simple bills of material (such as machine shops) can benefit from using MRP. In fact, the simpler the requirements, the easier MRP is to use, which is all the more reason to go ahead and use it! It is vastly superior to reorder point planning as a means of determining what and when to buy or make.

Some MRP systems automatically generate work orders and purchase orders and can significantly reduce the time it takes to physically prepare orders.

To use MRP you must have unique part numbers on all items, accurate bills of material, and you must use work orders and purchase orders (Cybor Communications Limited 1998d).

2.3.1 Benefits of MRP

Effective planning is essential in a manufacturing system whether manual or computerized. I use the term planning to encompass the range of activities (forecasting, scheduling, material requirements, plant maintenance, capacities) that insure that materials, labor, and third party contractor services are coordinated so that products are made efficiently, on time, without fuss.

Manufacturing planning is quite a complex process. Each phase in the process is simple to understand, but when all of the processes involved at the same time is beyond what most humans can manage with pencil and paper. Except for the very smallest shops, a computer system is an important requirement for production planning. Planning is the complete foundation on which the manufacturing system stands. Planning refers to the scheduling of work orders and the materials and outside services needed by work orders. Effective planning means having the materials on hand when needed and working on the right things at the right time. Planning is fundamental. Without it you can never escape the expediting nightmare. Can a computer system magically schedule a factory at a push of the button? The answer is no. People have tried to do so with every possible software solution imaginable, but they have all failed. Why? Because the manufacturing environment is one of constant change. What can affect the production schedule? Customers do have emergencies and change due dates or product specifications or need rush orders. Key components don't arrive on time from vendors. Machines unexpectedly break down. Key employees don't show up for work. Forecasts are wrong. Equipment doesn't work properly. Quality problems result in unexpected scrap, rework or even failure. The transport company goes on strike (normally restricted to your busy periods). Murphy's laws are about the only constant.

A change made in one delivery date can affect all the supporting schedules for subassemblies, materials, and services. Lets face it, if one item doesn't come in on time, all jobs that require that component will have to be rescheduled, all jobs that require a sub assembly that needs that one component will need to be rescheduled and on it goes. These changes don't happen once a week, they can happen many times a day. The one thing you can surely count on is that the production environment is in a constant state of change (Cybor Communications Limited 1998c).

There is no way that a manual system can possibly keep up with constant change. Only a computerized system can process constant change and re establish dates and times accordingly.

In the inventory models, the questions answered were, how much to order and when to order. While dependent demand makes inventory scheduling and planning more complexes, it also makes it more beneficial. Some of the benefits of MRP are:

(a) increased customer service and satisfaction;

(b) improved utilization of facilities and labor;

(c) better inventory planning and scheduling;

(d) faster response to market changes and shifts;

(e) reduced inventory levels without reduced customer service;

(f) reduced inventory with fewer (none) shortages;

(g) improved direct labor productivity;

(h) reduced purchasing cost;

(i) reduced traffic cost;

(j) reduced obsolescence;

(k) reduced overtime;

(1) having the numbers to run the business;

(m) having accountability throughout the organization;

(n) improved quality of life.

2.3.2 MPS/MRP

Master Production Scheduling (MPS)/Material Requirements Planning (MRP) is designed to increase service to the customer, provide purchasing suggestions and improve the utilization of manufacturing resources. MPS/MRP creates suggested production quantities for each parent item and sub-assembly, calculates a projected start date based on raw material availability and production lead times, and calculates the date the item will be needed in inventory.

The Master Production Schedule takes the monthly production plan rates for each product line and can convert them into a daily/weekly product mix with the identification of specific models, features and options to be produced while taking into consideration raw material shortages and purchasing lead times.

Material Requirements Planning is a time-phased priority planning system that schedules material to meet the master schedule. The goal of material planning is to have the right quantity of parts to meet the needs of sub-assemblies and assemblies at the time specified in the master schedule without carrying excess inventory.

(a) Instant Visibility into Material and Capacity Availability;

(b) Maintains Flexibility in Setting up Production Plans;

(c) Can Combine Sub-Assembly Requirements to Create a Single Capacity Schedule;

(d) Allows Automatic Scheduling of Work Orders;

(e) Ensures Inventory Coverage Throughout the Planning Period;

(f) Similar Raw Materials Can be Combined to Provide Gross Order Quantities;

(g) Flexibility to Adjust Production Quantities After Release;

(h) Analyzes Demand Across Multiple Locations;

(i) Creates Suggested Production Quantities for Parent Items and Sub-assemblies;

(j) Ability to Back-Schedule from the Required Completion Date;

(k) Allows Manual Editing and Approval Prior to Release;

(1) Suggests Purchasing and Manufacturing Quantities.

2.3.3 Is MRP the Same as Scheduling?

No. MRP, depending on the implementation, usually generates rough plans of which tasks will be done during a given planning bucket. However, the exact sequence of carrying out the plan, including the allocation of finite resources among the potentially many products, is not generated. Since MRP does not typically analyze the details of carrying out its plan, the feasibility of the plan is not necessarily guaranteed. In particular, capacity may actually be overestimated by an MRP system, which can result in unrealistic production goals. Often, compensation for this deficiency takes the form of adjustments to actual production rates to take into account estimates of lost production time due to finite shared resources, changeovers, and breakdowns.

2.3.4 MRP and Inventory Control

Every manufacturing company has inventory, even job shops that purchase material for each job. It's difficult to purchase just what is needed without any surplus material left over at the end of the job. Surplus material becomes inventory. It is now a common practice for customers to place blanket orders with small monthly releases. Most shops are forced to make longer runs (because small runs are not cost effective) and therefore hold finished goods inventory. It's difficult for any company to escape having an inventory.

Purchasing just what is needed for specific jobs can be inefficient; if you can combine commonly needed materials for several jobs into one order, you can get better prices. Any savings is pure profit. Many job shops purchase just for the job simply because they have no easy way of identifying common material requirements.

For make-to-stock companies that require on-hand inventory, many companies use a reorder level to trigger purchase orders. The reorder level is usually determined by average usage of the material, the lead time it takes to get in, and some safety stock to cover unusual usage. For example, take an item with an average usage of 100 per week and a lead time of four weeks. The reorder level might be set at 500, which covers four weeks usage and includes 100 extras as safety stock. Any combination of requirements causing inventory to dip below the reorder level triggers a purchase order or work order. There are two major problems with this method. One is that it is only workable for a very short time horizon. Material requirements, though, usually have to be planned over many weeks or months. Current and long term requirements can easily get mingled, resulting in more inventory than is needed.

The other problem is that in manufacturing the due dates not often get changed to reflect delays. Work orders get delayed all the time for a variety of reasons -- lack of a key component, machine breakdowns, late vendor deliveries, etc. If all the related due dates for materials and subassemblies don't get moved out, everything looks like it's due now. Either too much inventory is brought in, or more typically, companies revert to ignoring due dates and go back to using shortage lists and expediting, the most costly and inefficient method by far.

An MRP system, which schedules and reschedules material requirements as new orders come in and existing orders get changed, is a clearly superior planning method for any type company, even job shops with very simple material requirements.

All that is needed to make an MRP program work are accurate bills of material and dedication to keeping dates accurate. If you object to maintaining accurate dates as too much work, you are just kidding yourself. The work required to maintain good dates involves far less time than the alternative — worthless dates and planning by shortages (Cybor communications limited 1998b)..

2.3.5 Regeneration and Net Change

A material requirement plan is not static. Once a bill-of-material and material requirements plan is established, change in design, schedules, and production processes occur. Thus, if one of the production time estimates was one week less than it should have been, that week must be added to the material requirements plan. Likewise, if a design improvement allows construction of one of the intermediate inventory items with fewer parts, then an alteration in the bill-of-material and the material requirements plan is necessary. Scrapped components, missed receiving, dates, and machine breakdowns contribute to such alterations in the material requirements plan. Similarly, alterations occur in an MRP system when changes are made to the master production schedule. Regardless of the cause of any changes, the MRP model can be manipulated to reflect them. In this manner, an up-to-date schedule is possible. Such a schedule would depict when to begin production of all items so that the production schedule is satisfied.

2.3.6 Lot-Sizing Techniques

Thus far in our discussion of MRP we have used what is known as a lot-for-lot determination of our production units. This is evident in our planned order releases where we produced what we need, and no more and no less. The objective in an MRP system is to produce units only as needed, with no safety stock and no anticipation of further orders. Such a procedure is consistent with small lot sizes, frequent orders, low just-in-time inventory, and dependent demand. However, in cases where the setup costs are significant or where management has been unable to implement a philosophy of **JIT,** lot-for-lot can be an expensive technique. There are alternative ways of determining lot size, namely economic order quantity (EOQ). Indeed, there are numerous ways of determining lot sizes in MRP systems. Many commercially available MRP systems include the option of a variety of lot-sizing techniques. We will review a few of them.

(a) Lot-for-Lot

Lot-sizing technique where we produced exactly what was required.

(b) Economic Order Quantity

EOQ can be used as a lot-sizing technique. But as we indicated there, EOQ is preferable where relatively constant independent demand exists, not where we know the demand. The assumption of our MRP procedure, remember, is that dependent demand is present. Operations managers should take advantage of this information, rather than assuming a constant demand. The EOQ formula averages demand over an extended time horizon.

2.4 Management of Maintenance, Repair and Operating

Except for utilities and transportation companies, the management of maintenance, repair and operating (MRO) supplies is not a top priority. In most manufacturing companies the annual usage value of MRO supplies is less then ten percent of the direct materials required for production. Utilities and transportation companies recognize the absolute necessity of high inventory service levels of MRO supplies to maintain their equipment and provide uninterrupted service to their customers.

Yet, neither utilities and transportation companies, nor manufacturing companies have made full use of the tools which are available today to provide maximum customer service with minimum investment in inventories. Established accounting practices of expensing many MRO supplies upon receipt and not maintaining a record of quantities on hand, further contribute to a lack of emphasis on effective inventory management.

(a) Unique Problems

Inventory planning and control of MRO items poses several unique problems. There is no Production Plan and Master Production Schedule to drive an MRP (Material Requirements Planning) system. Also, there is no Sales Forecast to project demand of future requirements.

Since the frequency of demand for many items is quite irregular, historic usage data is not a valid indicator of anticipated need for many of the MRO items. In many cases, the majority of the items are used less than once a year, which is particularly true of repair parts.

The problem of managing vendor lead times is also more complex for MRO items. One time the item may be available from a local distributor's shelf; the next time it may have to come from the original equipment manufacturer (OEM). Every inventory system-Order Point or MRP-depends on valid lead times. For example, an item may have a one week lead time if it is available at the distributor. On the other hand, if the distributor does not have the item in stock, it may take eight weeks if it has to be ordered from the manufacturer. Which lead time do we use in the inventory system? And how often are lead times updated? Who should update the leadtimes?

How about the management of inactive items? Every time we replace a piece of equipment the parts for that equipment may become obsolete. This creates excess MRO inventory. When cost justifying a piece of new equipment, you should consider the cost of writing off not only the old machinery, but also the parts which are unique to that machinery and which should be written off.

(b) Analysis of Existing Systems

An in-depth analysis of the existing system for inventory management of MRO items is the first step. In conducting such a survey, consideration must be given to the application of the tools and techniques which are available today for cost-effective inventory management of MRO items.

(c) Segmentation of MRO Inventory

A major grouping of items by inventory segment should be established. Typical inventory segments are: Machine and Equipment Preventive Maintenance Repair Parts; Other Machine and Equipment Maintenance and Repair Parts; Tools; Maintenance Supplies; Office Supplies; etc. The purpose of establishing inventory segments is to develop applicable management policies and controls which pertain to each specific segment. It is so important to establish separate segments for machine and equipment repair parts which are replaced regularly as a result of scheduled preventive maintenance, and those parts which are maintained in stock in case of equipment failure.

(d) Assignment of Item Numbers

All inventory systems require that each item be identified by its own item number (i.e. part number, stock number, etc.). Many companies have assigned their own number to each MRO item. Maintaining an up-to-date catalog of tens of thousands of numbers is a major effort, particularly in maintaining cross-references to different manufacturers' part numbers and specifications. A further complication arises in that the assignment of an item number may delay the procurement of a new part which is urgently needed.

On the other hand, the use of the vendor's item number also has several disadvantages. The same item may be available from several vendors, each having a unique item number. Which number do you use for identifying the item in inventory? Another disadvantage is that a vendor may change his specification for the item without changing the number. The item you reorder may not fit your requirements.

In most cases, the use of a primary vendor's item number preceded by a commodity classification is a viable approach. Alternate vendors and their numbers should be entered on the system for cross-reference.

(e) Organizational Responsibility

Accountability for effective inventory management of MRO items must be clearly defined. Since nearly all MRO items are supplied by vendors, the MRO purchasing function should be fully integrated with the inventory management function. Stockless purchasing where the vendor carries the bulk of the inventory and the full use of maintenance agreements are prime examples of the need for such integration.

(f) Determining Future Demand

If we could predict what items would be required, when and how many, MRO inventory management would be simple. Many companies have installed complex statistical forecasting systems to arrive at the right answer. The more sophisticated the system, the more they relied on the forecast. Not so! The relatively small percentage of the number of MRO items which have a monthly or even greater frequency of demand can be forecasted using a simple average or single level exponential smoothing. However, the majority of the number of items, where the demand frequency may be once a year or even less, can not be forecasted with any degree of reliability.

Classification of Items

In light of the difficulty to forecast the majority of the number of MRO items, classification by value, priority, and availability from source is essential to determine the best inventory level to maintain.

The Distribution by Value (ABC) Analysis will identify those items where ample inventory levels, protected by high safety stocks, can be maintained with minimum inventory investment. The assignment of priority codes to identify the critical availability requirement of each MRO item is also of utmost importance. There are items which, regardless of cost or anticipated demand, must be available immediately. Others must be available within a short time period. Still others should be available within a day or so. These priority codes should be established by the user -- the maintenance technician responsible for maintaining the equipment and using the item. It should be the user who should be consulted in determining the appropriate inventory level for such items.

Another classification of MRO items is by availability from source. While the purchasing lead time provides us with the normal replenishment time, there are usually options to expedite delivery, albeit at a premium cost. Establishment of availability codes which identify the shortest delivery time for certain items by expediting or premium transportation is of significant help in detenning the quantity to be carried in inventory.

(h) Selecting the Inventory System

A time-phased order point system is the best type of system for MRO items, since it reflects scheduled deliveries by due date and projected availability. The time-phased order point system is in fact an MRP system. It uses MRP logic. It accepts the independent demand of each MRO item instead of the gross requirements derived from a bills of material explosion. If you have already installed an MRP system, or are in the process of installing one, use it for MRO inventory management. Most software packages contain all the data elements you need for effective management of MRO items.

One added plus for using the MRP system in the time-phased order point application is the capability of the MRP system to handle requirements for preventive maintenance programs. Bills of material can be created for parts and material requirements for preventive maintenance services on specific machines and equipment. Based on preventive maintenance schedules, these bills of material can be exploded and requirements for parts and materials can be computed automatically by the system.

(i) Timeliness and Integrity of Data

Ideally, inventory transactions should be entered on-line via CRT terminals and the inventory record should be updated in real time. As a minimum, transactions should be batch-processed with each inventory record being updated at the end of each day. Inventory systems should be run weekly or more frequently and should operate on a management-by-exception basis, issuing order action, expedite action, and reschedule action notices.

Of paramount importance is inventory record accuracy. An effective cycle counting program should be in place and result in a high degree of inventory record accuracy.

(j) Summary of MRO

Management of MRO supplies requires a thorough understanding of the unique inventory management characteristics of these items. Establishing the right inventory segment for each group of MRO supplies is of paramount importance. Other factors to be considered are the assignment of item numbers, establishing a viable organization for inventory management and purchasing, determining future demand, classifying each item by annual usage value (ABC code), as well as an appropriate priority code and an availability code. Timely transaction reporting and an effective cycle counting system should provide high integrity of inventory data.

A well-tuned inventory system for MRO supplies will pay significant dividends in terms of optimum availability of plant equipment, high productivity and reduced operating costs.

III. THE EXISTING SYSTEM

3.1 The History of Valentine Drinking Water Company

The founder of Valentine Drinking Water is Mr. Piyapong Assavalahaphun, who has inherited the family business from his father since 1980. Originally, Valentine Drinking Water used to be called "Sahaphol." However, with the growing market, he renamed into more Internationalized as Valentine Drinking Water in 1993. Mr. Piyapong started his fortune business with delivering the product around neighborhood's area, known as Nonthaburi. As a result, the business seemed to be successfully done. Then, he expanded the market into a larger area such as delivery service to office buildings, condominiums, houses, schools, and many other institutions in Bangkok area.

Valentine Drinking Water Company is a company using a unique system which is like running the family business. However, it has been operated systematically for a long time. The current system that the company is using is based on inventory models called EOQ.

3.2 The Basic Economic Order Quantity (EOQ) Model

The economic order quantity is one of the oldest inventory control techniques. EOQ is still popular among a large number of organizations today. This technique is relatively easy to use. There are five important assumptions of EOQ, which are:

(a) Demand is known and constant.

The historical pattern of demand for the item, which in turn determines the forecast for the item and the mean average deviation (which is the measurement of the inherent variability of the item). The company mostly received the constant order from customers every week. Therefore, it is very easy for the purchasing manager to do the prediction.

(b) Lead time is known and constant.

After the company orders raw materials, the time between the placement order and the receipt order is known and constant. The lead time and order frequency associated with the routine reordering of the item. It would be handy to be able to determine this quantity, either for a given item, or for an entire group of items. It would provide a base point against which to measure our actual inventory. For example, the company orders the raw materials on Friday. The raw materials will arrive on Monday.

(c) Quantity discounts are not possible.

Another use of inventory is to take advantage of quantity discounts such as many suppliers offer discounts for large orders. If purchasing in larger quantities, it can substantially reduce the cost of products. However, there are some disadvantages of buying in larger quantities that higher costs due to storage, spoilage, damaged stock, theft, and insurance will be subjected. Although company orders the large amount of quantity, supplier will not decrease the price of raw materials except orders over 500,000 dozens which is not impossible for Valentine Drinking Water Company; because it is a small-spaced company, so there is no space to stock the raw materials.

(d) The only variable costs are setup cost and holding or carrying cost.

Setup cost is the cost to prepare a machine or process for manufacturing an order. For example, the company must run the machine in the morning before starting fill-up water in the bottle minimum of 15 minutes. In a mean time, many environments setup cost is highly correlated with setup time.

Holding costs are the costs associated with holding or "carrying" inventory over time. Therefore, holding costs definitely also include costs related to storage, such as insurance, extra staffing, interest, and so on. For example, Valentine Drinking Water has opened the storage policy with the insurance company in case if the storage is on fire and the products are damaged; therefore, the insurance company must be responsible for the destructive valuables due to the policy.

(e) Stockouts (shortages) can be completely avoided, if orders are placed at the right time.

Because demand is constant over time; therefore, inventory drops at a uniform rate over time. For example, if the stocks of Valentine Drinking Water Company in the inventory level reaches 0, the new order is placed and received, and the inventory level again jumps to Q units. In addition, since the manager of Valentine Drinking Water Company knows the constant of demand and lead time in advance, it is impossible that stockouts will happen.

IV. THE PROPOSED SYSTEM

4.1 Master Production Schedule (MPS) Technique

4.1.1 General Information of the Company's System

From the interview with the owner of Valentine Drinking Water Company, the author knows that:

(1) Speed of production time to fill drinking water in the bottle is 960 dozens/ day.

(2) There are 10 repeated customers that regularly order the product every week.

(3) There are four sizes of bottle at the Valentine Drinking Water Company.

Valentine Drinking Water company produces four sizes of bottle which are product size of 500 cc., 750 cc., 1500 cc. and 950 cc. while bottle size 950 cc. is produced from different material of other.

(4) The amount of each size of bottle that the customers need in 1 week.

The manager of the company surveys demand by averaging in each day and size. Demand of each product is surveyed from Monday to Sunday respectively. Demand of product size 500 cc. is 400, 300, 300, 400, 250, 100 and 50 respectively. Demand of product size 750 cc. is 300, 150, 150, 200, 150, 80 and 20 respectively. Demand of product size 1500 cc. is 200, 100, 70, 200, 100, 100 and 30 respectively. Demand of product size 950 cc. is 500, 300, 200, 400, 300, 200 and 100 respectively.

So demand of product size 500 cc. in one week is 1800 dozens. Demand of product size 750 cc. is 1050 dozens. Demand of product size 1500 cc. is 800 dozens. Demand of product size 950 cc. is 2000 dozens.

4.1.2 Problems and Solutions

In order to maintain the stock in order to parallel with the customers' need, the following experiments are suggested:

(1) Produce each size of bottle in the same quantity in 1 day.

(2) Produce each size of bottle until it meets the customers' need for the next day.

(3) Produce each size of bottle on the average scale of customers' need in 1 week.

(a) Meet the maximum profit.

(b) Meet the safety stock.

The following charts demonstrate the fine solutions whether it works to solve the above problem or not.

(1) Produce each size of bottle in the same quantity in 1 day.

This production will describe the production of each size in the same quantity which the total of production is 960 dozens/day. Company has 4 size of products so each of the products will be produced 240 dozens/day.

Calculation of this production and the result of week 1 and 2 of this production are shown in Tables 4.1 and 4.2 respectively.

Begin with the setting the start stock of each product.

Start stock of product size 500 cc. is 500 dozens.

Start stock of product size 750 cc. is 200 dozens.

Start stock of product size 1500 cc. is 200 dozens.

Start stock of product size 950 cc. is 500 dozens.

Condition: The sum of production in 1 day must not exceed 960 dozens / day.

Table 4.1. Master Production Schedule for Calculation (1) Week 1.

	Size 500cc. Week 1						
Start stock = 500	M	T	W	TH	F	S	SU
Gross requirements	400	300	300	400	250	100	50
Schedule receipts	240	240	240	240	240	240	240
Projected on-hand inventory	340	280	220	60	50	190	380

	Size 750cc. Week 1						
Start stock = 200	M	T	W	TH	F	S	SU
Gross requirements	300	150	150	200	150	80	20
Schedule receipts	240	240	240	240	240	240	240
Projected on-hand inventory	140	230	320	360	450	610	830

	Size 1500cc. Week 1						
Start stock = 200	M	T	W	TH	F	S	SU
Gross requirements	200	100	70	200	100	100	30
Schedule receipts	240	240	240	240	240	240	240
Projected on-hand inventory	240	380	450	490	630	770	980

	Size 950cc. Week 1						
Start stock = 500	M	T	W	TH	F	S	SU
Gross requirements	500	300	200	400	300	200	100
Schedule receipts	240	240	240	240	240	240	240
Projected on-hand inventory	240	180	220	60	0	40	180

Table 4.2. Master Production Schedule for Calculation (1) Week 2.

	Size 500cc. Week 2						
Start stock = 380	M	T	W	TH	F	S	SU
Gross requirements	400	300	300	400	250	100	50
Schedule receipts	240	240	240	240	240	240	240
Projected on-hand inventory	220	160	100	**-60**			

	Size 750cc. Week 2						
Start stock = 830	M	T	W	TH	F	S	SU
Gross requirements	300	150	150	200	150	80	20
Schedule receipts	240	240	240	240	240	240	240
Projected on-hand inventory	770	860	950	990			

	Size 1500cc. Week 2						
Start stock = 980	M	T	W	TH	F	S	SU
Gross requirements	200	100	70	200	100	100	30
Schedule receipts	240	240	240	240	240	240	240
Projected on-hand inventory	1020	1160	1330	1370			

	Size 950cc. Week 2						
Start stock = 180	M	T	W	TH	F	S	SU
Gross requirements	500	300	200	400	300	200	100
Schedule receipts	240	240	240	240	240	240	240
Projected on-hand inventory	**-80**	**-140**	**-100**	**-260**			

First in the Table 4.1 the author will calculate from the start stock of each size of product. It shows how many stocks that company is holding before starting work of the week. The schedule receipts show how many products that machine will produce on that day. Projected on-hand inventory shows how many products are left at the end of the day. For example, on Monday company has start stock 500 dozens and machine will produce product size 500 cc. 240 dozens. Then stock of product size 500 cc. of Valentine Drinking Water Company is 740 dozens but gross requirements is 400 dozens on Monday. So projected on-hand inventory at the end of Monday is 740 — 400 equal 340 dozens. And projected on-hand inventory of Monday will become start stock of Tuesday.

The first experiment failed to solve the problem. Because Table 4.1 shows that if the company produces product like those from the charts that are shown above, it will give the inventory problem such as in the first week of Product size 500 cc. does not seem to have problem because there are finished bottle of water left in the stock. Nevertheless, Product size 750 cc. and Product size 1500 cc. does have a big problem because there are a lot of finished bottle of water left over in the stock and a result of that will make the space in the stock full. Moreover, the products seem to be increasing every day. Product size 950 cc. has no problem in the first week. Even though there are no product left in the stock on Friday, it has no problem because the machine can produce enough products for the customers' need on Saturday.

In Table 4.2, many problems appear in each product. Product size 500 cc. lacks stock on Thursday; therefore there is no stock to sell for the next day. In the mean time, Product size 750 cc. and Product size 1500 cc. are being over produced. As a result, the stock is overloaded. However, product size 950 cc. lacks stock since Monday and it will continue to get the same result if the machine is continuing to produce the same method.

In order to solve these problems, the author needs to compute that what day the machine should stop producing which product and select other products to be produced instead. But, it has to be computed day by day. Therefore, it is a waste of time and confusions may exist. Also, it will lead the production to the complication. Other than that, the company must extend the working time and that causes a lost profit.

(2) Produce each size of bottle until it meets the customers' need for the next day.

To experiment the way to solve in problem 2, the company must receive re-confirmed order and control inventory equals to the need of the next day. Then, the company will know the scheduled receipts of each day.

Calculation of this production and the result of week 1 of this production is shown in Table 4.3.

Begin with the setting of start stock of each product.

Start stock of product size 500 cc. is 500 dozens.

Start stock of product size 750 cc. is 200 dozens.

Start stock of product size 1500 cc. is 200 dozens.

Start stock of product size 950 cc. is 500 dozens.

Condition: The sum of production in 1 day must not exceed 960 dozens/ day.

Table 4.3. Master Production Schedule for Calculation (2) Week 1.

	Size 500cc. Week 1						
Start stock = 500	M	T	W	TH	F	S	SU
Gross requirements	400	300	300	400	250	100	50
Schedule receipts	200	300	**400**				
Projected on-hand inventory	300	300	400	250	100	50	400

	Size 750cc. Week 1						
Start stock = 200	M	T	W	TH	F	S	SU
Gross requirements	300	150	150	200	150	80	20
Schedule receipts	250	150	**200**				
Projected on-hand inventory	150	150	200	150	80	20	300

	Size 1500cc. Week 1						
Start stock = 200	M	T	W	TH	F	S	SU
Gross requirements	200	100	70	200	100	100	30
Schedule receipts	100	70	**200**				
Projected on-hand inventory	100	70	200	100	100	30	200

	Size 950cc. Week 1						
Start stock = 500	M	T	W	TH	F	S	SU
Gross requirements	500	300	200	400	300	200	100
Schedule receipts	300	200	**400**				
Projected on-hand inventory	300	200	400	300	200	100	500

Table 4.3 shows the need of products on Thursday is 1200 dozens which exceeds the limit that the machine can produce on Wednesday. Thus, the company will not have enough products for customers' need. If the company wants to meet the needs of the customer, the operation time of the machine must run over time and this is leading to the extra expenditure. However, to solve this problem by running the machine over time is only solving for the short-term period which is just to have enough products for Sunday and so on.

To solve this problem is to compute what kind of product is shorten for the future order, and then use the free time of the day before that future order to produce product. So, the machine does not work over time.

Produce each size of bottle on the average scale of customers' need in 1 week.

Calculation of this production and the result of week 1 and 2 of this production are shown in Tables 4.3 and 4.4 respectively.

To produce product in this production the company has to calculate the amount of demand in each day of each product size.

The company needs to produce product size 500 cc. 1800 dozens/week = 258 dozens/day. The company needs to produce product size 750 cc. 1050 dozens/week = 150 dozens/day. The company needs to produce product size 1500 cc. 800 dozens/week = 115 dozens/day. The company needs to produce product size 950 cc. 2000 dozens/week = 286 dozens/day.

So the machine needs to produce product 258+150+115+286 = 809 dozens/day that does not exceed the limit of the machine.

Start the setting with the start stock:

Start stock of product size 500 cc. is 500 dozens.

Start stock of product size 750 cc. is 200 dozens.

Start stock of product size 1500 cc. is 200 dozens.

Start stock of product size 950 cc. is 500 dozens.

Condition: The sum of production in 1 day must not exceed 960 dozens/ day.

Table 4.4. Master Production Schedule for Calculation (3) Week 1.

	Size 500cc. Week 1						
Start stock = 500	M	T	W	TH	F	S	SU
Gross requirements	400	300	300	400	250	100	50
Schedule receipts	258	258	258	258	258	258	258
Projected on-hand inventory	358	316	274	132	140	298	506

	Size 750cc. Week 1						
Start stock = 200	M	T	W	TH	F	S	SU
Gross requirements	300	150	150	200	150	80	20
Schedule receipts	150	150	150	150	150	150	150
Projected on-hand inventory	50	50	50	0	0	70	200

	Size 1500cc. Week 1						
Start stock = 200	M	T	W	TH	F	S	SU
Gross requirements	200	100	70	200	100	100	30
Schedule receipts	115	115	115	115	115	115	115
Projected on-hand inventory	115	130	175	90	105	120	205

	Size 950cc. Week 1						
Start stock = 500	M	T	W	TH	F	S	SU
Gross requirements	500	300	200	400	300	200	100
Schedule receipts	286	286	286	286	286	286	286
Projected on-hand inventory	286	272	358	244	230	316	502

Table 4.5. Master Production Schedule for Calculation (3) Week 2.

	Size 500cc. Week 2						
Start stock = 506	M	T	W	TH	F	S	SU
Gross requirements	400	300	300	400	250	100	50
Schedule receipts	258	258	258	258	258	258	258
Projected on-hand inventory	364	322	280	138	146	304	510

	Size 750cc. Week 2						
Start stock = 200	M	T	W	TH	F	S	SU
Gross requirements	300	150	150	200	150	80	20
Schedule receipts	150	150	150	150	150	150	150
Projected on-hand inventory	50	50	50	0	0	70	200

	Size 1500cc. Week 2						
Start stock = 205	M	T	W	TH	F	S	SU
Gross requirements	200	100	70	200	100	100	30
Schedule receipts	115	115	115	115	115	115	115
Projected on-hand inventory	120	135	180	95	110	125	210

	Size 950cc. Week 2						
Start stock = 502	M	T	W	TH	F	S	SU
Gross requirements	500	300	200	400	300	200	100
Schedule receipts	286	286	286	286	286	286	286
Projected on-hand inventory	288	274	360	246	232	318	504

You will see that in Tables 4.4 and 4.5 if the company uses this production method, it will cancel all the problems. Because there is no lack of products, but the company must insure there is a safe start stock first. Thus, company has to calculate the best start stock to make the maximum profit. But, in the real business world it is impossible that the demand of product will be constant. Frankly, there are two alternative choices for the company in stocking the product: (a) meet the maximum profit (Less stock) and (b) meet the safety stock

(a) Meet the Maximum Profit

Company needs to make stock close to 0 or equal to 0 in one week in each product. First, the company has to assume start stock equals to 0 in Table 4.6, then calculate the lowest inventory in the first week and use that number to be real start stock.

Table 4.6. Master Production Schedule for Calculation (a) to Find Start Stock.

	Size 500cc. Calculate						
Start stock =0	M	T	W	TH	F	S	SU
Gross requirements	400	300	300	400	250	100	50
Schedule receipts	258	258	258	258	258	258	258
Projected on-hand inventory	-142	-184	-226	-368	-360	-202	6

	Size 750cc. Calculate						
Start stock =0	M	T	W	TH	F	S	SU
Gross requirements	300	150	150	200	150	80	20
Schedule receipts	150	150	150	150	150	150	150
Projected on-hand inventory	-150	-150	-150	-200	-200	-130	0

	Size 1500cc. Calculate						
Start stock =0	M	T	W	TH	F	S	SU
Gross requirements	200	100	70	200	100	100	30
Schedule receipts	115	115	115	115	115	115	115
Projected on-hand inventory	-85	-70	-25	-110	-95	-80	5

	Size 950cc. Calculate						
Start stock =0	M	T	W	TH	F	S	SU
Gross requirements	500	300	200	400	300	200	100
Schedule receipts	286	286	286	286	286	286	286
Projected on-hand inventory	-214	8	-142	-256	-270	-184	2

After calculating the company gets that:

The lowest projected on-hand inventory of product size 500 cc. is —368 dozens.

The lowest projected on-hand inventory of product size 750 cc. is —200 dozens.

The lowest projected on-hand inventory of product size 1500 cc. is —110 dozens.

The lowest projected on-hand inventory of product size 950 cc. is —270 dozens.

So the author will use each number of them from the calculation to be start stock of each product size.

Start stock of product size 500 cc. is 368 dozens.

Start stock of product size 750 cc. is 200 dozens.

Start stock of product size 1500 cc. is 110 dozens.

Start stock of product size 950 cc. is 270 dozens.

Calculation of this production and the result of week 1 of this production is shown in Table 4.7.

Table 4.7. Master Production Schedule for Calculation (a) to Meet Lowest Inventory.

	Size 500cc. Week 1						
Start stock = 368	M	T	W	TH	F	S	SU
Gross requirements	400	300	300	400	250	100	50
Schedule receipts	258	258	258	258	258	258	258
Projected on-hand inventory	226	184	142	0	8	166	374

	Size 750cc. Week 1						
Start stock = 200	M	T	W	TH	F	S	SU
Gross requirements	300	150	150	200	150	80	20
Schedule receipts	150	150	150	150	150	150	150
Projected on-hand inventory	50	50	50	0	0	70	200

	Size 1500cc. Week 1						
Start stock = 110	M	T	W	TH	F	S	SU
Gross requirements	200	100	70	200	100	100	30
Schedule receipts	115	115	115	115	115	115	115
Projected on-hand inventory	25	40	85	0	15	30	115

	Size 950cc. Week 1						
Start stock = 270	M	T	W	TH	F	S	SU
Gross requirements	500	300	200	400	300	200	100
Schedule receipts	286	286	286	286	286	286	286
Projected on-hand inventory	56	42	128	14	0	86	272

Company can use this production method to make the maximum profit only if it has the constant demand of the ordered products. As a result, this will make less stock in the company, and it will save cost of inventory.

(b) Meet the safety stock.

After I had interviewed with the owner, I knew that the demand is not constant for the whole month. It may be changed +20% or — 20%. So, if the company needs to have a safety stock when the demand changed, it has to produce with more start stock about 20% of each demand in one week.

The company needs to increase start stock of product size 500 cc. = 1800*0.2 = 360 dozens. So safety start stock of product size 500 cc. = 368 + 360 = 728 dozens.

The company needs to increase start stock of product size 750 cc. = 1050*0.2 = 210 dozens. So safety start stock of product size 750 cc. = 200 + 210 = 410 dozens.

The company needs to increase start stock of product size 1500 cc. = 800*0.2 = 160 dozens. So safety start stock of product size 1500 cc. = 110 + 160 = 270 dozens.

The company needs to increase start stock of product size 950 cc. = 2000*0.2 = 400 dozens. So safety start stock of product size 950 cc. = 270 + 400 = 670 dozens.

Calculation of this production and the result of week 1 of this production is shown in Table 4.8.

Table 4.8. Master Production Schedule for Calculation (b) to Meet Safety Stock.

	Size 500cc. Week 1						
Start stock = 728	M	T	W	TH	F	S	SU
Gross requirements	400	300	300	400	250	100	50
Schedule receipts	258	258	258	258	258	258	258
Projected on-hand inventory	586	544	502	360	368	526	734

	Size 750cc. Week 1						
Start stock = 410	M	T	W	TH	F	S	SU
Gross requirements	300	150	150	200	150	80	20
Schedule receipts	150	150	150	150	150	150	150
Projected on-hand inventory	260	260	260	210	210	280	410

	Size 1500cc. Week 1						
Start stock = 270	M	T	W	TH	F	S	SU
Gross requirements	200	100	70	200	100	100	30
Schedule receipts	115	115	115	115	115	115	115
Projected on-hand inventory	185	205	245	160	175	190	275

	Size 950cc. Week 1						
Start stock = 670	M	T	W	TH	F	S	SU
Gross requirements	500	300	200	400	300	200	100
Schedule receipts	286	286	286	286	286	286	286
Projected on-hand inventory	456	442	528	414	400	486	672

After the company gets the safety start stock, it should consider on the speed of the production when the limit is 120 dozens/hours or 960 dozens/day. The sum of production in 1 day equals 258 + 150 + 115 + 286 = 809 dozens. The company wants to stop the machine one-day a week for maintenance. So, it should calculate the new production in one day. Machine produces 809 * 7 = 5663 dozens in 7 days. But it should produce product in the same quantity in 6 days. So, the machine has to produce 5663 / 6 = 944 dozens /day and it shows that the new production does not exceed the limit of machine. Then, the company has to know the increasing product in each production in 1 day.

The new production produces 135 dozens more than the old production. So, the company has to know how much the increasing product of production in each product.

Product size 500 cc. has to be increased of production 258 / 809 * 135 = 44 dozens/day. Product size 750 cc. has to be increased of production 150 / 809 * 135 = 26 dozens/day. Product size 1500 cc. has to be increased of production 115 / 809 * 135 = 20 dozens/day. Product size 950 cc. has to be increased of production 286 / 809 * 135 = 48 dozens/day. The exact increasing product is 44 + 26 + 20 + 48 = 138 dozens/day.

The sum of production in one day equals 809 + 138 = 947 dozens, and it does not exceed the limit of production. The company could stop the machine for 1 day a week.

The company needs to produce product size 500 cc. 258 + 44 = 302 dozens/day. The company needs to produce product size 750 cc. 150 + 26 = 176 dozens/day. The company needs to produce product size 1500 cc. 115 + 20 = 135 dozens/day. The company needs to produce product size 950 cc. 286 + 48 = 334 dozens/day.

Table 4.9 shows the result of the production to meet the safety start sock.

Table 4.9. Master Production Schedule for Calculation (b) to Stop Machine on Sunday.

	Size 500cc. Week 1						
Start stock = 728	M	T	W	TH	F	S	SU
Gross requirements	400	300	300	400	250	100	50
Schedule receipts	302	302	302	302	302	302	0
Projected on-hand inventory	630	632	634	536	588	790	740

	Size 750cc. Week 1						
Start stock = 410	M	T	W	TH	F	S	SU
Gross requirements	300	150	150	200	150	80	20
Schedule receipts	176	176	176	176	176	176	0
Projected on-hand inventory	286	312	338	314	340	436	416

	Size 1500cc. Week 1						
Start stock = 270	M	T	W	TH	F	S	SU
Gross requirements	200	100	70	200	100	100	30
Schedule receipts	135	135	135	135	135	135	0
Projected on-hand inventory	205	240	305	240	275	310	280

	Size 950cc. Week 1						
Start stock = 670	M	T	W	TH	F	S	SU
Gross requirements	500	300	200	400	300	200	100
Schedule receipts	334	334	334	334	334	334	0
Projected on-hand inventory	504	538	672	606	640	774	674

So, the company is able to maintenance and check the equipment of the machine. It will make the machine life last longer and save cost to hire employees on Sunday.

4.2 Inventory Models

In this sector, it shows the steps of calculation of inventory models, which contains optimum number of units per order, expected number of orders, expected time between orders, total annual cost and reorder point.

4.2.1 Calculation of Optimum Number of Units per Order

From the previous sector, the author knows that the estimate demand of each size of bottle. The author knows how much to produce product in each week. A lot of units per order does not mean that it is the optimum number so the author has to find out the optimum number of units per order. The author knows that in each week:

Demands of product size 500 cc. are 1800 dozens.

Demands of product size 750 cc. are 1050 dozens.

Demands of product size 1500 cc. are 800 dozens.

Demands of product size 950 cc. are 2000 dozens.

The author has to calculate annual demand by change demand each week to annual demand. The author knows that 1-year equal to 52 weeks.

So: Annual demand of product size 500 cc. = 1800 * 52 = 93600 dozens.

Annual demand of product size 750 cc. = 1050 * 52 = 54600 dozens.

Annual demand of product size 1500 cc. = 800 * 52 = 41600 dozens.

Annual demand of product size 950 cc. = 2000 * 52 = 104000 dozens.

Number of working days in a year = 52 * 6 = 312 days

Lead time for a new order in days = L = 3 days

Working days in one week = 6 days.

Holding or carrying cost per unit per year (H) and setup or ordering cost for each order (S) are set from Valentine Drinking Water Company.

Valentine Drinking Water Company has some spaces to store product. There are 4 rooms whose dimension are 6*5*2 meters. So the volume of each room is 60 cubic meters. The author has to determine how many dozens of each product can be stored in 1 room.

Product size 500 cc. 1 dozen equal 12 * 0.5 = 0.6 liter or 0.006 m^3

Product size 750 cc. 1 dozen equal 12 * 0.75 = 0.9 liter or 0.009 m^3

Product size 1500 cc. 1 dozen equal 12 * 1.5 = 1.8 liter or 0.018 m^3

Product size 950 cc. 1 dozen equal 12 * 0.95 = 1.14 liter or 0.0114 m^3

Valentine Drinking Water Company can earn 1000 bahts/month if the room is used for rent. So the company will get 12000 bahts/year for each room.

Each room can store product size 500 cc. 10000 dozens or product size 750 cc. 6666.66 dozens or product size 1500 cc. 3333.33 dozens or product size 950 cc. 5263.16 dozens.

Holding cost(H) of product size 500 cc. = 12000/10000 = 1.2 bahts/dozen/year

Holding cost(H) of product size 750 cc. = 12000/6666.66 = 1.8 bahts/dozen/year

Holding cost(H) of product size 1500 cc. = 12000/3333.33 = 3.6 bahts/dozen/year

Holding cost(H) of product size 950 cc. = 12000/5263.16 = 2.28 bahts/dozen/year

Ordering cost(S) is combined from phone call, paper preparing, factory overhead and etc. is about 100 bahts.

After the author gets these data, I will find the optimal number of units per order of each size of product.

Q* of product size 500 cc. = $\sqrt{2DS/H}$ = $\sqrt{2(93600)(100)/1.2}$

= $\sqrt{15600000}$ = 3949.68 dozens = 3950 dozens

Q^* of product size 750 cc. = $\sqrt{2DS/H}$ = $\sqrt{2(54600)(100)/1.8}$

= $\sqrt{6066666.66}$ = 2463.06 dozens = 2463 dozens

Q^* of product size 1500 cc. = $\sqrt{2DS/H}$ = $\sqrt{2(41600)(100)/3.6}$

= $\sqrt{2311111.11}$ = 1520.23 dozens = 1520 dozens

Q^* of product size 950 cc. = $\sqrt{2DS/H}$ = $\sqrt{2(104000)(100)/2.28}$

= $\sqrt{9122807.02}$ = 3020.39 dozens = 3020 dozens

4.2.2 Calculation of Expected Number of Orders

This calculation will show how many times that company should order raw materials in one year of each size of product. The author can also determine the expected number of orders placed during the year (N) as follows:

Expected number of orders $N = D/Q^*$

Expected number of orders of product size 500 cc. = 93600/3950

= 23.70

= 24 orders per year

Expected number of orders of product size 750 cc. = 54600/2463

= 22.17

= 22 orders per year

Expected number of orders of product size 1500 cc. = 41600/1520

= 27.37

= 27 orders per year

Expected number of orders of product size 950 cc. = 104000/3020

= 34.44

= 34 orders per year

4.2.3 Calculation of Expected Time between Orders

This calculation will show that how long the company should order raw materials of each product again. The author can also determine the expected time between orders (T) as follows:

Expected time between orders = (Number of working days in a year)/N

Expected time between orders of product size 500 cc. = 312/24

= 13 days between order

Expected time between orders of product size 750 cc. = 312/22

= 14.19

= 14 day between order

Expected time between orders of product size 1500 cc. = 312/27

= 11.56

= 12 days between order

Expected time between orders of product size 950 cc. = 312/34

= 9.18

= 9 days between order

4.2.4 Calculation of Total Annual Cost

This calculation will show the total annual cost of the company, which contains the ordering and holding costs.

Total annual cost Ordering cost + Holding cost

DS/Q + QH/2

Total annual cost of product size 500 cc. = (93600*100/3950) + (3950*1.2/2)

= 4739.62 bahts

Total annual cost of product size 750 cc. = (54600*100/2463) + (2463*1.8/2)

= 4433.51 bahts

Total annual cost of product size 1500 cc. = (41600*100/1520) + (1520*3.6/2)

= 5472.84 bahts

Total annual cost of product size 950 cc. = (104000*100/3020) + (3020*2.28/2)

= 6886.51 bahts

4.2.5 Calculation of Reorder Point

The author has to calculate the reorder point (ROP); it will show the time when to order materials, the level at which an order should be placed.

Reorder point (Demand per day)(Lead time for a new order in days)

ROP = d * L

First, the author has to calculate the demand per day of each product size.

Demand per day = d = D / Number of working days in a year

Demand per day of product size 500 cc. = 93600/312

300 dozens/day

Demand per day of product size 750 cc.	=	54600/312
	-	175 dozens/day
Demand per day of product size 1500 cc.	=	41600/312
	-	133.33 dozens/day
Demand per day of product size 950 cc.	–	104000/312
		333.33 dozens/day

Then calculate the reorder point as follows:

ROP of product size 500 cc.	-	300 * 3
	-	900 dozens
ROP of product size 750 cc.	-	175 * 3
	-	525 dozens
ROP of product size 1500 cc.	-	133.33 * 3
	-	400 dozens
ROP of product size 950 cc.	-	333.33 * 3
	-	1000 dozens

Figures 4.1, 4.2, 4.3, and 4.4 show reorder point curve of each product. Hence, when the inventory stock of product size 500 cc. drops to 900 dozens, product size 750 cc. drop to 525 dozens, product size 1500 cc. drop to 400 dozens and product size 950 cc. drop to 1000 dozens, an order must be replaced. The order will arrive three days later, just as the company's stock is depleted.

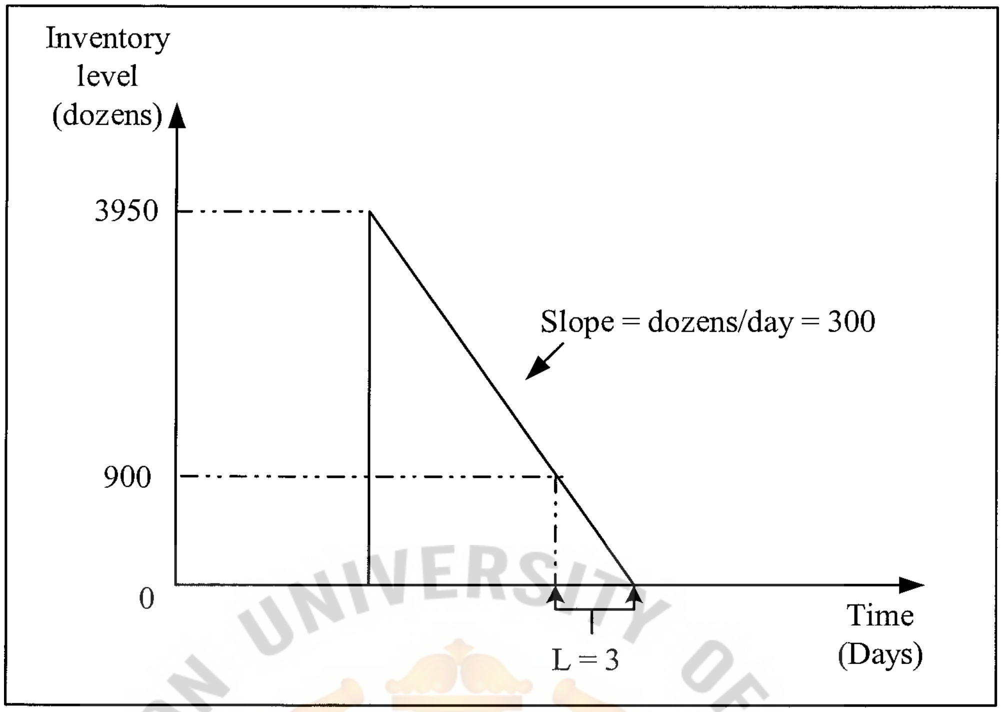

Figure 4.1. Reorder Point Curve of Product Size 500 cc.

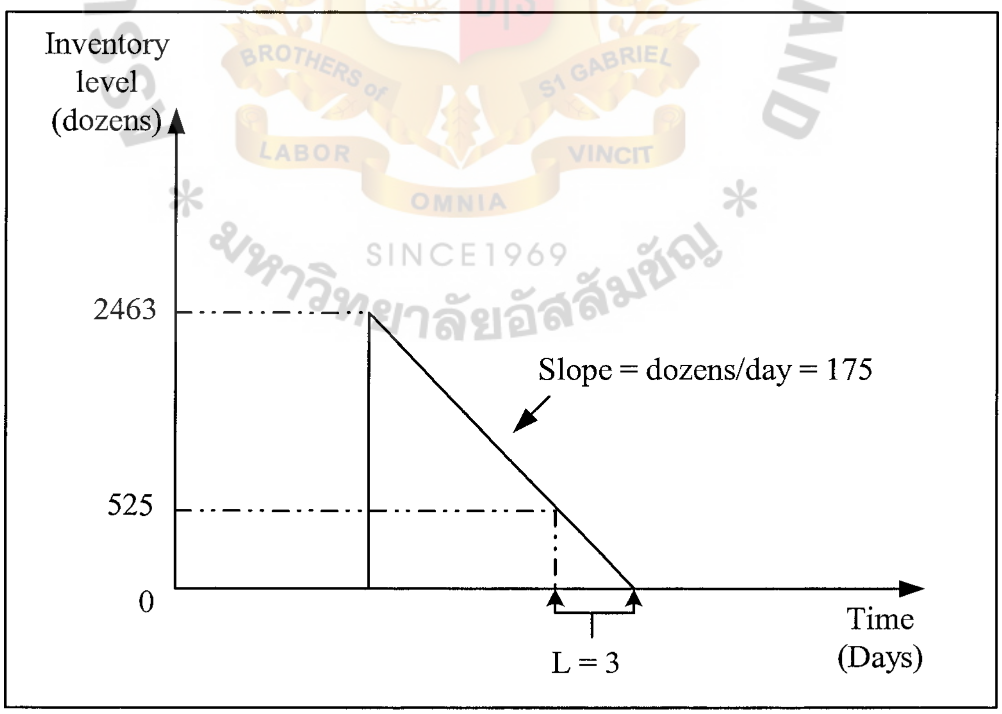

Figure 4.2. Reorder Point Curve of Product Size 750 cc.

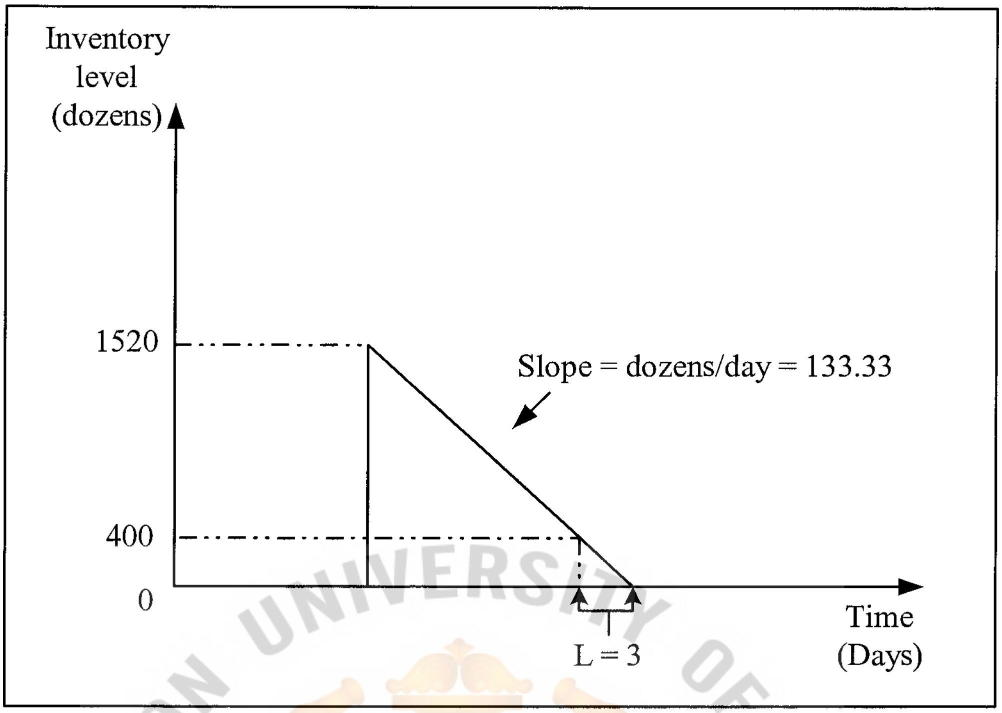

Figure 4.3. Reorder Point Curve of Product Size 1500 cc.

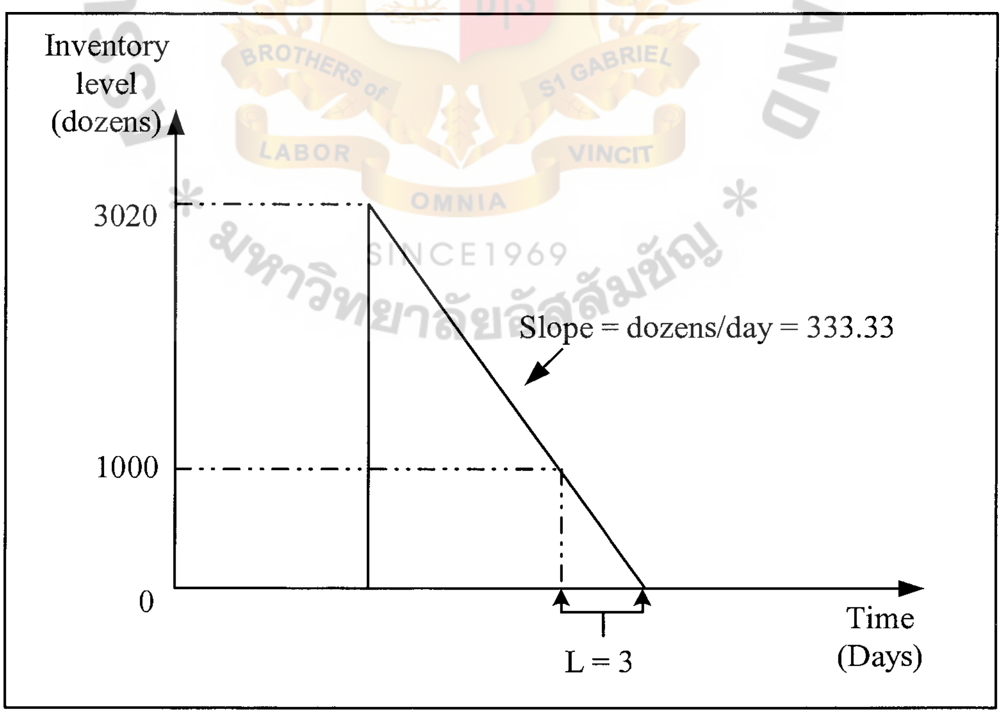

Figure 4.4. Reorder Point Curve of Product Size 950 cc.

V. SYSTEM EVALUATION

After the author gets the optimum number of units per order, expected number of orders, expected time between orders, total annual cost and reorder point already, the author will compare the result of these with the existing system. It will show which system is better.

5.1 Calculation of Annual Ordering Cost of the Existing System

The author has to calculate the annual Ordering cost of the existing system. The raw materials must be ordered once a week.

Company orders raw materials size 500 cc. = 1800 dozens/week

Company orders raw materials size 750 cc. = 1050 dozens/week

Company orders raw materials size 1500 cc. = 800 dozens/week

Company orders raw materials size 950 cc. = 2000 dozens/week

Annual ordering cost = (No. of orders placed/year)(Setup or order cost/order)

= (Annual demand/No. of units in each order)(Setup or order cost/order)

= (D/Q)*S

Annual ordering cost of product size 500 cc. = (93600/1800)*100

= 5200 bahts

Annual ordering cost of product size 750 cc. = (54600/1050)*100

= 5200 bahts

Annual ordering cost of product size 500 cc. = (41600/800)*100

= 5200 bahts

Annual ordering cost of product size 500 cc. = (104000/2000)*100

= 5200 bahts

From the result above the author will see that each of annual ordering cost of Valentine Drinking Water Company is the same because the company is ordering raw materials once a week of each size of product.

5.2 Calculation of Annual Holding Cost of the Existing System

The author has to calculate annual holding cost of the existing system to compare with the proposed system to see which system is working more efficiency.

Annual holding cost = (Average inventory level)(Holding cost/unit/year)

= (Order quantity/2)(Holding cost/unit/year)

= (Q/2)*H

Annual holding cost of product size 500 cc. = (1800/2)*1.2

= 1080 bahts

Annual holding cost of product size 750 cc. = (1050/2)*1.8

= 945 bahts

Annual holding cost of product size 1500 cc. = (800/2)*3.6

= 1440 bahts

Annual holding cost of product size 950 cc. = (2000/2)*2.28

= 2280 bahts

5.3 Calculation of Total Annual Cost of the Existing System

This calculation will show the total annual cost of the company, which contains the ordering and holding costs.

Total annual cost = Ordering cost + Holding cost

TC = DS/Q + QH/2

Total annual cost of product size 500 cc. = 5200 + 1080

• 6280 bahts

Total annual cost of product size 750 cc. 5200 + 945

6145 bahts

Total annual cost of product size 1500 cc. 5200 + 1440

6640 bahts

Total annual cost of product size 950 cc. 5200 + 2280

7480 bahts

5.4 Comparison of Total Annual Cost

From the results above the author will use these data then sum it to get the total annual cost of each system then compare which system works efficiently.

Total annual cost of existing system - 6280 + 6145 + 6640 + 7480

- 26545 bahts

Total annual cost of proposed system 4739.62 + 4433.51 + 5472.84

+ 6886.51

- 21532.48 bahts

From the results of the calculations, the author sees that total annual cost of Valentine Drinking Water Company of the existing system is higher than the proposed system.

Figures 5.1, 5.2, 5.3 and 5.4 show ordering cost, holding cost and total cost of product size 500 cc., 750 cc., 1500 cc. and 950 cc. respectively. The optimum number of units per order of product size 500 cc., 750 cc., 1500 cc. and 950 cc. are 3060 dozens, 2337 dozens, 2040 dozens and 3225 dozens respectively.

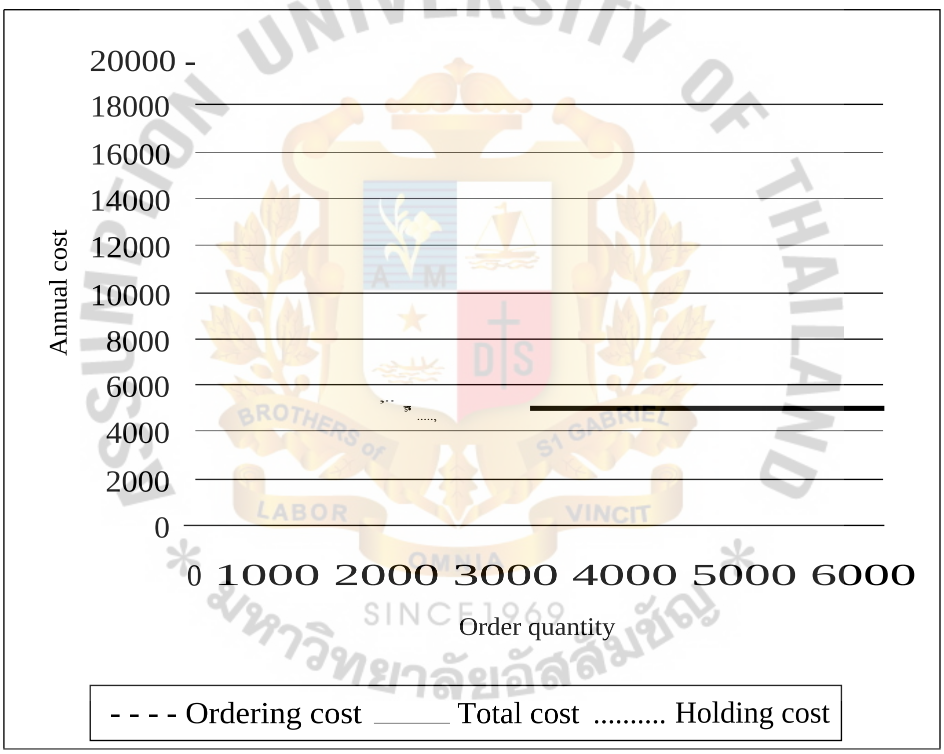

Figure 5.1. Total Cost of Product Size 500 cc.

The optimum number of units per order of product size 500 cc. is 3950 dozens which makes the total annual cost of Valentine Drinking Water Company lowest as shown in Figure 5.1 which equals 4739.62 bahts.

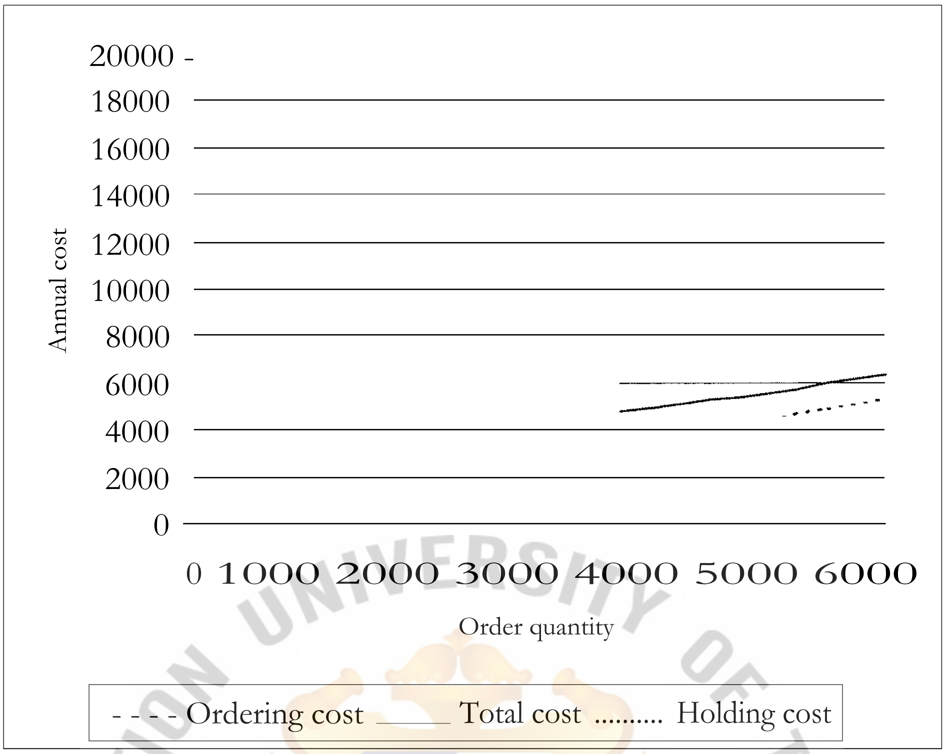

Figure 5.2. Total Cost of Product Size 750 cc.

The optimum number of units per order of product size 750 cc. is 2463 dozens which makes the total annual cost of Valentine Drinking Water Company lowest as shown in Figure 5.2 which equals 4433.51 bahts.

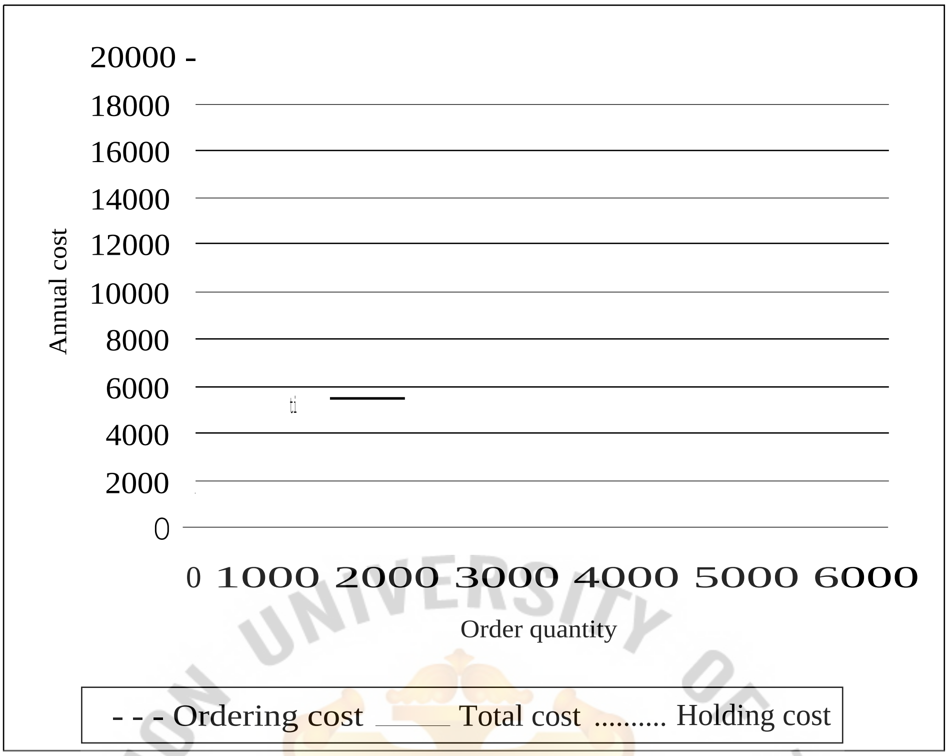

Figure 5.3. Total Cost of Product Size 1500 cc.

The optimum number of units per order of product size 1500 cc. is 1520 dozens which makes the total annual cost of Valentine Drinking Water Company lowest as shown in Figure 5.3 which equals 5472.84 bahts.

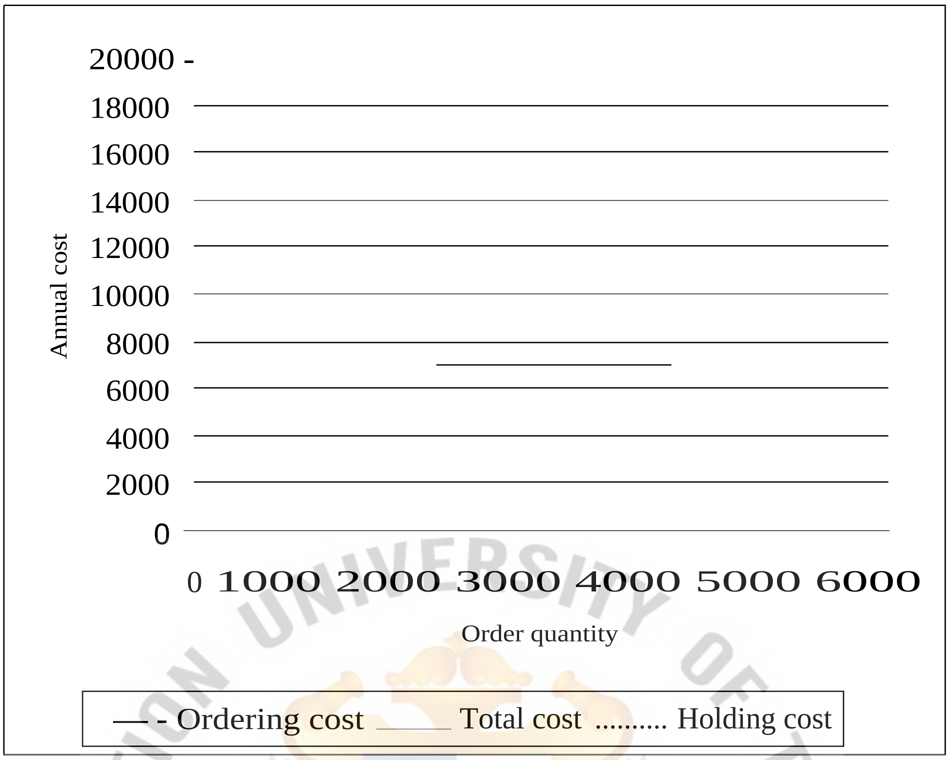

Figure 5.4. Total Cost of Product Size 950 cc.

The optimum number of units per order of product size 950 cc. is 3020 dozens which makes the total annual cost of Valentine Drinking Water Company lowest as shown in Figure 5.4 which equals 6886.51 bahts.

VI. CONCLUSIONS

In today's highly competitive environment, the distributor can use every advantage possible. In this regard, there is nothing that can compare to the competitive advantage of managing your customers' inventory for them.

However, many manufactures and factories are misallocating the importance of the inventory system. The reason is because the total cost of the inventory system is being lost gradually, so they do not notice the changes. Therefore, the manufacturers are losing their profits, which is not supposed to. Nevertheless, there are many ways to construct the good inventory management.

In order to have a strong inventory management, the manager must know the details of the infrastructure of the company through out the internal and external management system. For example, the current demand and the future demand must be recognized. However, the forecast demand should be estimated to the closest to the demand in the future. This result will lead the inventory system to become more effective and strong reliability.

Regarding to the Valentine Drinking Water Company, the management team is using the Existing System Model to run the company. The delivering system is being done once a week. Therefore, the safety stock never happens. According to this result, the problem of lacking of products may easily occur.

On the other hand, the proposed system is created to plan the future production in one week, and then calculate to find the safety stock in order to decrease the lack of products problem. In addition to this calculation, there is also a calculation to find the optimum units per order, the ordering cost, the holding cost, the reorder point and the total cost. As a matter of fact, these cost results will indicate the differences of each system: Existing System and Proposed System. As a result, the manager is able to decide which system is better to be used.

According to this project, the author makes the decision to build up the safety stock as the company never planned before. The safety stock can eliminate the problems in production process, including lead-time period, and etc. Just-In-Time technique is not used in this project because it is appropriated for demand that is constant but demand in business of drinking water is not constant. Demand may be increased or dropped immediately when the capacity of machine can't support for a large demand increased immediately.

VII. RECOMMENDATIONS

This project is concerned about inventory management method is likely to be useful for any organization that needs to improve performance of inventory and solve some existing problems about stock holding. For those organizations that have never used inventory management method, it is easy to work through the guideline to their work systems. Inventory management will help the manager of those organizations work easily and can control raw materials in the stock and forecast demand in the future.

Theories in this project are sufficient to analysis for some organizations that their inventories are not complicated. However, more theories are available at some sources for the organizations that are interested in inventory management method and they may be more useful for the organizations.

In this project, some ordering cost can be reduced if the manager orders many types of products in the same time but the company has to find the appropriate solutions to solve the problems.

This project is not used in the real situation due to the limitation of time but it is accepted for the good result by the theory. For better result the organization has to implement and study further to verify that the outcome will practically follow the proposed system.

The final caution is that to perform this function you need an outstanding inventory management system that assimilates the customers' data and makes sound recommendations that will not trigger questionable orders. For example, it must have a reorder point logic that can deal with slow moving and fast moving product equally effectively without manual intervention. Finally, it must be extremely easy to use so that you do not assume an unmanageable and high cost administrative burden. Therefore, these practices will lead to the strong and good inventory management.

This project uses the estimate customers' demand that may cause an approximate result but it can be acceptable by the theories because in the real business of Drinking Water it is impossible that the customers' demand will be constant. But this project may be useful for the organizations that make contract with the customers for a long period.

Time taken in the implementation of inventory management is depended on each organization. Some organizations that take this concept into action may get the result in a short period of time whereas others may take a longer time to implement due to the complication of inventory in the organizations. But if organizations take a long enough time to implement proposed system it will be likely to get better results.

There are many factors that can make this project fail. Organizations have to survey and collect the data of inventory exactly or close to the real. Some data are concerned with many factors if you miss some factors the result will fail.

This project can be adjusted for the suitability and appropriateness of each organization which the inventory has the difference from this project.

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