Chapter III

Theoretical Considerations and Literature Review

3.1 Theoretical Consideration

3.1.1 Inventory Strategies

The company's inventory strategy translates the inventory investment and service level aspects of higher-level strategies into average inventory levels, reorder quantity policy and timing, and safety stock levels. If the Inventory strategy aligns properly with manufacturing process and supplier, it will truly create competitive advantage and customer value. The inventory strategy must take the manufacturing complexity, including factors such as time of season and demand variability, cumulative versus marketing lead time, and management policy into the consideration.

3.1.1.1 Definition of Inventory

Those stocks or items used to support production (raw materials and work-in-process items), supporting activities (maintenance, repair, and operating supplies), and customer services (finished goods and spare parts). Demand for inventory may be dependent or independent. Inventory functions are anticipation, hedge, cycle (lot size), fluctuation (safety, buffer, or reverse), and transportation (pipeline) and service parts.
(APICS Dictionary, 9th ed., 1998)

In the theory of constraints, inventory is defined as those items purchased for resale and includes finished goods, work in process, and raw materials. Inventory is always valued at purchase price and includes no value-added costs, as opposed to the traditional cost accounting practice of adding direct labor and allocating overhead as work in process through the production process.
(APICS Dictionary, 9th ed., 1998)

3.1.1.2 Types and Classifications of Inventory

1. Raw Materials (RAW): Raw Materials represent any material inputs used in manufacturing process. It also includes manufacturing products from suppliers as refer to finished goods at supplying company.
2. Work In Process (WIP): Work In Process is another form of Raw Materials, once Raw Materials have been transferred from stock to production line. While these materials are in different stage of completion, they are referred to as Work In Process Inventory. The quantity and amount of Work In Process Inventory depend on specific production process and inventory policy.
3. Finished Goods (FG): Finished Goods represent output of the whole production process which will be sold to the customer or transfer to the sister division in a vertically integrated company.
4. Maintenance, Repair, and Operating Supplies (MRO): Maintenance and spare parts inventory are maintained and review by typical visual review, since these items are low cost and numerous. Operating Supplies are also included office and janitorial supplies.

3.1.2 Order Review Methodologies

The purpose of Order Review is to determine the schedule and quantity of purchase of work orders. Companies may use a variety of order review methodologies and techniques that consistent with the types of inventory being managed.

1. Material Requirement Planning (MRP): MRP is a computer logic process which calculate material requirement for an entire demand. The major benefit of MRP is to accommodate ordering strategies for parts with variable dependent and independent demand profiles. This ability supports the company to establish effective plans and controls by item category, and item as required, in order to achieve the inventory strategy targets. The MRP characteristics can be described as following details.

   i. The final material requirement (end-item demand) is based on a forecast and/or master schedule.

ii. The final material requirement (end-item demand) is likely to be discontinuous if not scheduled in daily batches.

iii. Bill of material need to be defined properly according to the relationship in order to get the right end item demand.

iv. The final material requirement (end-item demand) is excluded safety stock since that are subject to only dependent demand, and that have sufficient lead time to meet.

2. Reorder Point: A set inventory level where, if the total stock on hand plus on order falls to or below that point (the set level), action is taken to replenish stock (APICS Dictionary, 9th ed., 1998)

ROP= Reorder Point

DDLT= Demand during Lead Time

SS = Safety Stock

ROP= DDLT + SS

Reorder Point technique assumes that a replenishment order can be released and received before stock out occurs. Since this technique is typically used for independent demand items, safety stock is required to be maintained in timely manner. The required assumption for this technique is stable demand.

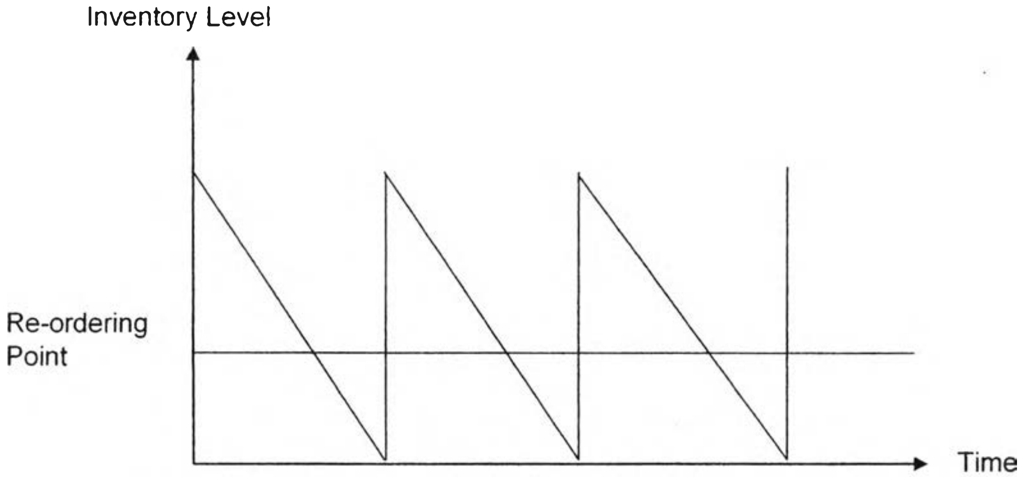

Figure 3.1.2 Reorder Point Saw tooth Graph

3. Time Phased Order Point: A Time Phased Order Point is an approach that uses time periods, thus allowing for lumpy withdrawals instead of average demand. (APICS Dictionary, 9^{th} ed., 1998) The advantage of time phased order point over reorder points is it combines both dependent and independent demand in a time-phased manner. Another distinctive assumption is no stable demand profile.

    ROP= Reorder Point
    DDLT (dependent) = Dependent Demand during Lead Time
    DDLT (independent) = Independent Demand during Lead Time
    SS = Safety Stock
    ROP= DDLT (dependent) + DDLT (independent) + SS

4. Periodic Review: Periodic Review is also known as a fixed-interval order system, or fixed reorder cycle inventory model. The order quantity is variable and essentially replaces the items consumed during the current time period. Let M be the maximum inventory desired at any time, and let x be the quantity on hand at the time the order is placed. Then in the simplest model, the order quantity will be M-x. The quantity M must be large enough to cover the maximum expected demand during the lead time plus a review interval. The order quantity model becomes more complicated whenever the replenishment lead time exceeds the review

complicated whenever the replenishment lead time exceeds the review interval, because outstanding orders then have to be factored into equation. (APICS Dictionary, 9^{th} ed., 1998)

5. Visual Review: Visual Review is the system that reviews the reordering under the consideration of the amount of inventory on hand. Visual review is usually applied to low value items by establishing minimum and maximum inventory levels. When the minimum is reached, adequate inventory is purchased or produced to raise the inventory levels back to the maximum level.

6. Kanban: Kanban is generally known as a replenishment signal. The replacement quantity is determined as part of a comprehensive analysis. Kanban can be described as a pull system. The basic idea behind Kanban is that it is a visual aid, used to show which areas of the production cycle require work/materials and which areas are holding most of the work/materials. In essence a Kanban system can be used to replenish material. Buckets/Pots holding material could be placed on the shop-floor, where a progress man could be in charge of making sure the material holding does not drop below a certain level to ensure that the machines do not stop working and highly paid operators are not left walking up and down the shop-floor to the stores area.

3.1.3 Lot Sizing Techniques

3.1.3.1 Economic Order Quantity (EOQ)

The Economic Order Quantity is based on an assumption of uniform annual demand. EOQ is the optimal order quantity that will minimize total inventory cost (Russell and Taylor, 1995). EOQ recognizes the tradeoff between the cost of carrying inventory and the cost to process the order and set up cost (Ptak, 2000). Theoretically, the optimum order quantity on the horizontal axis below where the two cost curves intersect in figure 5, which also coincides with the point at which the total cost curve, is at a minimum. The dashed vertical line represents this point. The point on the

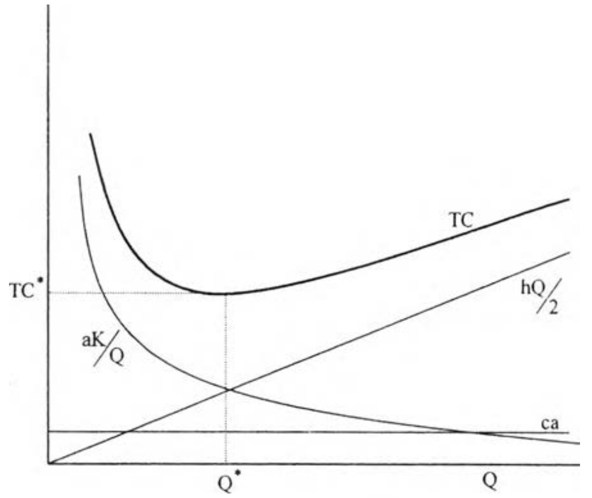

Figure 3.1.3.1 Order Quantity Cost Comparison

EOQ concept is mainly competent as a technique for demonstrating the relationship between carrying costs and ordering costs. EQO formula is formed under the consideration of carrying costs and ordering costs.

EOQ = √2AS/CI

A = Annual Usage; generally determined as twelve times monthly usage

S = Cost per Order; consists of ordering cost and setup cost

C = Cost of Item; typically the standard cost

I = Annual Cost to Carry

3.1.3.2 Fixed Order Quantity

Fixed Order Quantity is usually stipulated by some condition related to shipping, handling, or line replenishment. Fixed Order Quantity will generally generate consistent orders with consistent order quantities but at a variable frequency without the regard of demand variability.

3.1.3.3 Lot for Lot

Lot for Lot is the sum of requirements for a period. A lot size method in which the suggested quantity is equal to the net requirement for a given day, and is not rounded up to a minimum or multiple. A lot-for-lot technique will generate a greater volume of orders than a fixed lot size system, with smaller quantities per order and a smaller inventory investment due to ordering exact requirements only. Lot for Lot technique is a straightforward methodology for lot sizing techniques. The lot-for-lot ordering system entails inventory requirements equal to the demand requirements that were not satisfied by existing inventory levels.

3.1.3.4 Minimum Cost per Period (Silver Meal) Approach

Minimum cost per period approach is a 'near optimal' method of order quantities building by taking a marginal analysis approach. The procedure considers each potential purchase quantity sequentially and calculates the average cost per period covered as the sum of the ordering and holding costs implied by the potential buy divided by the number of periods covered by such an order. The decision rule is adding the next period of demand to the current order quantity unless the average cost per period covered would not be reduced. As long as the average cost per period covered by the order would be reduced by adding an additional period worth to the order.

$$CPP(Q) = (Q/2)*h + S/(Q/d)$$

S = Cost per Order; consists of ordering cost and setup cost

Q = Order Quantity

h = Holding Cost

d = Average Requirement per period

3.1.3.5 Period Order Quantity Approach

From the study, lot sizing is crucial for MRP. However, EOQ technique is not working well with the real situation. The problem is that assumption of EOQ technique is continuous and uniform demand. In real situation, demand of the product tends to be fluctuate and lumpy which means discontinuous and non uniform demand. By using EOQ technique with real life demand, lot sizes are not able to cover the whole periods of demand. The Period Order Quantity (POQ) model was designed to avoid remnants and give lower costs with lumpy demand. The POQ logic is straightforward. According to EOQ, the objective is to balance ordering and holding costs, however we order only in whole periods of demand. To determine the number of periods to order, the first step is to compute the EOQ quantity. Then, we determine the average number of periods of demand covered by the EOQ, which is POQ.

3.1.3.6 Least Unit Cost Approach (LUC)

The objective of least Unit Cost approach is to minimize cost per unit. Least Unit Cost is a dynamic lot sizing technique by using trial and error methodology to figure out the lot size with the lowest unit cost by minimize ordering and inventory carrying cost

3.1.3.7 Least Total Cost Approach (LTC)

The objective of LTC approach is trying to balance the holding and setup costs. The methodology to figure out the lot size for LTC is by adding the demand for that period to the lot. If the cumulative carrying costs are less than or close to the setup cost, then continue adding future periods demand until the total cumulative cost exceeds the setup cost. As a consequent, the lot sizing quantity will be the biggest quantity that total cumulative cost less than the setup cost.

3.1.3.8 Part Period Balancing (PPB)

The Part Period Balancing approach is a variation of the LTC method. The objective of PPB is trying to balance the setup and holding cost through the use of economics part periods.

3.1.4 Inventory Management

Inventory management methodology concerning inventory from two directions:

1. Optimizing inventory levels while considering the order fulfillment process as a constraint.
2. Managing order fulfillment process across the supply chain management.

Inventory management is a crucial issue for every industrial, since the objective of inventory management is to control inventory level by balancing the requirement of part supply and minimizing the holding inventory and its cost.

3.1.4.1 Definition of Safety Stock

Safety Stock is a quantity of stock decided to be in inventory in order to smooth the production during the fluctuations in demand or supply. Safety stock is the level of stock, over and above the expected usage between the times a replenishment order is processed and replenishment actually occurs, that is held in reserve to try to prevent stock-out, should there be a delay in delivery of stock by the vendor. Safety stock is the quantity of additional stock procured and/or held to satisfy unexpectedly high demand. Safety stock planning within Supply Network Planning allows you to meet a service level while creating a minimum amount of safety stock throughout your entire supply chain for all intermediate and finished products at their respective locations.

3.1.4.2 Purpose of Safety Stock

One of the purposes of safety stock is to increasing company's revenue. It will definitely improve order fill rate, whenever the demand arise unexpectedly. Another purpose of safety stock is to lowering working capital. Since safety stock will act as a buffer, protecting stock from running out of stock, for mainly unanticipated demand. This will instantly improve capital utilization, more effective on managing fixed assets and resources, increase inventory turn over, and lower work in process inventory.

3.1.4.3 Safety Stock Technique and calculation

(Piasecki, 2001) One of the most widely accepted methods of calculating safety stock uses the statistical model of Standard Deviations of a Normal Distribution of numbers to determine probability. This statistical tool has proven to be very effective in determining optimal safety stock levels in a variety of environments. The basis for this calculation is standardized; however, its successful implementation generally requires customization of the formula and inputs to meet the specific characteristics of your operation. Understanding the statistical theory behind the formula is necessary in correctly adapting it to meet your needs. Errors in implementation are usually the result of not factoring in variables which are not part of original statistical model

Standard deviation is calculated by the following steps:

1. Determine the mean (average) of a set of numbers.
2. Determine the difference of each number and the mean
3. Square each difference
4. Calculate the average of the squares
5. Calculate the square root of the average.

Safety Stock = $Z (\sigma_d) \sqrt{L}$

Z = Number of Standard deviations corresponding to the service levels probability

σ_d = The standard deviation of daily demand

L = Lead time in days

Service Level (%)	Safety Factor
50	0.00
75	0.67
80	0.84
85	1.04
90	1.28
94	1.56
95	1.65
96	1.75
97	1.88
98	2.05
99	2.33
99.86	3.00
99.99	4.00

Table 3.1.4.3 Table of Safety Factors

3.1.4.4 Inventory Valuation

There are three main valuation methods which are:

1. First-in, First-out (FIFO): Under FIFO, the cost of goods sold is based upon the cost of material bought earliest in the period, while the cost of inventory is based upon the cost of material bought later in the year. This results in

inventory being valued close to current replacement cost. During periods of inflation, the use of FIFO will result in the lowest estimate of cost of goods sold among the three approaches, and the highest net income.

2. Last-in, First-out (LIFO): Under LIFO, the cost of goods sold is based upon the cost of material bought towards the end of the period, resulting in costs that closely approximate current costs. The inventory, however, is valued on the basis of the cost of materials bought earlier in the year. During periods of inflation, the use of LIFO will result in the highest estimate of cost of goods sold among the three approaches, and the lowest net income.

3. Weighted Average: Under the weighted average approach, both inventory and the cost of goods sold are based upon the average cost of all units bought during the period. When inventory turns over rapidly this approach will more closely resemble FIFO than LIFO.

3.1.4.5 ABC Analysis

ABC Analysis is the straightforward method for classifying and analyzing inventory. The ABC Analysis is using the Pareto curve to determine and classify inventory type. Pareto analysis, sometimes referred to as the 80/20 rule, is a method of classifying items, events, or activities according to their relative importance. It is constantly used in inventory management where it is used to classify stock items into groups based on the total annual dollar usage. This ABC analysis definitely assists company to concentrate more detailed attention on the high value, significant and important items. The first step in the analysis is to identify those criteria which make a significant level of control important for any item. Two potential factors are the usage rate for an item and its unit value. For high usage rate items with high unit value is required intent controlling and monitoring. On contrary, low usage rate items with low unit value is not required intent controlling and monitoring. For low usage rate items with low unit value, the simple method of control is recommended to apply.

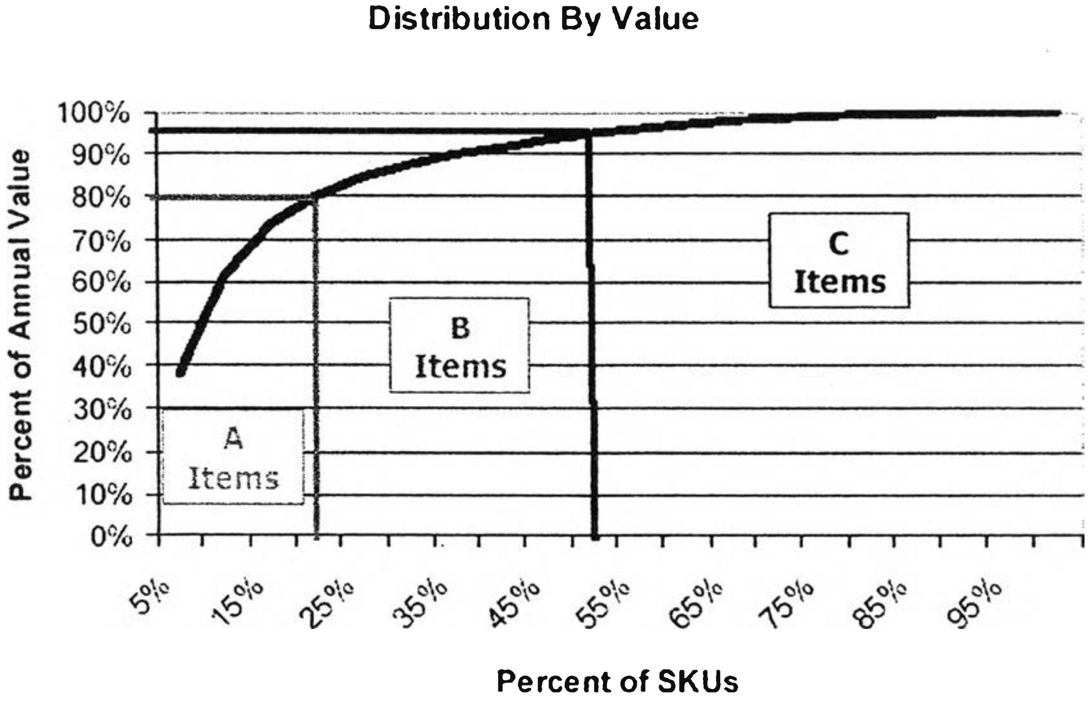

Figure 3.1.4.5 Pareto Analysis chart

3.1.4.6 ABC Calculation

The cost of each item in inventory and annual usage represented by the value are included in the fundamental data. Theoretically, the future annualized should be typified by the usage figures. The calculation can be performed once the input data are assembled. The steps of ABC calculation are as follow:

1. Calculate annual usage in units for each item: First of all, create the list of all inventory items includes usage of each item. Then tabulate all inventory items in descending order.
2. Multiply usage by unit cost to determine annual dollar usage: Secondly, multiply each inventory usage by unit cost. Then, the result of this calculation is the value of annual dollar usage.
3. Rank items by annual dollar usage from highest to lowest: Thirdly, rank all inventory items in descending order of annual dollar usage from highest to lowest. The result of the ranking in tabular form is called distribution by value as shown in "Distribution by value table"
4. Assign ABC categories: Finally, assign ABC categories

A = “high dollar usage” items. These items are the highest priority, the tightest control, frequent deliveries, close monitoring, and accurate records. To effectively manage these items, Material Requirements Planning, Economic Order Quantity or other lot sizing techniques such as Lot for Lot are recommended to be utilized. Typically, 10 % of the group A items volume accounts for 70% of the total inventory value

B = “medium dollar usage” item. These items are the priority when low or out of stock. To effectively manage these items, it requires normal control and maintenance of accuracy record. EOQ and other lot sizing methods can be used effectively with these items. However, same kind of controlling with group A, Material Requirements Planning, Economic Order Quantity or other lot sizing techniques can be applied with group B. (Caplice, 2003). Theoretically, group B items account for 20% of the total inventory value, and 20% of the inventory volume.

C = “low dollar usage” item. These items are the lowest priority, simplest method of control. To effectively manage these items, Min and Max technique is recommended for ordering. Typically, these parts represent 10% of the total value and 70% of the volume.

Theoretically, group A items are about 20 percent of the rank items and 80 percent of the total dollar usage.

Part ID	Price	Annual Demand	Annual $ Value	Cum $ Value	Pct Ann $ Value
55K2	$ 24.99	334	$ 8,347	$ 8,347	38%
58JH4	$ 7.70	675	$ 5,198	$ 13,544	62%
2M993	$ 4.45	612	$ 2,723	$ 16,268	74%
3HHT8	$ 6.10	220	$ 1,342	$ 17,610	80%
89KE	$ 1.32	786	$ 1,038	$ 18,647	85%
5497J	$ 2.25	260	$ 585	$ 19,232	87%
38JQ2	$ 0.77	690	$ 531	$ 19,763	90%
2340P	$ 6.22	66	$ 411	$ 20,174	92%
990RT	$ 3.89	89	$ 346	$ 20,520	93%
56M4	$ 3.10	110	$ 341	$ 20,861	95%
P001	$ 0.77	388	$ 299	$ 21,160	96%
978SD3	$ 7.75	24	$ 186	$ 21,346	97%
4503	$ 12.80	14	$ 179	$ 21,525	98%
3784	$ 0.85	148	$ 126	$ 21,651	98%
3K62	$ 2.85	43	$ 123	$ 21,773	99%
56TT7	$ 1.23	52	$ 64	$ 21,837	99%
78HJQ2	$ 0.68	77	$ 52	$ 21,890	100%
7UJS2	$ 4.05	12	$ 49	$ 21,938	100%
88450	$ 1.50	21	$ 32	$ 21,970	100%
23LK	$ 0.25	56	$ 14	$ 21,984	100%
		4,677	$ 21,984		

Table 3.1.4.6 Example of Distribution by value Table

3.1.4.7 Inventory Policy

Inventory Policy is a statement and guideline of a company on inventory management. In inventory system and policy, there are three significant aspects that required strong consideration. The three significant aspects is called decision variable.

1. Variety Decision: to decide what inventory items should be order.
2. Timing Decision: to decide when inventory items should be order.
3. Quantity Decision: to decide how many inventory items should be order.

There are two types of inventory control policies. One is periodical review policy and another one is continuous review policy. The characteristic of periodical review policy is that the inventory policy will monitor as a fixed time intervals for instance week, month, or year. Continuous review policy will monitor inventory level continuously. For periodical review policy, inventory target and reorder point will be assigned in order to track and monitor inventory level. Once inventory level is lower than reorder level, company is required to order the requested items in order to meet inventory target. For continuous review policy, inventory target and fixed quantity will be assigned in order to track and continuously monitor inventory level. Once inventory level is lower than reorder level, company is required to order fixed quantity of the requested items.

3.1.5 Material Requirement Planning

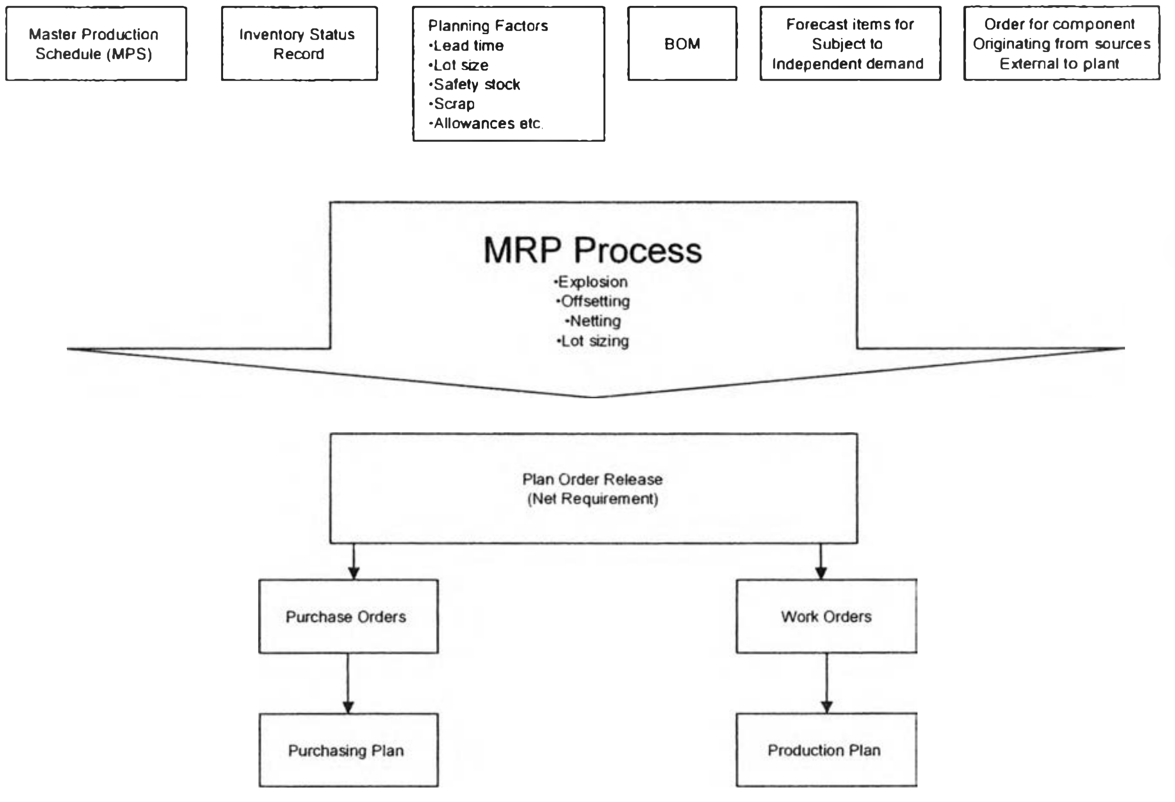

Figure 3.1.5 MRP Process Flow

3.1.5.1 Definition of Material Requirement Planning

MRP is a technique which uses Bills of Material, inventory data and the Master Production Schedule to calculate requirements for items. The objective of MRP is to make recommendations to release replenishment orders for material. MRP is a process, supported by computer logic, for calculating an entire demand versus ordering profile through the planning horizon. Primary benefit of MRP is its ability to accommodate ordering strategies for part with variable dependent and independent demand profiles. This ability allows the planner to establish plans and controls by item category, and item as required, to achieve the inventory strategy targets.

The following characteristics differentiate these types of inventories from end-item distribution inventories.

1. End-item demand is based on a forecast and/or master schedule
2. Demand tends to be lumpy and discontinuous if not schedule in daily batches. (This is more noticeable at the lower bill of material levels than at the higher ones)
3. Lower level demand is not forecasted if there is a defined bill of material relationship; it is calculated.
4. Little or no safety stock is needed to ensure a 100 percent service level for those parts that are subject to only dependent demand, and that have sufficient lead time to meet.

   (APICS Dictionary, 9^{th} ed., 1998)

3.1.5.2 MRP Inputs

1. Demand: There are two types of demand in MRP which are dependent demand and independent demand. Demand from customer, which is the company's products, is independent demand. Dependent demand is a demand that was generated by independent demand, which necessary to the satisfaction of independent demand. Generally in MRP, there are few independent demand while there are many dependent demand that cased by few independent demand. Complex product with many hierarchy and component is likely to have a complex dependent demand. In Master Production Schedule consists of independent demand. The details in Master Production Schedule are included of products, end items, finished goods, and services or repair parts.
2. Inventory Data
   i. Parts (items)
   ii. Item identification: Item identification includes the part number assignment for each raw material. Part number is very crucial information for MRP input since it significantly relate to independent and dependent demand. Part number should be unique and concise in order to avoid the confusion during the fluctuation

of independent demand. One set of part number should be used within a company. Having only one set of part number will make the same understanding through out company. Part number that inactive should not be reassigned. Part number should be kept uniform and avoid confusing letter.

iii. On order information by due date: Scheduled receipt is an order previously released to production or a supplier, which meets a due date. Scheduled receipt is considered as an active data. Scheduled receipt is also crucial information that MRP is required to take into account because of it directly impact on MRP result, planned-order releases.
iv. On hand balances at each stock location
v. Reorder and safety stock information: for raw material that used reorder technique for part supply management, reorder point is required to be maintained and reviewed.
vi. Financial information
vii. Usage
viii. Unit of measure
ix. Classification information
x. Sourcing
xi. Lead time

3. Bill Of Material: Bill of Material is sometimes called product structure. There are single level BOM and multi level BOM. Product structure is a diagram that shows the sequence in which raw material, purchased parts, and subassemblies are manufactured and assembled to form the end-item. BOM is a crucial resource for MRP since it contains usage of each item and the production lead time of each process level according to the hierarchy. The accuracy of BOM is considered as an important issue since it will directly impact on MRP result, planned-order releases.

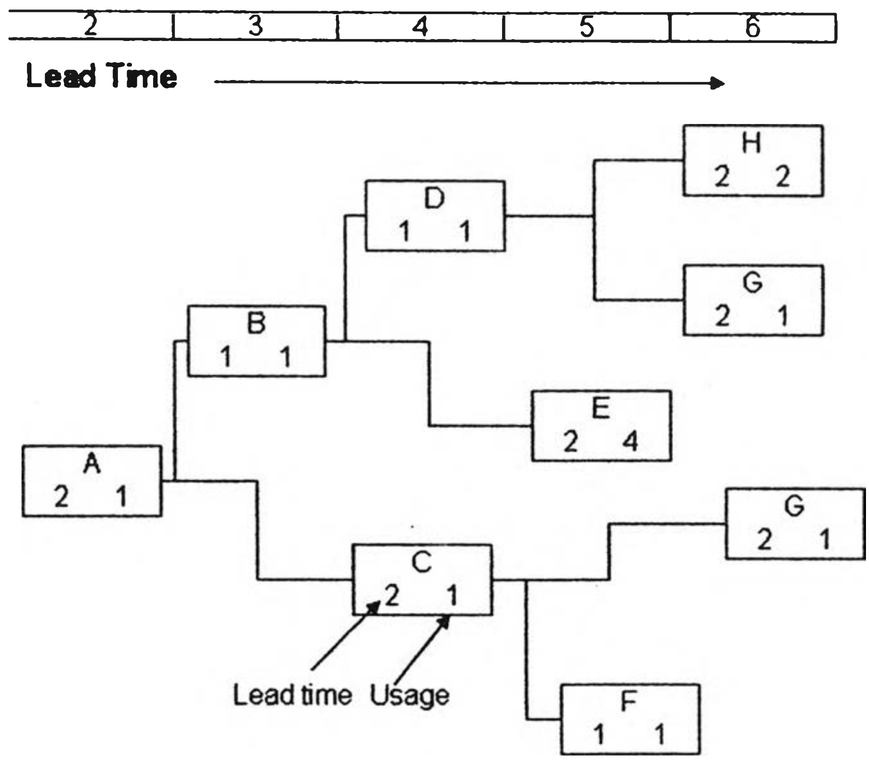

Figure 3.1.5.2 Example of Multilevel Bill of Material with Lead time offset

3.1.5.3 MRP Mechanism

The essence of MRP is to transfer the input into the most effective output. Transforming the input into output is done systematically and mathematically. The sequence steps of MRP called explosion, netting, offsetting, and lot sizing.

1. Explosion Process: Master Production Schedule (MPS) is exploded through the BOM to identify the sub-assemblies that need to be produced, and the raw materials and components that need to be purchased. If the BOM is a single level, just finished products, and raw materials/components, then this is complete with simple mathematic and technique. Some product structures allow each level of the BOM to be specified in a separate table, in which case a simple technique can be used to explode through each level of the BOM in turn. More complex product structures, where the same sub-assembly or component appears at different levels in the BOM, require a computerized MRP system.

2. Netting Process

   a. Netting-off inventory (Raw Materials): The MRP explosion process identifies the sub-assemblies that need to be produced, and the raw materials and components that need to be purchased. However, some of these may already have been produced or purchased, and be in inventory, so they do not need to be produced or purchased anymore. Netting-off inventory is the process that will reduce each part requirement (the quantity to be produced or purchased) with existed inventory in the system. Finally, after netting-off inventory (process complete, there is a list of the net quantities to be produced or purchased and any inventory that will remain after the last production run.

   b. Netting-off Work in Process (WIP): Sometimes during the MRP process, some sub-assemblies and components may have been issued to the production area waiting for the production to be started. The MRP system needs to recognize that these work in process inventories exist, and do not required to be produced or purchased again, but they will not be dynamically re-allocated to another product. Netting-off work in process is the process that will reduce each part requirement (the quantity to be produced or purchased) with existed work in process inventory in the system. Finally, after netting-off Work in Process complete, there is a list of the net quantities to be produced or purchased and any inventory that will remain after the last production run.

   c. Netting-off Quantity on order: Sometimes during MRP process, there is quantity on order which is an order previously released to production or a supplier, which meets a due date. Since quantity on order is considered as an active data, MRP system needs to recognize this quantity as an expected inventory in the future. Netting-off Quantity on order is the process that will reduce each part requirement (the quantity to be produced or purchased) with existed quantity on order. Finally, after netting-off Quantity on order complete, there is a list of the net quantities to be produced or purchased and any inventory that will remain after the last production run.

Net requirements = Gross requirements – on hand inventory (raw material & WIP) – Quantity on order

3. Offsetting Process: The offsetting process is the process to determine the timing of order release. The objective of this process is to receive raw material from supplier according to the required date and quantity from net requirement. In order to meet the net requirement, offsetting process will offset the production lead time and supplier delivery time from order releases.

4. Lot Sizing Process: Lot sizing is the last MRP process to identify the batch size to be purchased or produced.

3.1.5.4 MRP Output

1. Primary Output: Primary output of MRP consists of The Planned Order Schedule, which is a plan of quantity and date of material to be ordered. This information will be used for placing the orders to suppliers and upstream departments. The primary output also consists of changes in planned order. The changes of planned order come from the changes of MRP input especially Master Production Schedule and inventory data.

2. Secondary output: Secondary output of MRP consists of Exception reports, Action reports and Pegging reports. Exception reports require attention because it will show whenever something went wrong. Action reports suggest the action for each order for instance expedite, cancel, and de-expedite. These reports will assist the company on the order that required attention. Pegging reports are the report that shown the relationship between each item and gross requirement.

3.1.5.5 Additional MRP Aspects

Closed-Loop MRP originally developed by IBM in 1965, although the methodology is often attributed to work in 1971 by Joseph Orlicky, George Plossl and Oliver. The logic of the MRP technique made possible expanded computer systems that provide information for planning and controlling both the materials and the capacity required to manufacture products. The MRP logic is now becoming the key component in an information system for planning and controlling production operations and purchasing. The information, MRP Output, provided by MRP is highly useful in scheduling because it indicates the relative priorities of work orders and purchase orders. MRP applies production lead time and purchasing lead time estimates to determine the dates on which each level of assembly should be started in order to meet the scheduled completion date for the end product. The start date determines the time when an order for the item should be released to the internal production line or to some external vendor. The start date for one level of assembly is also the required date for all components of this assembly. If the actual complete date is the same as the required date then the schedule becomes valid. MRP is the basic foundation for production activity control or shop floor control, for vendor follow-up systems, and for detailed capacity requirements planning. When MRP is extended to include feedback from and control of vendor orders and production operations, it is called Closed-Loop MRP. Closed-loop MRP is the system that execution of the plan is feed back to MRP system.

3.1.6 Bullwhip Effect

3.1.6.1 Definition of Bullwhip Effect

The Bullwhip effect phenomenon is when there is an increasing of demand variable. The changes in demand can result in large variations in order placed upstream. The bullwhip effect has been observed across most industries, resulting in cost increasing and decreasing of supply chain management performance.

3.1.6.2 Causes of the Bullwhip Effect

The following causes are the feasible cause of the bullwhip effect:

1. In appropriate action for backlogs
2. Policy of the company is to concentrate on inventory reduction

3. Communication problem in supply chain flow
4. Information and material flow problem
5. Order batching: Large orders size effected on supply variability. Most of the time order batching came from the attempt to reduce ordering cost by taking advantage of transportation economics.
6. During the part supply shortage, customers tend to order more than they required expected that the partial shipments from supplier will be able to satisfy their demand.
7. Inaccurate Demand forecast

3.1.6.3 The effect of Bullwhip effect

1. Excessive inventory investments
2. Decreasing of customer service level
3. Missed production schedules
4. Reduction of revenues

3.1.6.4 Solutions for Bullwhip effect

The substantial key to effectively diminish the bullwhip effect is by aligning production and the supply chain with realistic customer demand. The important issue is that companies at all stages in the supply chain have to trust that their customers will provide the realistic through actual consumption patterns. By doing this, the company will become a demand driven company. However, company is required to initiate demand management tool in order to efficiently manage the requested demand. Before starting the effective demand management tool, company is required to improve the following issues:

1. Information: Information through the supply chain is required to operatively share among supply chain. The result of information sharing will help on both demand and supply visibility.
2. Operational efficiency: Operational efficiency is required to be improved. Wide range of production systems is required to consider the enhancements. Operational efficiency often leads to lead time reduction.

3. Lead time: Lead time in every possible process is required to be reduced. JIT, lean management, and order management can assist on lead time reduction.

3.1.7 Material Flow Management

3.1.7.1 Definition of Material Flow Management

Material flow management involves the processes of optimizing the inbound supply network and linking to the design process, and planning as well as managing supplier capacity and schedules. Material flow management is also including the generation of material replenishment schedules as well as the execution of replenishments including transportation and logistics. Material flow is also a crucial factor for success, efficient and competitiveness. Inventory Solutions can help you by optimizing your material flow. The benefits of Material Flow optimization are as follow:

1. Improve Product Quality
2. Reduce Purchasing Costs
3. Reduce Freight / Transportation Cost
4. Reduce Manufacturing Waste
5. Increase Production
6. Improve Customer Satisfaction
7. Reduce Downtime
8. Reduce Product Cost
9. Increase Cash Flow

3.1.7.2 Material Flow modeling method

Modeling of the material flows is the basis of material flow management. The material flow model shows the material flow from the supplier via the own site to the customer. There are four elements to be used in material flow modeling method.

1. Internal quantity centers: internal quantity center where material is transpired. The example of internal quantity centers are such as stores, supply areas, production areas, and production plants, etc.

2. External quantity centers: external quantity center where material is stored or processed. The example of external quantity centers are such as suppliers, sub-contractors, customer, and disposal operators etc.
3. Material flows: material flows normally move from one center to other quantity centers.
4. System Boundary: system boundary need to be identified in order to separate internal quantity center and external quantity center and to determine the investigated planning area.

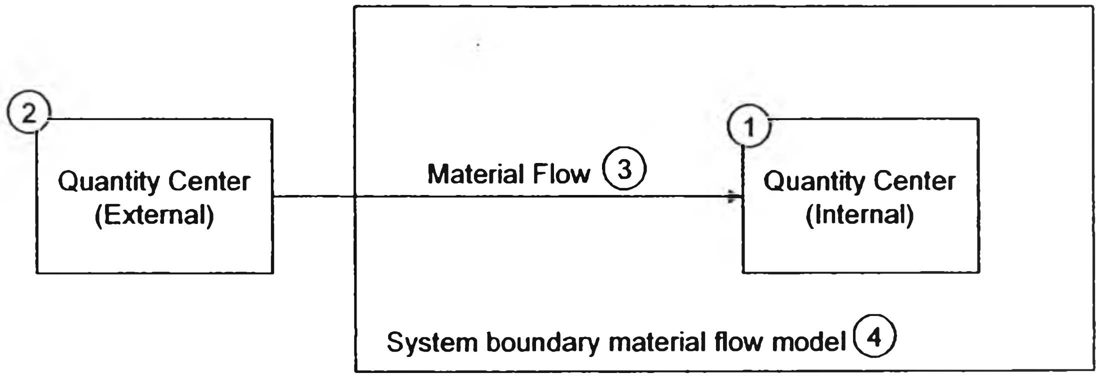

Figure 3.1.7.2 Material Flow modeling

3.1.7.3 Information Flow modeling method

There are six elements to be used in material flow modeling method.

1. Internal Information center: internal Information center is where information is generated, deleted, and stored. The example of internal quantity centers are such as sale, contract acceptance, production planning, procurement, goods receipt, dispatch etc.
2. External Information center: The examples of external information center are such as suppliers, sub-contractors, customers, disposal operators etc.
3. Comments: comments regarding information centers such as information centers naming, tasks, and functions of the information centers.
4. Information Flows: Information flows normally run between two information centers and have the fixed direction.

5. Information Units: Information Units specify and define the information which is contained in the information flows. Information units can, for example, be transmitted from one information center to another in the form of oral communication, writing or electronic data transfer. Typical information units are such as customer inquiry, quotation, contract, order, good receipt note, production order, and delivery notes or documents of transport.
6. System Boundary: system boundary need to be identified in order to separate internal information center and external information center and to determine the investigated planning area.

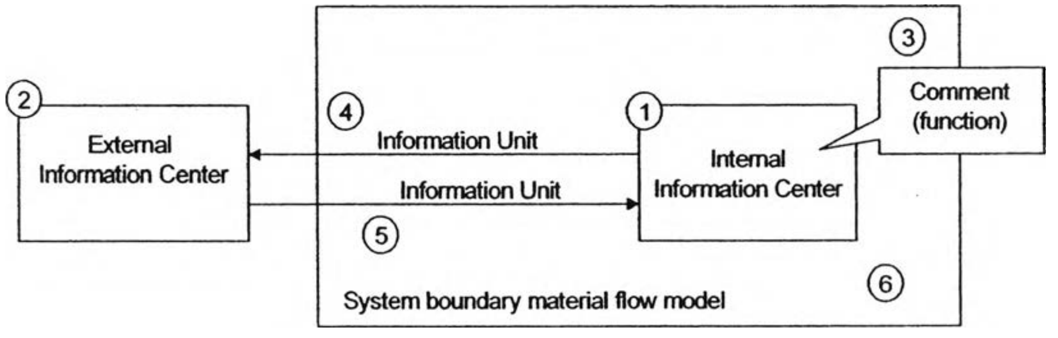

Figure 3.1.7.3 Information Flow modeling

3.1.7.4 Combined material and information Flow model

There is the relation between material flow and information flow. Material flow and information flow can definitely connect to a combined flow model. The measuring points are parts of the information flows as they generate information about material flows.

3.2 Literature Review

(Morton and Pentico, 1993) scheduling is the process of organizing, choosing and timing resource usage to carry out all the activities necessary to produce the desired outputs at the desired times, while satisfying a large number of time and relationship constraint among the activities and the resources.

(Chun-Hsien Li, 2002) this research uses a systematic approach to investigate the advantages and disadvantages of the material management system of a defense research and development organization. Based on the analysis and evaluation, it proposes an improved inventory control and material management policy to reduce inventory level. The proposed policy integrates several systems including procurement management, production control, inventory control, quality control, finance management, and project management. The new policy requests vendors to provide gradual delivery rather than one-time delivery for each order. This leads to a significant reduction of inventory level. This research also suggests data transparency and consistency to facilitate a more effective and efficient planning and integration of materials among different functional departments. A better data base management system is designed accordingly.

(Yeh, 2005) this research concentrates how enterprise improve their competitively, but the most important winning capability under high global competition. How to develop an advanced model of material supply to improve competitively is becoming a very important topic to all enterprise. Enterprise moves forward to worldwide operation following new challenges from globalization. In the future, the competition will not only exist in price, quality, efficiency, and customer service, but the ability of stock control. Behind strategy of price promotion, it is very important that how to support cooperation between vendors through effective supply chain management and come to a win-win situation. Successful supply chain management and strategy enable enterprise meet customer demand with lower cost and more channels. Beside operational service to handle global business, internal processes such as production management, material management and physical distribution are complicated and correspondent. Any errors would bring extra costs and reduce margin. This paper would like to study how a VMI supplier develop optimized operation model through process re-engineering to maintain service level and improve operational performance when facing its only customer's business decline.

(Edgar, 2003) this research focusing on how to design an efficient and effective material supply chain management system for the MH industry, it is necessary to accelerate the flow of information and products across the supply chain. To achieve this goal, the system needs three ingredients: generators of quick information flow, generators of quick material flow, and facilitators of both quick information flow and material flow. This paper proposes a material requirement planning (MRP) system that uses a database approach to manage the large amount of information involved in the material requirement estimation process. The Database has been created using information provided by a manufactured housing facility to demonstrate the benefits that the application of these systems can bring to the MH industry. The MRP database will be supported by a visual basic interface to demonstrate its functionality.

(Barriga, Jeong, Hastak, and Syal, 2003) this research is focusing on advanced techniques for material management in the Manufactured Housing (MH) industry. The current material flow and management systems in use at different MH factories are independent demand systems that are based on personal experience of the material managers. Several years ago independent demand inventory control systems were widely used in many manufacturing industries, but this technique leads to a large amount of inventory at the factories and is slowly becoming obsolete. On the other hand, dependent demand systems reduce inventory levels at the factory using new techniques, such as, supply-chain management and just-in-time supply. They are being successfully applied in manufacturing industries and could also present substantial benefits for the MH industry. This paper applies lean inventory control and supply chain management techniques to the current material flow and management system, and proposes an effective and efficient material supply management system that can be applied at any MH factory.