The Lecture Contains:

Application of stochastic processes in areas like manufacturing

Concepts of queueing theory along with the knowledge of stochasticity of order and lead times is extensively used in areas like (i) Inventory Management, (ii) Production Planning and Control (PPC), (iii) Supply Chain Management (SCM) and other such related areas of manufacturing. In the context of this module, a manufacturing system denotes the whole gamut of operations like manufacturing, inventory, supply chain management, etc. We also know it includes other important concepts like scheduling, sequencing, etc., but we would not discuss the applications of stochastic processes in these areas, as it is already a part of our discussion under the module titled ***Application of stochastic processes in areas like scheduling***. Hence this chapter would dwell into the use of stochastic process in inventory management/systems only.

In inventory management/system our aim is to effectively deal with an optimum level of stock of products so that one is able to meet the demand of goods required by the buyer(s) which is/are being supplied by the seller(s). In the real sense, the word inventory denotes the ***on hand*** stock of goods. It is likely that there may be instances when the total requirement of goods, is not met by the seller(s)/manufacturer(s) which results in shortage. These shortages are termed as ***back orders*** if the buyer(s) is/are willing to wait, else they are termed as ***lost sales***, whereby the buyer(s) is/are not interested to wait for late delivery of the same after the agreed upon date of delivery as decide in the contract.

The quantum of goods which is the sum of ***inventory at hand*** plus the ***goods in order*** minus the ***back-order*** is known as ***system stock***. For the convenience of the reader the schematic diagram of the flow of goods from manufacturer/supplier end to the customer's end is depicted in Figure 9.1. With respect to the figure it should be remembered that by using the word supplier and buyer we imply any two players in the system, and there may be instances where it may denote the manufacturer and distributor or the distributor and the retailer or even the distributor and the customer as the case may be.

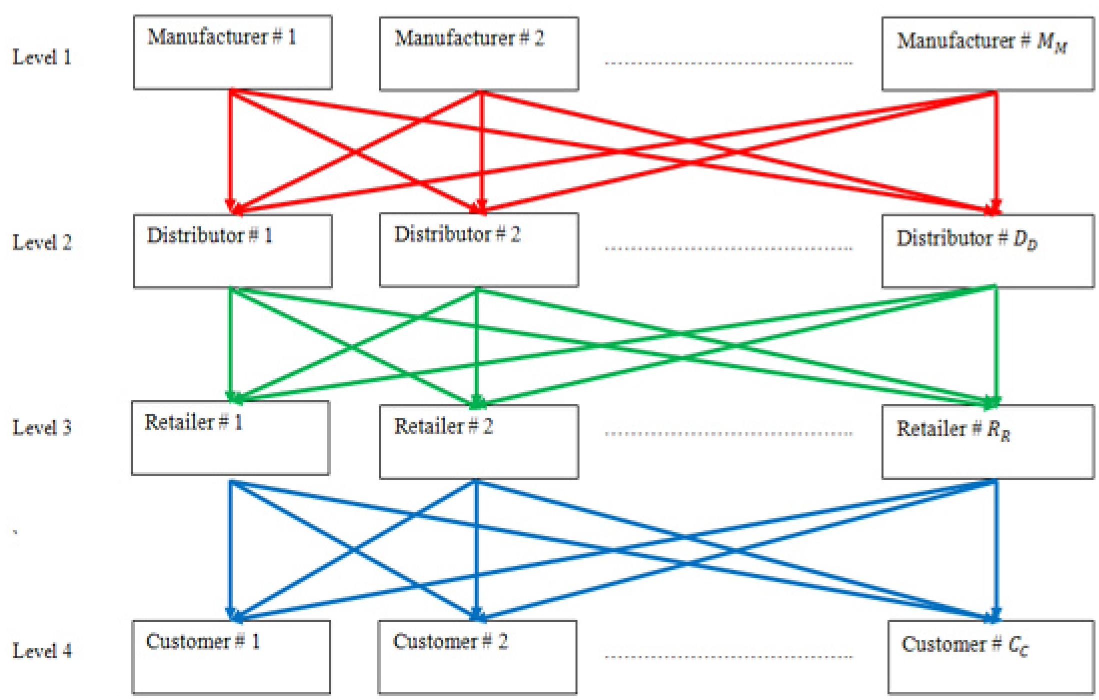

Figure 9.1: Schematic layout of the typical Supply Chain involving different

levels (echelons)

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On should remember that the supplier(s) may plan to place an order on a regular/fixed interval or random interval of time for additional replenishment of stock on hand. Added to that there is one other important concept known as lead time, , which denotes the time taken for the goods to be delivered from the time they have been ordered. The next important set of facts which are impotant for the reader to understand are the different variables which effect the inventory system, different decision making functions which are important while planning the inventory system, different metrics which are used for analyzing the manufacturing/inventory/supply chain system, etc. Hence before discussing the mathematical models let us highlight the important points which are essemtial for an in-depth understanding of the inventory system one has at hand and they are :

Product(s)/Good(s) to be produced : We consider goods being manufactured may be similar or of different varities. Moreover products can be complementary or supplementary such that the production schedule or the plan of production for different goods can be planned accordingly. On the other extreme the production schedules can be totally different for dissimilar products and goods.

Decision variables : These may include the amount to be produced/ordered and in general is a function of the current inventory position. Other factors affecting or factors which must be taken into consideration when deciding this important decision variables are pricing, sequencing and scheduling of jobs, sequencing of delivery dates, inspection schedule, policies for inspection, capacity of production, specific set-up requirements, quality standards to be maintained for the goods being manufactured, wages and costs being incurred for manufacturing the goods, machine run time and time of production, maintenance schedule, etc.

Structure of decision problem : In general the objective to be optimized can be a single valued, like cost or may be multi-valued like cost, production quantity, run time of production, etc. The motivation of having the right structure for the decision problem, is to have the optimal order amount being placed at the right time (may be discrete or continuous) so that the inventory level may be reviewed optimally.

Demand : In general the demand (which can be discrete or continuous) of goods which is placed by the buyer on to the supplier may be based on trends of past demand. Forecasting methodologies are used to understand these trends. Else, it may be based on some thumb rule for which no scientific rationale may exist. In general it is seen that the demand of one period is dependent on the demand of previous time periods. Moreover demand of one product may be inter related to the demand of other existing produced which are being supplied along with the first product, Hence the forecasting techniques which are to be used should be sophisticated enough to capture these intricacies to the maximum possible extent.

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Ordering/Production Cost : The ordering and production costs may just be the function of the order quantity and in general includes set up cost along with production cost (which may be either increasing or decreasing). Depending on the mathematical property of the cost of production this cost function may be convex/concave or more general in nature. One should note that the set up cost may include some sort of opportunity cost also, where this opportunity cost may be exogenous or dictated by other external variable function in the model (i.e., it is endogenous). The ordering cost can also include cost to change the level of production and hence becomes a function which is no longer dependent on order quantity only.

Holding : Holding costs includes costs such as physical holding costs, financial holding costs, etc. These costs in general account for the opportunity cost of capital which is blocked for holding an inventory. Depending on circumstances pilferage, obsolence, spoilage, defects, etc., may also be considered under the concept of holding cost.

Shortages : As described above, shortages costs influences the decision making for production system as well as of the supply chain system. It may also be possible that future demands may be affected by shortages and hence effective planning and strategies would be required while designing a production system or a supply chain management network such that the effects of shortages are minimized.

Supply : Supply of goods can be deterministic or stochastic. Apart from that we may have a supply which varies with time but is predictable. The quantum of goods to be supplied depends on many factors, amongst which demand of goods required may be considered as significant. Other important factors which effects demand are ordering policies of other products in case order is being made to a production facility which manufacturer different products, value of lead time of orders, variability in production and the factors affecting the same, etc. Furthermore the actual quantum of goods which is delivered may differ from the quantum of order or supply made as there may be pilferage, wastage, quality deterioration, etc.

Physical System : By the word physical system we mean the facilities which are used for the production and manufacturing. Depending on the location of the facilities one can have series, parallel or arborescence types of facilities. In case one has different products in the production process, and if all or some of the products use same or similar types of facilities like machines, etc., then planning for the physical system for an efficient production set-up becomes very important.

Information Structure : By the word information structure we mean the sytem in place through which we collect the data, collate it, process the same and then utilize it for use in the production system. This information system should be designed keeping in mind whether we have a continuous or a periodic review system. Information related to demand of the product, its production or transportation costs, etc., all can be gathered from the information system if designed properly.

Resource usage : Apart from raw materials, labour, etc., there may be other resources which are used for the prodution and manufacturing process. Few examples are electricity, transportation, grinding tools, coolant, etc. Hence the aim is to use all these resources judiciously so that wastages are minimized while at the same time the objective(s) of the production/manufacturing process is/are met as per the desired level.

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Economies of scale : The concept of making goods according to economy of scale is relevant when we have set up cost, hodling cost, change over cost, fixed cost, etc. The different costs mentioned would either be fixed or would vary depending on the quantum of production. Hence it would make sense to increase the batch size of production in order to compensate the fixed cost component. In doing so one should also remember that the variable cost component also increases. So a compromise on the total number of goods is made which would result in increasing the revenues and at the same time decrease the input cost, so that the profit is maximized. Economies of scales also make sense when there are discounts, change of technology which increases the rate of production substantially, etc.

Variability : Variability can be either predictable or unpredictable. The concept of variability can be present when one orders good, procures them, tries to do a demand analysis of the quantum of goods required, explores cost of inventory depending on its fluctuation, examines the cost of goods being procured, evaluates the existing demand and supply of the goods in the existing markets, etc. These type of variability effects the planning of the production system and a judicious choice of well thought out plans helps one to achieve the objective at hand.

Conflicting Interests : In making a decision like how many goods to supply, from where to get the goods dependning on quality, how fast to get the products delievered, etc., would always result in different plans which may not be at concurrence with each other. Hence to plan a production system in detail and have a well thought out supply chain mechanism in place would results in many situations where conflicts arise. But the main emphasis of the production planning system should always be to have some concrete objective(s) of the production planning system in mind so that it/they can be met without being bothered about any individual objective, however practical it may be.

Single period model

Assume you have a single period for which you need to order a demand D, where demand $D \sim N(\mu, \sigma^2)$, per unit production cost is c, per unit shortage cost or penalty is c_p, per unit holding cost is c_H, per unit left over stock cost is c_L. Now if y is the stock level after ordering, then, $\Phi(y^*) = \left(\frac{c_p - c}{c_p - c_H}\right)$, where y^* is the optimum stock level. In case one is interested to find the buffer stock, then its value is given by the quantity $(y - \mu)$. If $\left(\frac{c_p - c}{c_p - c_H}\right)$ is the crucial factor, then the optimal objective function value can be written as $c\mu + \{(c + c_H)z + (c + c_H)I_N(z)\}\sigma$, where $z = P_N\left(\frac{c_p - c}{c_p - c_H}\right)$ and I_N is the unit normal loss function. In case we have discontinuous product or distribution function, then $\Phi(y^*) \geq \left(\frac{c_p - c}{c_p - c_H}\right)$. On the other hand if demand distribution is known in its functional form but the parameters are unknown, then one assumes some priors to solve such problems.

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