Chapter 2

Literature Survey

2.1 Concerned Theory

2.1.1 Job Shop Scheduling (Smith (1))

In a **job shop**, work centers and departments are organized by function, such as forging, turning, milling, assembly, or painting. Unlike in a flow shop, each item produced may have different routing. Each work center processes many different items. The job shop may be **open**, that is, it accepts orders from outside customers, or **closed**, meaning that orders are internally generated.

The number of possible schedules for a job shop is very large, and selecting the best by some criterion becomes a computationally difficult problem. Suppose, for example, there were **n** jobs to be processed on **m** machines and each job had one operation on each machine. Then the **n jobs** could be sequenced **n!** different ways on each machine. And the total number of schedules would be $(n!)^m$. For even a very small shop, say, **n** = 10 and **m** = 5, the number of different schedules would exceed six followed by 32 zeros. Some of these schedules would be infeasible because of routing restrictions. Nevertheless, the remaining number of feasible schedules would be extremely large.

2.1.1.1 Priority Rules

Various mathematical models of the job shop scheduling problem have been formulated and theoretically could be solved to provide an optimal schedule. However, in practice most job shop scheduling problems are too large to make this approach computationally feasible. As a result, interest has focused on heuristic approaches and, in particular, **priority rules.** These rules are used to rank job in a queue at a work center to determine the sequence in which they should be run. The priority rule assigns a value to each job in the queue and the job with the lowest value is run next.

2.1.1.2 Order Splitting

Order splitting involves dividing an order in process into two orders, the most common reason for which being that there is an urgent need for some number of units of the item but less than the total quantity on the original order. The quantity urgently needed is split off and sent ahead. Because the quantity is reduced, the lead time on the **send ahead** is reduced by the reduction in running time. Because of its urgency, the send ahead is usually given a high priority and expedited. Another reason for splitting an order is to help resolve a temporary overload situation at a work center. Only the quantity actually needed on the order 's due date is processed and sent ahead, while the remainder is held for later processing.

Regardless, of the reason for order splitting, the decision must be carefully weighed because an additional cost is incurred of one setup for each remaining operation.

2.1.2 Multi-echelon distribution systems (Smith(1))

In **multi-echelon distribution systems**, there are one or more stocking points between the plant and the customer. A company may choose this mode of operation for several reasons. First, by providing an inventory near the customer, the company can provide faster service in filling customer orders. Second, transportation costs may be saved because an efficient rail carload or truckload can be shipped to the branch warehouse and smaller, less efficient shipments made shorter distances from there to customers. Third, whether or not it is actually the case, customers tend to feel more confident that their needs will be satisfied from a nearby warehouse as opposed to dealing with a source several states away.

Branch warehouse stock finished products and service parts, A branch warehouse is frequently called a **distribution center (DC),** and a warehouse that serves a group of satellite warehouses is called a **regional distribution center.**

Figure 2-1 shows a two-echelon distribution system. Goods are manufactured in the factory, stored in the central supply warehouse, and shipped from there to replenish stocks in the central supply warehouse, and shipped from there to replenish stocks in the distribution centers. Customer orders are filled in the distribution centers and shipped from there to the customers.

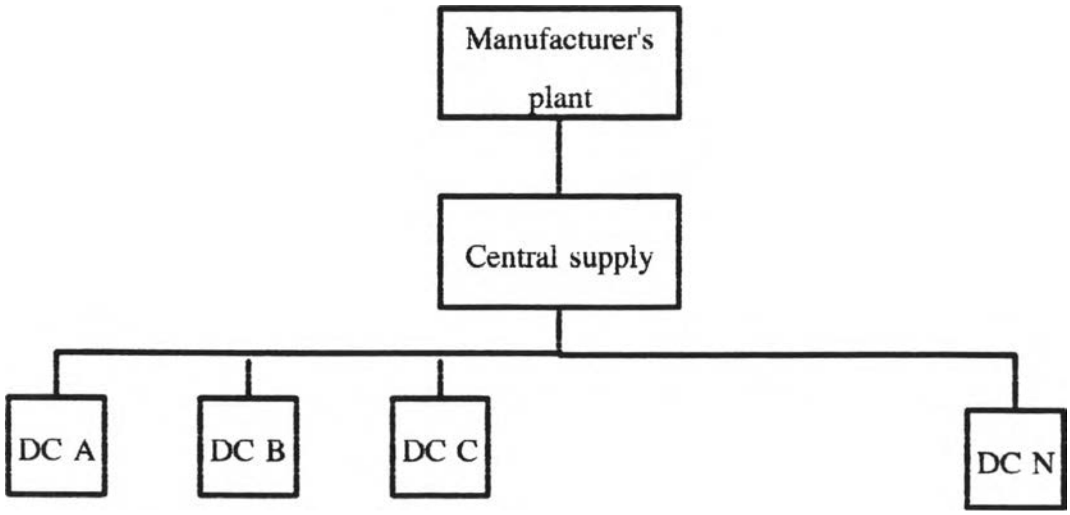

Figure 2-1 : A two-echelon distribution system

2.1.3 Allocation among distribution centers (Smith(1))

In a week when central supply has a number planned shipment of an item to distribution centers(DC), if at least the total quantity required is available, then the planned shipments are made. If, however, the available inventory is less than the sum of planned shipments, a decision must be made as to how to allocate the quantity that is available.

One common approach is to allocate the quantity available among DCs so that the expected time until the inventory reaches zero is the same at each DC. This shipment quantity is called a **Fair Share.** The procedure is as follows:

Let Q = the supply available at central supply

r_i = the forecast per week at DC_i

Q_i = the current inventory position at DC_i

q_i = the shipment quantity to DC_i

Step 1. Calculate the total supply available in the system:

Total system supply = $Q + \sum Q_i$

Step 2. Calculate the number of weeks supply available in the system:

Number of weeks supply = (Total system supply)/$\sum r_i$

Step 3. Calculate tentative shipment quantity to each DC:

q_i = (Number of weeks supply)r_i - Q_i

Step 4. If all the quantities calculated in step 3 are non negative, these are final shipping quantities. If not, remove DCs. with negative tentative shipping quantities from consideration and return to step 1.

2.1.4 Moving Averages (Smith(1))

Suppose it has been determined that the past demand has been horizontal with random variation. Then a simple constant model is given by

$$x_t = a + e_t$$

when x_t = demand in period t

a = constant

e = random variation in period t

We will use a caret (^) to indicate an estimate or forecast. Let $\hat{x}_t(T)$ = forecast of x_T made at the end of period t and $\hat{a}_t$ = estimate of a made at the end of period t. The forecast for any period in the future will be

$$\hat{x}_t(T) = \hat{a}_t, \qquad T = t+1, t+2, \ldots\ldots\ldots\ldots$$

We still have to estimate a. One method of doing this is by using a moving average. A **moving average** is an arithmetic average of the last **N** observations and is updated each period by eliminating the oldest observation in the average and introducing the current observation.

Let M_t = moving average calculated at the end of period t. Then

$$M_t = (x_t + x_{t-1} + \dots\dots\dots + x_{t-N+1}) / N$$

Another way of calculating M_t would be to take the old moving average plus one-N th of the new observation minus the old observation:

$$M_t = M_{t-1} + (x_t + x_{t-N}) / N$$

2.1.5 Measurement of Forecast Errors (Smith(1))

By its nature, forecasting involves errors. Only very rarely will demand be exactly equal to the forecast. Almost always there will be an error-a small, medium, or large deviation above or below the forecast.

In order to be able to make production scheduling and inventory decisions, it is necessary to be able to determine the probability that demand will exceed a certain figure or the expected number of units short if a certain level of inventory is provided. In order to make these calculations, it is necessary to have a measure of the size of the forecast errors. This measure is as important as the forecast itself. A forecast should always be accompanied by measure of forecast error.

2.1.5.1 Standard Deviation (1)

An error in period **t** will be designated by $\mathbf{e_t}$ and will be defined as the actual demand minus the forecast.

$$e_t = x_t - \hat{x}_t \qquad ; t = 1, 2, 3, 4, \dots\dots$$

A measure of forecasting error is provided by the **standard deviation.** Standard deviation is estimated by:

$$\sigma = \sqrt{\sum_{i=1}^{N} e_t^2 / N}$$

where N = Number of forecasts.

2.1.6 Economic Order Quantity (EOQ) (Stevenson(2))

Economic Order Quantity (EOQ) model identifies the optimal quantity in terms of minimizing the sum of annual costs of holding inventory and the annual costs of ordering inventory. This model involves a number of assumptions, some of which may appear to be idealistic. They are lists as follows:

1. There is only one product involved.
2. Annual usage (demand) requirements are known.
3. Usage is spread evenly throughout the year as that the usage rate is reasonably constant.
4. Lead time does not vary.
5. Each order is received in a single delivery.
6. There are no quantity discounts.

An expression for the optimal order quantity can be determined by the following equation.

$$Q_o = \sqrt{(2DS)/H}$$

where Q_o = Optimal order quantity

D = Demand, in units per year

S = Ordering cost, in dollars

H = Carrying cost, in dollars per unit per year

Carrying costs are sometimes stated as percentage of the purchase price of an item rather as a dollar amount per unit. However, as long as the percentage is converted into a dollar amount, the EOQ formula is still appropriate.

2.1.7 Reorder Point (ROP) (Stevenson (2))

EOQ model answers the question of how much to order, but they do not address the question of when to order. The latter is the function of model that identify the **reorder point (ROP)** in terms of a **quantity**: the reorder point occurs when the quantity on hand drops to a pre specified amount. That amount generally includes expected demand during lead time and perhaps an extra cushion of stock, Which serves to reduce the probability of experiencing a stock-out during lead time. There are four determinants of the reorder point quantity:

1. The rate of demand (usually based on a forecast)
2. The length of lead time.
3. The extent of demand and lead time variability.
4. The degree of stock-out risk acceptable to management.

The concerned cases for this thesis is **variable demand rate and variable lead time.** The following symbols are used in the models:

1. $\bar{d}$ = Average demand rate
2. σ_d = Standard deviation of demand rate or forecast error.
3. $\overline{LT}$ = Average lead time
4. σ_{LT} = Standard deviation of lead time.

The model generally assumes that any variability in both demand rate and lead time can be adequately described by a normal distribution. However, this is not a strict requirement- the model provide approximate reorder points even in case where actual distributions depart substantially from normal.

Variable Demand Rates and/or Variable Lead Times

Under normal circumstances, demand rate and/or lead time exhibit some variability. In order to discuss these realistic cases ,two additional concepts must be introduced: **safety stock** and **service level.**

Safety Stock

When there are variations in either the demand rate or the lead time, the possibility of stock-outs must be dealt with. It is no longer known how much stock will be needed to satisfy demand during lead time. Variations in the demand rate can result in temporary surge in demand, which will drain inventory more quickly than expected, and variations in delivery times can lengthen the time a given supply must cover. In order to compensate for uncertainties in either demand rate or lead time. additional stock-out during the lead time interval. This buffer, or **safety stock,** is stock that is held in excess of expected demand. In essence, it is a form of insurance. The stock-out protection is needed only during lead time. If there is a sudden surge at any point the cycle, this will trigger another order, and once that order is received, the danger of an imminent stock-out is negligible.

In general, when variations exist in either usage or lead time the ROP is:

ROP = Expected demand during lead time + Safety stock

Service Level

Because it costs money to hold safety stock, a manager must carefully weigh the cost of carrying safety stock against the reduction in stock-out risk it provides, since the service level increases as the risk of stock-out decreases. Order cycle **service level** can be defined as the probability that demand will not exceed supply during lead time. Hence, a service level of 95 percent implies a probability of 95 percent that demand will not exceed supply during lead time. An equivalent statement is that will be satisfied in 95 percent of such insurance. It does not mean that 95 percent of demand will be satisfied. The risk of a stock-out is the complement of service level; a customer level of 95 percent implies a stock-out risk 0.5 percent. In general.

Service level = 100 - Stock-out risk

The amount of safety stock that is appropriate for a given situation depends on the following factors:

1. The average demand rate and average lead time.
2. Demand and lead time variabilities.
3. The desired service level.

For a given order cycle service level, the greater variability in either demand rate or lead time, the greater the amount of safety stock that will be needed to achieve that service level. achieving an increase in the service level will require increasing the amount of safety stock. Selection of a service level may reflect stock-out costs or it might simply be a policy variable.

Variable Demand Rates and Variable Lead Time

When both the demand rate and the lead time are variable, it seems reasonable that safety stock should be larger than if one of these were constant , in order to compensate for the increased a variability. In this case, expected demand during lead time is average daily demand multiplied by average lead time (in days)

If daily demand is normally distributed and if lead time is also normally distributed, then total demand lead time will be normally distributed with a mean equal to d(LT). Its variance is actually the sum of the variances of demand and lead time, and the standard deviation I the square of that sum:

$$\text{Standard deviation of total demand during lead time} = \sqrt{\sigma^2_{demand} + \sigma^2_{lead\ time}}$$

$$\text{where} \quad \sigma_{demand} = \sqrt{LT}\,\sigma_d$$

$$\sigma_{lead\ time} = \bar{d}\sigma_{LT}$$

Hence,

$$\sigma_{dLT} = \sqrt{(\sqrt{\overline{LT}}\sigma_d)^2 + (\bar{d}\sigma_{LT})^2} = \sqrt{\overline{LT}\sigma^2_d + \bar{d}^2\sigma^2_{LT}}$$

$$ROP = \bar{d}(\overline{LT}) + z\sqrt{\overline{LT}\sigma^2_d + \bar{d}^2\sigma^2_{LT}}$$

Note that every variable under the square root sign is squared except LT.

2.1.8 ABC Analysis (Stevenson (2))

ABC approach involves classifying inventory items according to some measure of importance- usually annual dollar (i.e., dollar value per unit multiplied by annual usage rate)- and then allocating control efforts accordingly. Typically three classes if items are used: A (very important), B (moderately important), C (least important). However, the actual number of categories may vary from organization to organization, depending on the extent to which a firm wants to differentiate control efforts. Generally speaking with three classes of items, A items often account for about 20 percent of the number of items in inventory but about 80 percent of dollar usage. At the other end of the scale, C items might account for about 50 percent of the number of items but only about 5 percent of the dollar usage of an inventory. These percentage vary from firm to firm, but the point is that, in most instances, a relatively small number of items will account for a large share of the value or cost associated with an inventory, and these items should receive a relatively greater share of control efforts. For instance, A items should receive close attention to make sure the customer service levels are attained, through frequent reviews of amounts on hand and control over withdrawals, where possible. The C items should receive only loose control (two-bin system, bulk orders), and the B items should have a control effort that lies between these two extremes.

2.2 Concerned Theses

1. Chatcharin Suwanwatin, 1980 (14)

In this paper it has studied in details about various kinds of cost which incur from these inventory system along with the introduction of the new system that will reduce the operating costs and no shortage is allowed to be used as a working plan for the concerning officers.

2. Orawan Tunsirijareankun, 1980 (15)

The purpose of this study was to find a better clustering of garbage pick-up areas and a better sequence of collection waste from the garbage pick-up point. In this study, we decided to study in Bang Khen District. A heuristic approach was introduced to solve the problem. The objective in solving the problem was to design a route that minimized the total travel distance and satisfy all capacity of vehicle and amount of trip constraints. The procedure had three steps. First, we used a traveling of salesman problem to routing a giant tour. Second, a solid waste collection area was districted. Third, we designed an optimal route of vehicles.

3. Chaiyaphruk Santipanth, 1981 (16)

This research deals with problems concerning the inventory control of the spare parts of P.g.M.'s Engines.

4. Apinan Klawwutinun, 1980 (17)

This thesis presents the result of applying Material Requirements Planing technique in steel furniture manufacturing by introducing computer program in recording information of vendor, inventory transaction order, purchasing order, and single level bill of materials. We can find the quantity on hand more accurate, and calculate gross requirement, net requirement, and planned order release by studying information from bill of materials, stock status, purchasing lead time, ordering cost, holding cost. We also study technique of calculation lot size to purchase in order to calculate demand of various materials as well.

5. Suthee Sripetchdamon, 1992 (18)

This thesis is to propose the study and modeling of the vehicle routing for shipment from a central depot to several customers by utilizing more than a truck. The research starts from the processes of a sample company's shipment, delivery routings, loading preparation, and product shipment, concerned literature's, and finally theory application. Then the model of the distribution requirement is constructed by using the CLARKE-WRIGHT heuristic on micro-computer. The shipment simulation is created on micro-computer to test the model. The comparison between the tested result and the real shipment is made. Most of the results from the model are more satisfactory than the current shipment.