

**CHAPTER  
4**

# Business Intelligence Applications

**Syllabus Topic : Marketing Models : Relational Marketing**

## 4.1 Relational Marketing

**Q. 4.1.1 Explain Relational marketing and various factor associated with it.**

(Ref. Sec. 4.1)

**(5 Marks)**

- Let's understand relational marketing with example. Most of us have noticed that whenever a mobile company is about to launch a new device into the market a survey is done by the company so that they get different opinions from their customers, which helps them to enhance the functionality provided by that device.
- And it is not only about a mobile phone, when you visit a restaurant waiters get the feedback forms along with the bills wherein the customers have to rate the restaurant in different aspects so that they improvise themselves.
- Almost all the companies study the behaviour and the feedbacks given by the customers and try to inculcate the features that are been required by the customers into their device with a reasonable and effective cost price so that the customers are attracted towards the product and thus sale of the company is increased.
- Most of the e-commerce company store huge database which have collective information about their customers and the data regarding their previous purchases which helps the company to provide options to its customers which are more likely to be liked by the customers again resulting in growth in the sales of the customers.
- The strategy that is been followed in relational marketing is to start, strengthen, objectify and maintain the relationship between the customers, stakeholders and the company, which is been presented by the customers, analysis is done, planning is done accordingly, executed and evaluated to achieve the objectives.



Relational Marketing evolved and became popular in late 1990s to increase customer's satisfaction so that the competitive advantage is achieved.

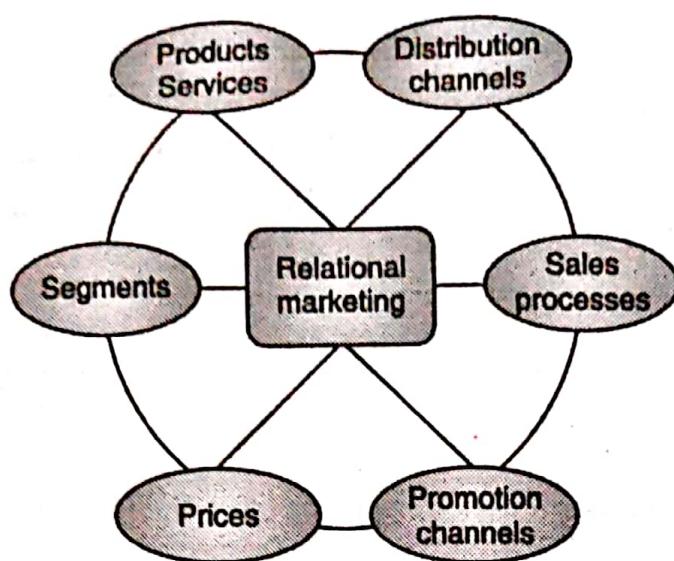
Initially this approach was initiated by companies providing financial and telecommunication services and later on implemented by almost all the companies wherein they are more concern about what the customer actually needs and accordingly implement the same into their respective products so as to sustain the competitive market.

#### 4.1.1 Motivations and Objectives

Reasons to spread relational marketing are complex but interconnected which are listed below :

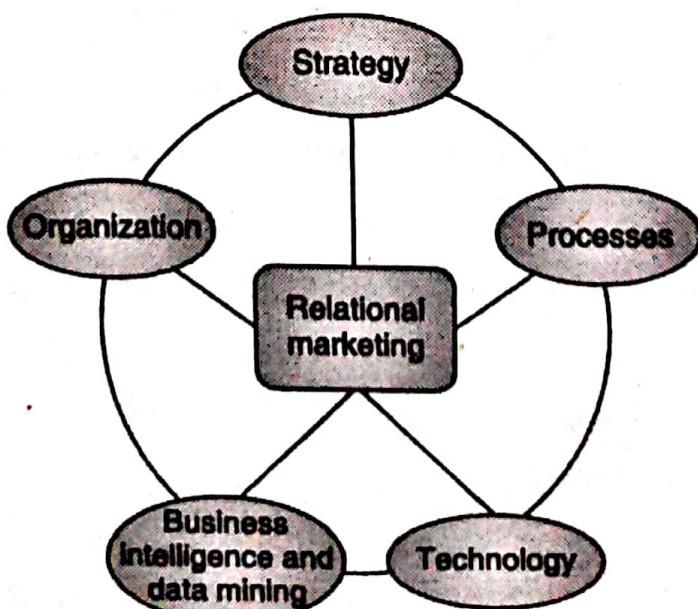
- With evolution of companies in the respective fields, the number of customers has also increased comparatively.
- Earlier it was innovation-production and obsolescence cycle which was eventually compressed from 1980s which happened to boost customized business intelligence options for customers.
- Increase transparency and flow of data an also addition of e-commerce sites lead to global comparisons between different features, prices and also reviews from the customers who have used that particular product.
- Due to increased competitors in the market, it is very uncertain whether the customer will renew the existing service or opt a new one because the facilities to change the services have become much easier and convenient to use.
- Most of the companies have maintain different levels/versions of the products and services provided by them so that the customer has got the flexibility of choosing the services according to its requirement and also switch between the services as and when required.
- Data is gathered of the transactions and products and services that are been used by the customers so that the company has huge range of data to analyze what is expected next by the customers, advanced automation techniques are used to analyze this data so that accurate observation is achieved.

- Strategies of relational marketing rotate around the following choices :



**Fig. 4.1.1(a) : Decision-making options for a relational marketing strategy**

- Above mentioned are the choices through which the strategies for relational marketing can be constructed and implemented.
- Product services are the services that can be provided by the company for the maintenance of the product post purchase.
- Various distribution channels can be constructed to make the product available for the customers, like nowadays the companies are not sourly depended on traditional approach where the product is distributed to various shops from where the customers would purchase the same instead the products are been distributed to e commerce sites and sales with attractive offers due to which customers get wide range of options to purchase the product.



**Fig. 4.1.1(b) : Components of a relational marketing strategy**

- Segments and prices of the product is also maintained to compete in the market. Different creative promotions are done to attract the customers and make them aware about the specification of the product.
- Above mentioned are the different components that are been used in relational marketing strategy where in the organization, its technologies, business strategies and its data mining, process implemented to construct and promote the product together help in achieving efficient and strong relationship among its customers and also the company.
- Fig. 4.1.1(c) represent the different people involved in relational marketing strategy where all the nodes are interconnected to each other.

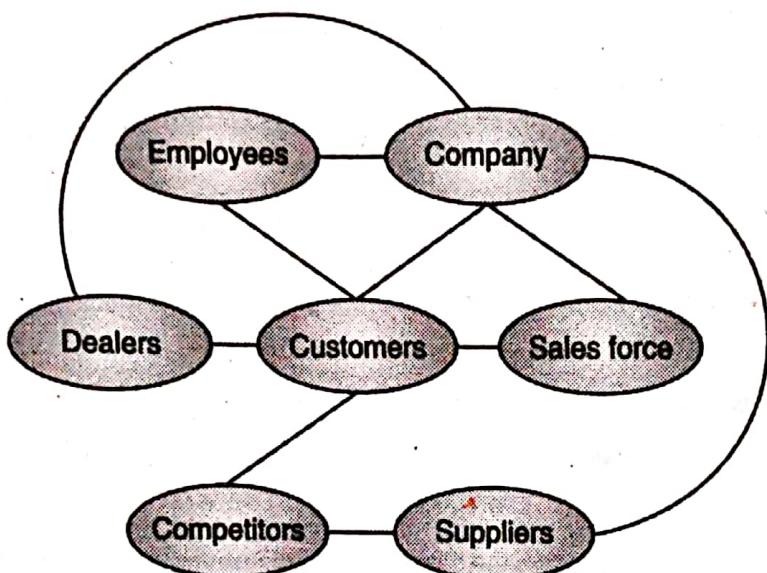


Fig. 4.1.1 (c) : Network of relationships involved in a relational marketing strategy

#### 4.1.2 An Environment for Relational Marketing Analysis

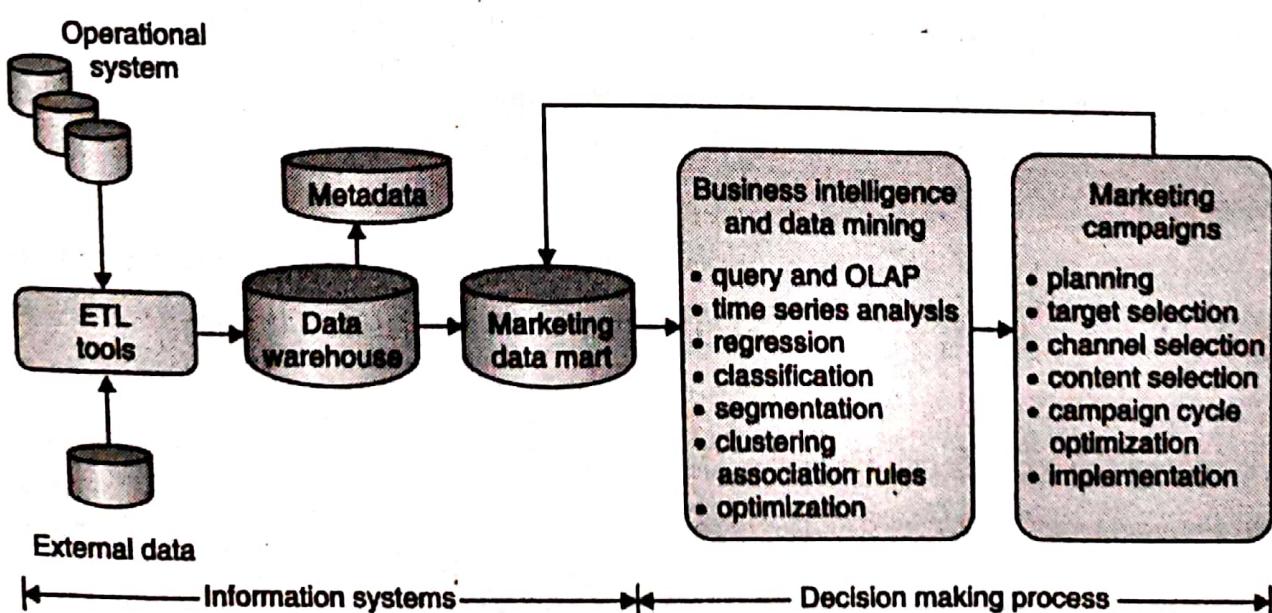


Fig. 4.1.2(a) : Components of an environment for relational marketing analysis

- Fig. 4.1.2(a) shows the main elements that are been used to create an environment for relational marketing analysis.
- Information infrastructures consist of the company's data warehouse, which is been achieved by collecting data from different internal and external data sources, and also from marketing data mart which gives business intelligence and data mining analyses for understanding the potential of the company and identifying the actual customers that the company has.
- With different machine learning and pattern recognition models it is easy to achieve various sections of customer base which can be later on used to define and design policies for marketing actions.
- Classification model can also be generated to classify different objectives of the company say as for example the classification model can be made to check what the customer is frequently buying from the offers been provided by the company and project the similar kind of offer to only those customers where the possibility of their acceptance to the model is more.
- Managing marketing campaign is a difficult task which needs strong planning for every type of customer, what would be the actions taken and communication channels through which the customer can communicate with the company and how can the available resources both human and finance is been used.
- This decision making process can be managed and formally expressed with the help of optimization models. The end phase of marketing activity cycle is execution of the campaign that is been planned with appropriate gathering of results.
- The data that is been collected through this results is then put into marketing data mart for future data mining analysis.
- Whenever a campaign is been executed it is important to set procedures which will help to control the campaign and also analyze the data which is been obtained in the form of result.
- To test how effective the campaign has been it is important to restrict the campaign to selected set of people which will have same features as of the people who would be using that product without taking any action against them.

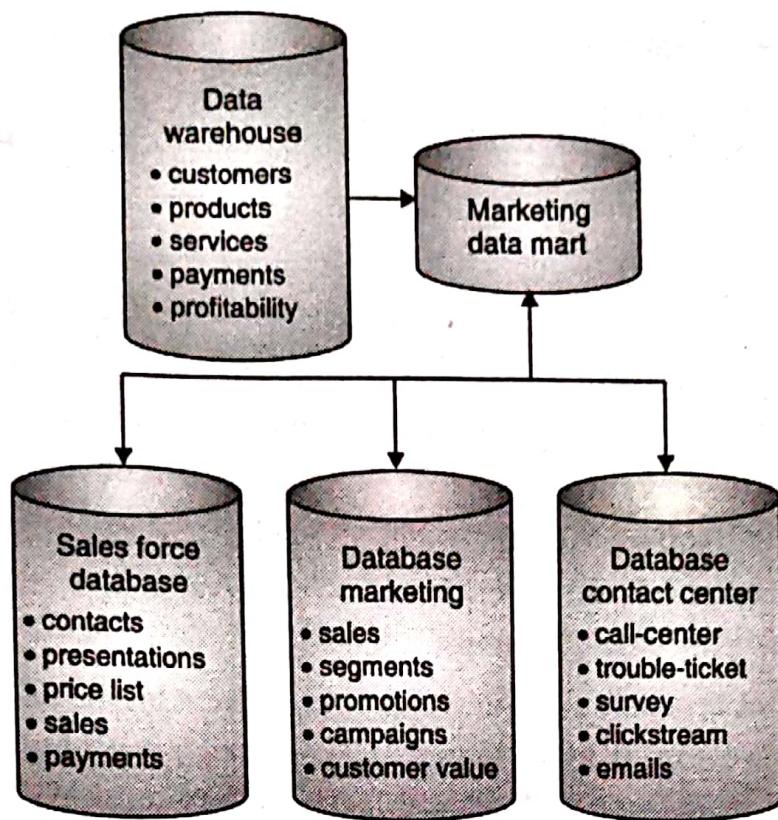


Fig. 4.1.2(b) : Types of data feeding a data mart for relational marketing analysis

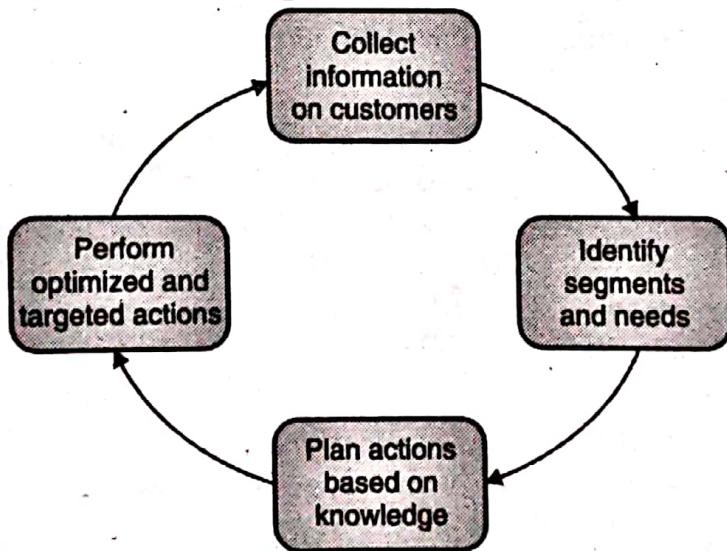


Fig. 4.1.2(c) : Cycle of relational marketing analysis

#### 4.1.3 Lifetime Value

- Following are the main stages of customer lifetime which show cumulative value of customer throughout the time.
- It also shows the different actions that can be taken for a customer by any company. In the starting phase any individual is a prospect or also known as potential customer who has not yet started purchasing the product or using the services provided by the company.

- For these customers acquisition actions are been carried out in both directly and indirectly fashion.
- In direct acquisition the customer is been given information about the product or service via calls, emails, oral talks with the agents of the company and so on.
- In indirect acquisition advertising and information about the product is displayed on the dashboard of the company's website highlighting the new products or services.
- This actions includes cost which will be assigned to the customers and then calculate the loss as all the customers that are been approached would not agree the buy the product or service.
- This event can have different forms in different situations like the service may require subscription of the service, or the customer will only be able to buy the product when he/she opens an account with the company and so on.
- Before the prospect becomes a customer for the company he/she will be getting constant reminders from the company in the form of messages, call, and emails in order to get their customer ship.
- This lead to generation of cost which has an progressive amount and if the prospect is not convinced to buy the product this ultimately puts the company at the loss which is stated to be negative outcome.

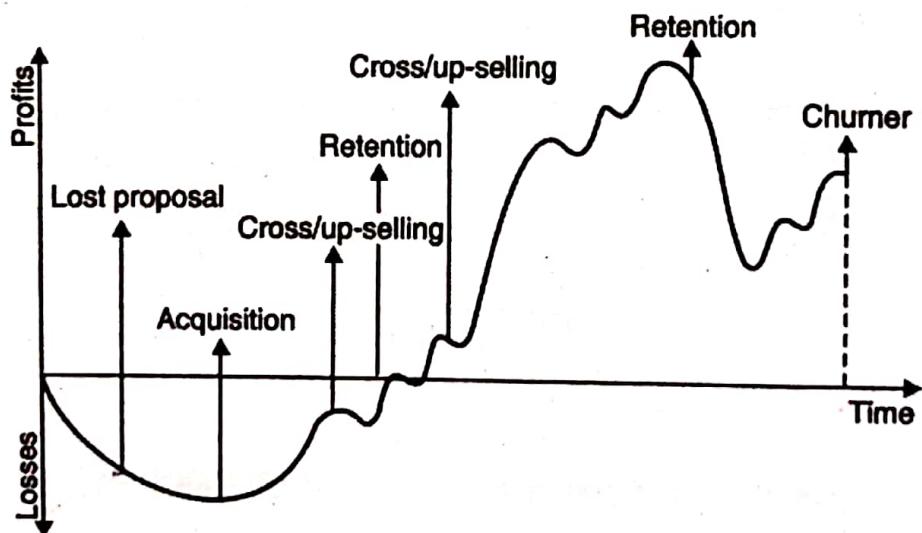


Fig. 4.1.3(a) : Lifetime of a customer

- This phase which is considered to make the relationship between the customer and company strong and also known as maturity phase may also lead to retention, cross selling and up selling to sustain the revenue invested on the customer.
- The last phase is interruption of relationship where the customer calls off the service of the company and moves on to the competitor company due to the inconvenience in terms of payments or various other problems like change in office or residence address.

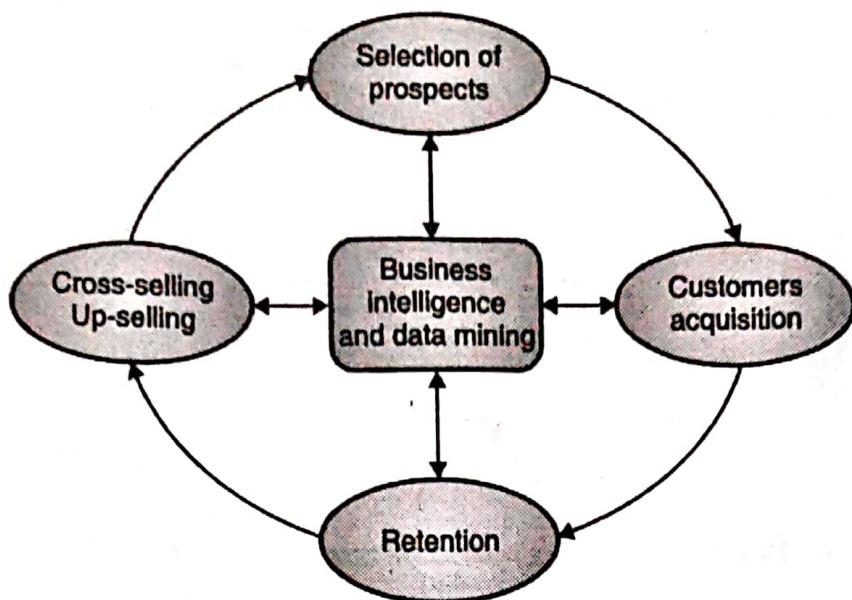


Fig. 4.1.3(b) : Main relational marketing tasks

#### 4.1.4 The Effect of Latency in Predictive Models

- Fig. 4.1.4 illustrates the logic for development of classification model for analysis of relational marketing taking into consideration the temporal dimension. Let's assume  $t$  is the current time period which needs to be derived as inductive learning model of classification problem.
- Say for example at the beginning of month January a mobile provider wants to develop a classification model to find the probability of its customer. The data mart will contain data from past periods which will be updated as  $t-1$ . In our case will have data up to December.
- Imagine the provider wanted to get the probability of future  $h$  months in advance say for supposing next 2 months that is February and March so in that case probability will be generated from the data that you have till December.
- Here you have to note that data for period  $t$  will not be used to predict because the data for period  $t$  will not be clear at starting of period  $t$ .
- To develop classification model the values of target variables are used for last known period as  $t-1$ , which are the customers that were seethed in December month.
- For testing the model the data from  $t-2$  should not be used because that is the training period of the model.

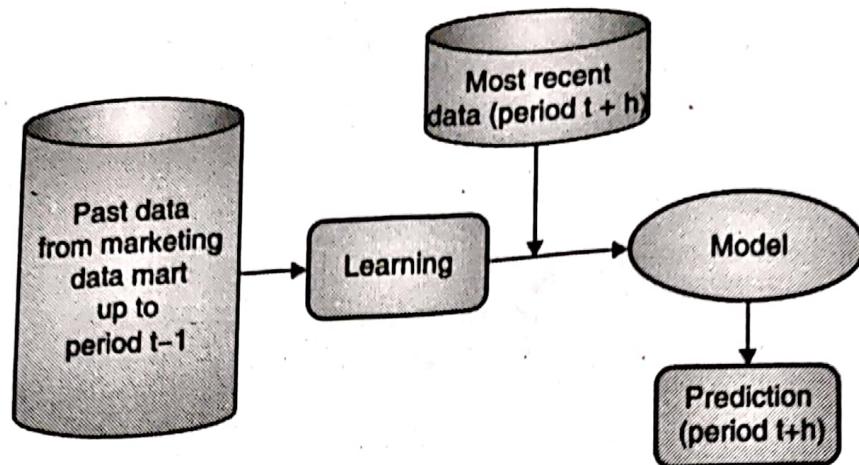


Fig. 4.1.4 : Development and application flow chart for a predictive model

#### 4.1.5 Acquisition

**Q. 4.1.2 Explain the concept of acquisition. (Ref. Sec. 4.1.5)**

**(5 Marks)**

- Even if retention is the important aspect of relational marketing strategies acquisition is also an important factor for some of the companies.
- It is a process which requires identification of new prospects which are said to be potential customers which can be or may be partially or completely unaware about the products or services that are been provided by the company for did not require this products or services in the past and now are in need of one or the might also be customers of the competitors who are hunting for better services or the other case would be that the customer has switched from your company to the competitor.
- Once the company has identified the prospects it is important to assign acquisition campaign with high profitability to both the prospects and the company with various levels marketing strategies along with the marketing resources available with the company.
- Traditional marketing strategies are where the advertising and campaign is based on the earlier pools taken from the public in order to enhance the quality of products and services that are been provided which is been fed into data mart to derive classification rules which provides characteristics for the profiles of acquisition.

#### 4.1.6 Retention

- Due to the reach of maturity stage by most of the products and services and its saturation in market has lead to competition amongst companies.

- Due to this the negative side effect is that the expansion of customer base of company has more of switch mechanism like acquisition of customer at cost of that taken by other company which is common in service industries for saving management, telecommunication and so on.
- Due to this many companies invest more amounts in resources to analyze and characterize the attributes due to which customer's switches from their company to another.
- The other reason could be the attractive offers given by the competitive company to grab the attention of the prospects and thus bring the market strategies of the company down.
- Also there can be various reasons that the customer would not find the charge relevant to pay for the services provided by the company and thus hunt for an alternative one and switch for the same.
- There are various other aspects that would lead to retention of products and services that are been provided by the company and thus the company has to be keen about the same.

#### 4.1.7 Cross-selling and Up-selling

- Data mining models can also contribute to relational marketing analysis which aims to identify different market segments through which most of the possibility for purchasing additional services or products from the company.
- For example assume a mobile shop where there is an offer that if the customer buys a smart phone then she can pay extra Rs. 100 to get annual subscription of Netflix along with smart phone but there is no compulsion that every customer purchasing smart phone would be interested for the subscription and due to this the mobile provider get the classification of customer who are interested and people who are not interested in the offer.
- And if the number of interested customer is more the shop owner will have to get more services from Netflix. This demographic information about the customer can be fed into data mart which can be used as explanatory attributes to develop classification model which will help to develop various offers in forthcoming period and how customer would react to it.
- Cross selling means trying to sell a product or service to the customer who is already active and is in relationship with the company.

- Through classification model the company can understand which all customers are interested in cross selling and approach only those customers.
- For example, we often get calls from our banks asking us to upgrade our debit cards to credit once, now this calls are only been done to the customers holding debit card and not to those holding credit. So this defines a margin for acquisition to call only those customers holding debit card.
- This can also be stated as up selling where the customer is informed and asked to own the product or services which are one level higher than the existing one and will have more features and availability.

#### 4.1.8 Market Basket Analysis

- The main objective of market basket analysis is to get the exact view of what products the customers are purchasing so that the company gets the required knowledge to organize and plan their marketing strategies.
- Usually used to analyze what kind of product is sold more on e commerce sites or retail industries.
- It can also be applied to check the purchases done with help of credit card or landline services or complementary once to check whether the policies taken are been taken by same households.
- Data used here can also be referred as purchase transactions which can be associated with time dimension to track the purchase.

#### 4.1.9 Web Mining

- As it is well known fact that web is the most common and easier way of communication with the maximum of the crowd.
- And most of the companies are using social media platform to promote their products to the people. E commerce sites are considered to be the important sales channels.
- Since web mining is used to analyze data from the activities that are been carried out on those sites by the visitor this web mining methods are mostly used for three purposes content mining, structure mining and usage mining.

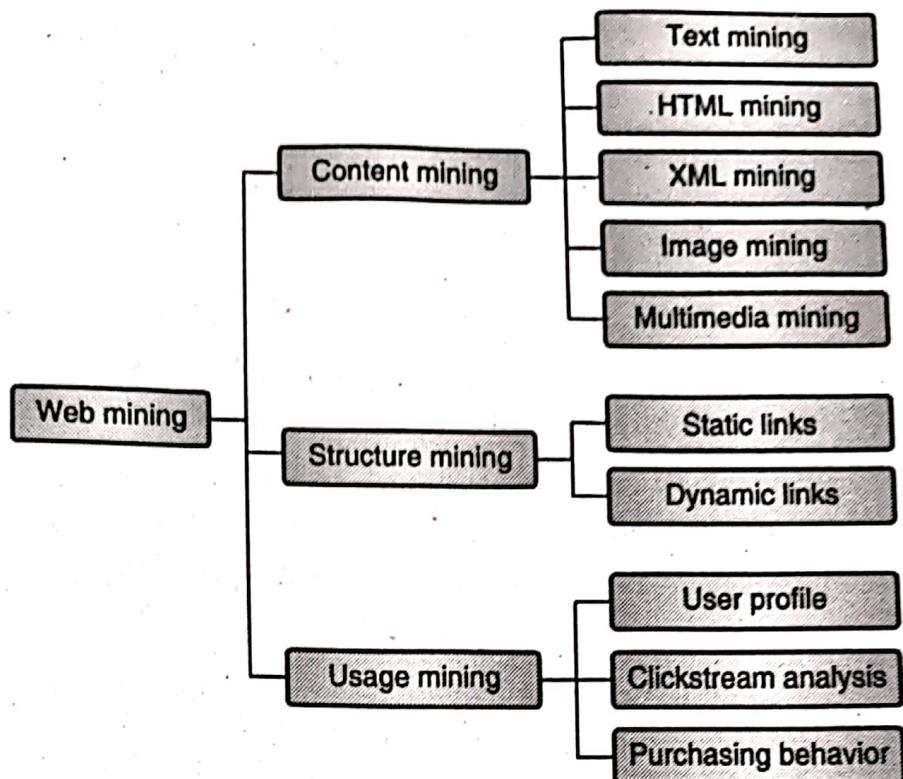


Fig. 4.1.9 : Taxonomy of web mining analyses

→ **1. Content mining**

- It involves analyses of content that is there on the web page to remove required information. Search engines like Google also perform content mining to provide links to data that is been required by the customer.
- It can also be tracked back to data mining problems for analysis of texts present on web page in format of HTML and XML, images and multimedia content.

→ **2. Structure mining**

- This type of mining is used to understand the structure of web using different links on different pages. Graphs can be created where nodes correspond to web pages and arches are going to the nodes that are the link to other page.
- Results and algorithms from graph theory is used to characterize web structure which identifies area of high intensity.

→ **3. Usage mining**

- It aims to certifying most relevant standpoint of relational marketing which explores paths that are been followed by navigators and behaviour during the visit to company's website.
- Methods that are been used for extraction of association rules are used to obtain correlations between different pages visited during session.



## Syllabus Topic : Marketing Models : Sales Force Management

### 4.2 Sales Force Management

**Q. 4.2.1 Explain sales force management and various factor associated with it.**

(Ref. Sec. 4.2)

**(5 Marks)**

- Nowadays almost all the companies have sales department into their organizations and rely on the employees of those department for the sales of product or services that are been offered by the company.
- Every employee is been given a target and depending upon how the targets are been achieved these employees play an important role in the profit that is been gained by the company.
- There are various marketing strategies that are been implemented by the sales department for selling off the product or services.
- The sales forces is a term coined for all the people and roles along with different tasks and responsibilities that are associated with sales as a process.
- The basic terms associated with sales forces based on the activities that are been carried out are stated below:
  - o **Residential** : This sales activities take place at one, or more places which are managed by company supplying products and services from where the customers can purchase, this includes sales at retail shops and wholesale dealers.
  - o **Mobile** : In this type of sales the agents of the company go to the customers house or office to give information about their product or service and also collect the orders. In this category the sale occurs within B2B(Business 2 Business) relationship it can also be encountered in B2C(Business 2 Customer) criteria.
  - o **Telephone** : This sales happens on telephonic conversations where the company agents call up the customers and promote the product and also collect the orders.
- When it comes to mobile sales force there are varies problem with it which can be subdivided into few main categories listed below :
  - o designing the sales network.
  - o planning the agents' activities.
  - o contact management.
  - o sales opportunity management.
  - o customer management.

- activity management.
- order management.
- area and territory management.
- support for the configuration of products and services.
- knowledge management with regard to products and services.
- When a sales network is been designed and when agent's activity are been planned there are requirement of decision making task which will take advantage of optimization model.
- Rest can be managed with help of automation tools also known as Sales Force Automation (SFA) which is nowadays implemented by almost all the companies.

#### 4.2.1 Decision Processes in Sales Force Management

- When it comes to designing and managing sales force various problems related to decision making arises as shown in Fig. 4.2.1. If this problems are successfully overcome then they yield maximum of profit, increases the efficiency of sales action and also sees to efficient use of resources along with professional rewards to the sales agents.
- The process of decision that is shown in the Fig. 4.2.1. It shows that how the strategic objective of the company should be taken into consideration along with different other components of marketing and see to it that the role assigned to sales force have broader framework with respect to relational marketing.

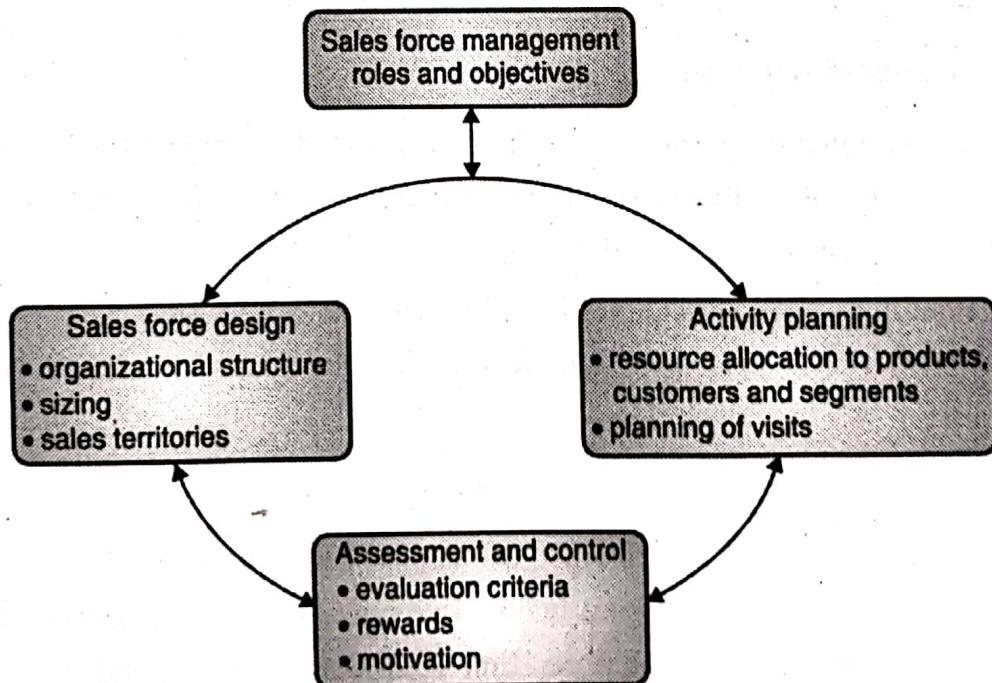


Fig. 4.2.1: Decision processes in sales force management

- The two ways arrow connection means that all the component interact with each other in consideration with marketing.
- The decision-making processes related to sales force management can be grouped into three categories: design, planning and assessment.

#### 4.2.1.1 Design

- It deals with the start phase of any commercial activity or during subsequent restriction phase.
- For example, during the planning of acquisition plans for the prospects or group of companies.
- This phase works in different parts of creation of market segments which is build. Salesforce design includes three types of decisions.

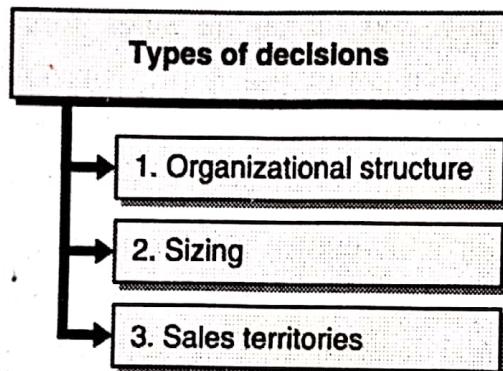


Fig. 4.2.2 : Types of Decisions

##### → 1. Organizational structure

- This structure can take different forms which corresponds to hierarchical cluster of agents with help of group of products, geographical areas or brands, in some cases markets are also been considered to form a cluster.
- For understanding organizational structure it is mandatory to analyze complexity of the customers, products and else activity to decide how can agents be specialized and to what extent.

##### → 2. Sizing

It is the working done on the number of agents that should work within a selected structure of sales which relies on different factors like count of customers and prospects, how much of sales area coverage should be done, time limit for every call and travelling time of every agent.

### → 3. Sales territories

- When it comes to designing sales territory means creating a cluster of geographical areas in a region and assigns that region to a particular agent or group of agent.
- Factors that should be considered while designing and assigning these territories to the agents are the sales potential of every area, time required to travel from one area to another and what time limit a particular agent has.

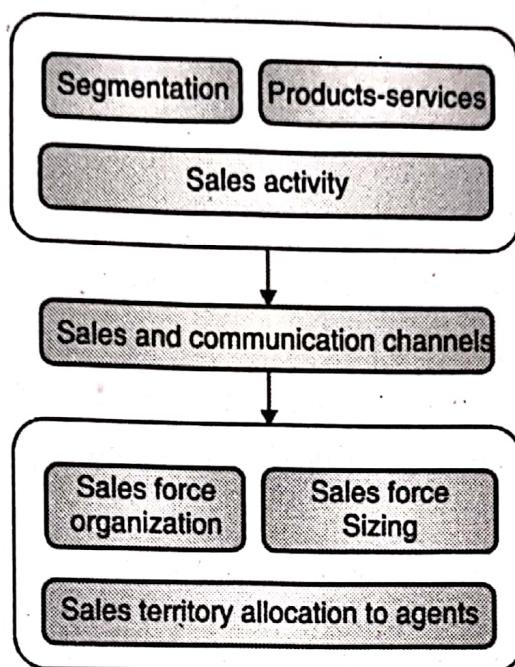


Fig. 4.2.3 : Sales force design process

#### 4.2.1.2 Planning

- Decision making tasks that are associated with planning are assignment of sales resources, structured and sized during the design phase, to market entities.
- Resources can be calculated as work time of the agent and the budget whereas market entities comprises of products, market segments, distribution channels and customers.
- Allocation can be calculated as the time spent on every customer to promote the product or service, time and cost required to travel and how effective the action was to convince the customer for the product.
- Further possibilities can also be considered like explaining the technical and functional features of the product or service and suggestions coming from the customers.

#### 4.2.1.3 Assessment

- Assessment is important to control the activities to check the effectiveness and efficiency of the agents in sales network so that proper remuneration and incentives can be designed for every individual.



- On account to measure effective efficiency of the agent it is very important to announce the criteria on which they would be judged.
- So that the agents give their full contribution towards the sales of the product and services thus increasing the profit of the company as well as their individual profit and also enhance their performance

#### 4.2.2 Models for Sales Force Management

- Following are some classes of optimization models for designing and planning salesforce. Before starting here are some of the notions that would be used in following sections so let's learn about it first.
- Let's assume that a particular region is divided into  $M$  geographical areas of sales, which is also known as sales coverage unit so let  $M = \{1, 2, \dots, M\}$ . Areas should be divided into disjoint clusters known as territories such that each area belongs to only one territory and is also connected to all areas of same territory.
- Time connection property implements that each area it is possible to reach another area of same territory.
- Time span can be divided into  $T$  intervals which are of same length which are usually weeks or months which can be indicated as  $t \in T = \{1, 2, \dots, T\}$ .
- Each territory has a sales agent associated with it which belongs to one area of the territory which is considered to be agent's residence.
- Time and cost of travelling from one area to another depends on the area of residence of the agent. Let  $N$  be number of territories so  $N = \{1, 2, \dots, N\}$ .
- In territories there are customers and prospects which would be visited by the agent to promote their product which will be given as  $H$  in some models it is considered to have various segments and thus they are counted same. So  $h = \{1, 2, \dots, H\}$ .
- And finally assume every agent sells  $K$  products and services during the call so let  $k = \{1, 2, \dots, K\}$ .

#### 4.2.3 Response Functions

- This plays an important role in formulating the models to design and plan sales network.
- In general it defines the flexibility of sales with respect to sales action and a formal way to describe complex relationships between sales actions and market reactions.
- Sales to which response functions refers to are expressed in products units or monetary units known as revenue or margins.
- They are presented as sales revenues formally. The anxiety of sales action can be related to different variables number of calls made to the customer in given period of time, how

many times product was mentioned in given period of time, how much time was given to customer in person during a given period of time.

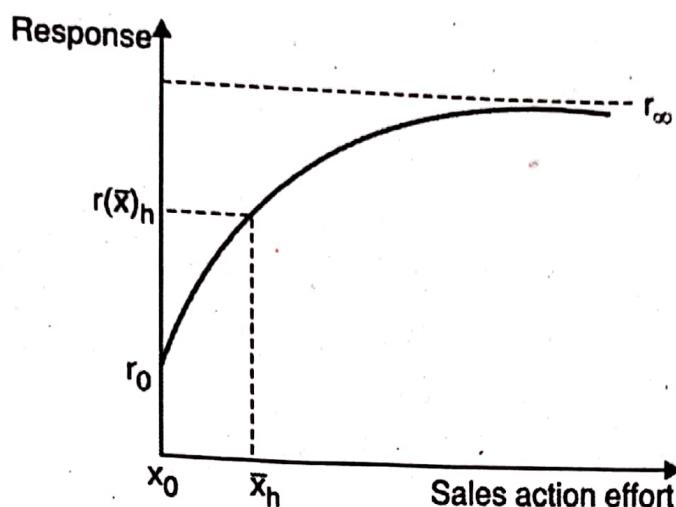


Fig. 4.2.4(a) : A concave response function

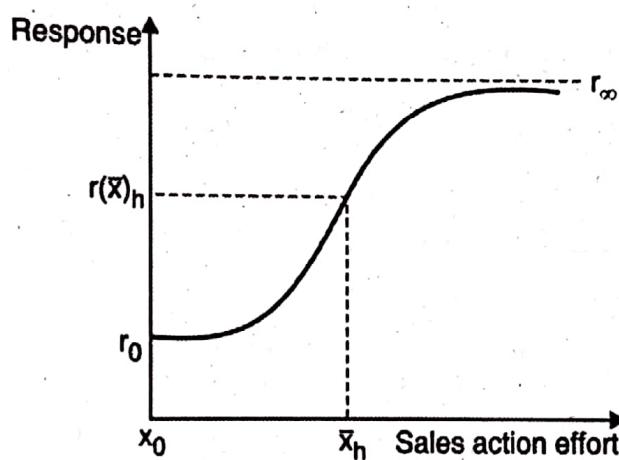


Fig. 4.2.4(b) : A sigmoidal response function

#### 4.2.4 Sales Territory Design

- It involves allocation of sales coverage units to a particular agent to minimize weighted sum of two terms, which represents total distance between the areas of same territory and inequality between the opportunities given to the agents.
- Every region is divided in  $J$  areas which are then combined into  $I$  territories whose number will be already decided. Every territory has an agent which would be associated to sales coverage unit which is considered to be residence of that agent.
- It is imagined that travel times with each area is slandered keeping in mind travel time between a pair of distinct areas.
- Every area will be identified by coordinates  $(e_j, f_j)$  of one of its point. Choose the point whose coordinates are obtained as the average of the coordinates of all points belonging



to that area. For every territory, let  $(e_i, f_i)$  denote the coordinates of the area where the agent associated with the territory resides.

- This area will be called centroid of territory  $i$ . The parameters in the model are as follows:  $d_{ij}$  is the distance between centroid  $i$  and area  $j$ . It is given by,

$$d_{ij} = \sqrt{(e_i - e_j)^2 + (f_i - f_j)^2}$$

- $a_j$  is the opportunity for sales in area  $j$ ; and  $\beta$  is a relative weight factor between total distance and sales imbalance. Consider a set of binary decision variables  $Y_{ij}$  defined as :

$$Y_{ij} = \begin{cases} 1 & \text{if area } j \text{ is assigned to territory } i \\ 0 & \text{otherwise} \end{cases}$$

- Define  $I$  additional continuous variables that express the deviations from the average sales opportunity value for each territory:

- $S_i$  = deviation from the average opportunity value  $\frac{1}{I} \sum_{j \in J} a_j$  for territory  $i$ .

- Hence, the corresponding optimization problem can be formulated as

$$\min \sum_{i \in I} \sum_{j \in J} a_j d_{ij}^2 Y_{ij} + \beta \sum_{i \in I} S_i$$

$$\text{s. to } \sum_{j \in J} a_j Y_{ij} - \frac{1}{I} \sum_{j \in J} a_j \leq S_i, \quad i \in I,$$

$$\sum_{j \in J} a_j Y_{ij} - \frac{1}{I} \sum_{j \in J} a_j \geq -S_i, \quad i \in I,$$

$$\sum_{i \in I} Y_{ij} = 1, \quad j \in J,$$

$$S_i \geq 0, \quad Y_{ij} \in \{0, 1\}, \quad i \in I, j \in J.$$

### **Syllabus Topic : Logistic and Production Models : Supply Chain Optimization**

#### **4.3 Supply Chain Optimization**

##### **Q. 4.3.1 Describe Supply chain optimization. (Ref. Sec. 4.3)**

**(5 Marks)**

- Supply chain can be stated as network of linked and interdependent institutional units which co-ordinates with each other to manage and improve the material quality and information related to material that is been given by the vendor to the customers after all the required process related to the delivery of the product is done.

- The aim and benefit of having an integrated planning and operations been carried out between the supply chain institutes to have systematic objectivity to make decisions and take actions accordingly to maintain the standard of sub programs which would be related to logistic operating of company system.
- Most of the companies involved in manufacturing are implementing such kind of logistic supply chain approach so that the upstream and downstream of the supply chain whereas the problems in the co-operation between the subprograms can also be tracked.
- Also the other advantage of having integrated logistic supply chain will reduce the cost of expenditure which includes cost of processing, cost for transportation and distribution. Also the inventory and equipment cost are been included and reduced in integrated supply chain.
- It is equally important to upgrade logistic supply chain by adding models and automated tools which would help in planning and analyzing the capacity in critical situations where the complexity is high in the logistic supply chain which is made to function.
- In most dynamic situations where the competition is much more high as the competitor company would also have all its efforts put into their supply chain to make it more effective.
- Competitor companies can be the companies which are production wide range of products and so these companies will require multi centric logistic supply chain which would effectively look into distribution of the products according to the demands of the customers.
- This multi centric logistic supply chains need to be widely spread with most of the automation which makes the work simpler and also these chains have large amount of financial investment done so as to automate and make the chains more effective.
- The effectiveness and features that are associated with logistic supply chain is directly proportional to the profile that the company maintains to communicate with the customers.

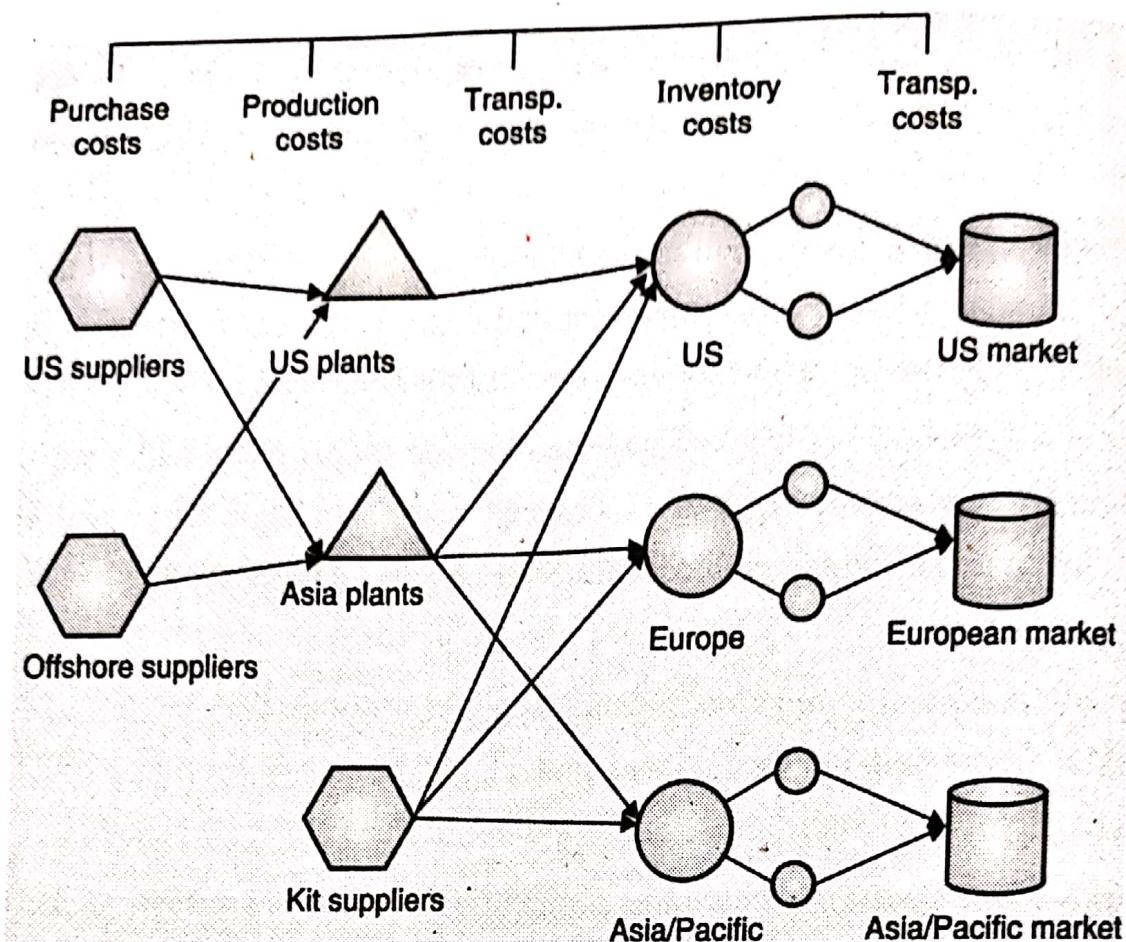


Fig. 4.3.1: An example of global supply chain

**Syllabus Topic : Logistic and Production Models : Optimization Models for Logistics Planning**

#### 4.4 Optimization Models for Logistics Planning

**Q. 4.4.1 Explain optimization logistics planning in Logistic and production models.**

(Ref. Sec. 4.4)

**(5 Marks)**

- Following are some of the optimization models which are associated with the features of logistic supply chain and logistic production systems.
- While learning about this models one should understand that real world logistic production systems have more than one element that are been considered so it would be more complex and it will have combination of different features of different elements.
- Before starting with detailed study of the models some notations that are usually used by these models should be known.



- In logistic systems I is products denoted by index  $i \in I = \{1, 2, \dots, I\}$ . Also the planning horizon is been further divided into time intervals T denoted as  $t \in T = \{1, 2, \dots, T\}$  which is usually of equal length with duration of weeks or months.
- The manufacturing company have some set of critical resources that are been shared among the companies during the manufacturing process and are also available in limited quantity.
- These resources may contain manpower, tools, assembly lines, specific fixtures and so on. These critical resources are denoted by R and given as  $r \in R = \{1, 2, \dots, R\}$ .
- When even a single critical resource is applicable to the manufacturing process the index value of r is completely omitted to maintain simplicity.

#### 4.4.1 Tactical Planning

- It is the first form where the main objective of planning is to regulate the amount of production for every product over T time period which includes midterm planning horizon as well which should also satisfy given demand and capacity limits for each and every resource that is been used in manufacturing process and which also keeps the cost to minimal which will sum up manufacturing and inventory costs.
- Hence decision variables like :
  - o  $P_{it}$  are products i which will be manufactured over t period of time.
  - o  $I_{it}$  are products I which is in inventory at end period of time t.
  - o  $d_{it}$  is the product demand I over t period of time.
  - o  $c_{it}$  is unit manufacturing cost for I product in t period of time.
  - o  $h_{it}$  is inventory cost for product I in t period of time.
  - o  $e_i$  is capacity absorption to manufacture a particular unit
  - o  $b_t$  is capacity available in period t.
- So the problem is formulated as follows :

$$\begin{aligned}
 \min \quad & \sum_{i \in I} \sum_{t \in T} (c_{it} P_{it} + h_{it} I_{it}) \\
 \text{s.to} \quad & P_{it} + I_{i,t-1} - I_{it} = d_{it}, \quad i \in I, t \in T, \\
 & \sum_{i \in I} e_i P_{it} \leq b_t, \quad t \in T, \\
 & P_{it}, I_{it} \geq 0, \quad i \in I, t \in T.
 \end{aligned}$$



#### 4.4.2 Extra Capacity

- The first model deals with resorting extra capacity with respect to over time, part time or third party capacity.
- The decision variables in first model are also considered here with addition of few more variables listed below.
- $O_t$  is extra capacity which is occupied in period  $t$ .
- And parameter like,  $q_t$  is unit cost of extra capacity in for  $t$  period.
- So the formula now becomes

$$\text{min } \sum_{i \in I} \sum_{t \in T} (c_{it} P_{it} + h_{it} I_{it}) + \sum_{t \in T} q_t O_t$$

$$\text{s.to } P_{it} + I_{i,t-1} - I_{it} = d_{it}, \quad i \in I, \quad t \in T,$$

$$\sum_{i \in I} e_i P_{it} \leq b_t + O_t, \quad t \in T,$$

$$P_{it}, I_{it}, O_t \geq 0, \quad i \in I, \quad t \in T.$$

#### 4.4.3 Multiple Resources

If the critical resources are to be included in the manufacturing process the formula will have few more parameters included and the decision variables required are already been included.

Additional parameters are listed below:

- $b_r$  is quantity of resource  $r$  available in  $t$  period of time.
- $e_{ir}$  is quantity of resource  $r$  absorbed to manufacture one unit of product  $i$ .
- So the formula is given as :

$$\text{min } \sum_{i \in I} \sum_{t \in T} (c_{it} P_{it} + h_{it} I_{it})$$

$$\text{s.to } P_{it} + I_{i,t-1} - I_{it} = d_{it}, \quad i \in I, \quad t \in T,$$

$$\sum_{i \in I} e_{ir} P_{it} \leq b_r, \quad r \in R, \quad t \in T,$$

$$P_{it}, I_{it} \geq 0, \quad i \in I, \quad t \in T.$$

#### 4.4.4 Backlogging

- This is an additional feature that is to be considered in logistic systems. Term backlog refers to possibility that a portion of demand is to be given in certain period of time and it

could not be completed so there is a penalty cost that is been involved and the work that was left after the time completion is said to be backlogged.

Backlog is a feature that usually happens in B2B industries which produce mass consumer goods, which is most likely to develop different variants in backlog which can be referred as lost sales which cannot be fulfilled and so the there is a subsequent lost.

This model is important to add new decision variables like  $B_{it}$  is units of demand for product  $i$  that are been delayed in period  $t$ .

And parameters  $g_{it}$  is unit cost of delaying the demand for product  $i$  over period of time.

So the formula becomes :

$$\min \sum_{i \in I} \sum_{t \in T} (c_u P_u + h_u I_u + g_{it} B_{it})$$

$$\text{s.to } P_{it} + I_{i,t-1} - I_{it} + B_{it} - B_i, t-1 = d_{it}, \quad i \in I, t \in T,$$

$$\sum_{i \in I} e_i P_{it} \leq b_v, \quad t \in T,$$

$$P_{it}, I_{it}, B_{it} \geq 0, \quad i \in I, t \in T.$$

#### 4.4.5 Minimum Lots and Fixed Costs

- More additional features needs to be added in manufacturing systems which are to be presented in minimum conditions which would be for technical and economy reasons only, sometimes the conditions are like the production values should be equal to 0 for one or more products or less than the threshold value that is been in minimum lot.
- To include these conditions in model binary decision variables listed below need to be included.

$$Y_{it} = \begin{cases} 1 & \text{if } P_{it} > 0 \\ 0 & \text{otherwise,} \end{cases}$$

- Also the parameters liked.
- $l_i$  which is minimum lot for product  $i$ .
- $\gamma$  is constant value larger than any producible volume for  $i$ .
- So the formula becomes :

$$\min \sum_{i \in I} \sum_{t \in T} (c_{it} P_{it} + h_{it} I_{it})$$

$$\text{s.to } P_{it} + I_{i,t-1} - I_{it} = d_{it}, \quad i \in I, t \in T,$$

$$\sum_{i \in I} e_i P_{it} \leq b_v, \quad t \in T,$$

$$\begin{aligned}
 P_{it} &\geq l_i Y_{it}, & i \in I, t \in T, \\
 P_{it} &\leq \gamma Y_{it}, & i \in I, t \in T, \\
 P_{it}, l_{it} &\geq 0, Y_{it} \in \{0, 1\}, & i \in I, t \in T.
 \end{aligned}$$

#### 4.4.6 Bill of Materials

- One more feature that can be added in planning model is bill of materials which is associated with complex structure.
- In which end product that is been made will have various components that are been used to build up the end product.
- Parameters that define the format of bill of materials are :
- $A_{ij}$  which is units of product  $i$  directly required by one unit of product  $j$ , in which term product refers to end product and associated components required which define different levels of bill of materials.
- So the formula becomes :

$$\begin{aligned}
 \text{min} \quad & \sum_{i \in T} \sum_{i \in I} (c_{it} P_{it} + h_{it} l_{it}) \\
 \text{s.to} \quad & P_{it} + l_{i,t-1} - l_{it} = d_{it} + \sum_{i \in I, j \neq i} a_{ij} P_{jt}, \quad i \in I, t \in T, \\
 & \sum_{i \in I} e_i P_{it} \leq b_v, \quad t \in T, \\
 & P_{it}, l_{it} \geq 0, \quad i \in I, t \in T.
 \end{aligned}$$

#### 4.4.7 Multiple Plants

- For this model it is been assumed that the company has network of  $M$  production plants which are situated at different locations which are manufacturing a single product.
- It is the responsibility of logistic system to supply  $N$  number of peripheral depots to every manufacturing plant turn by turn. Every manufacturing plant  $m \in M = \{1, 2, \dots, M\}$  is been featured by maximum product that are available there which is given by  $s_m$  when that particular plant has demand of  $d_n$  products.
- Also the transportation cost  $c_{mn}$  is included which include sending a production plant  $m$  to depot  $n$  and for every pair of  $(m, n)$  which is origin and destination we have logistic network.
- The main aim of company is to have optimistic logistic plan which satisfies the demands of depots in minimum cost without exploiting the availability of production plants.

Decision variables included in this model which represent the quantity that needs to be transported for every plant and depot pair is given by  $x_{mn}$  which is unit of product to be transported from  $m$  to  $n$ .

So the formula for the product becomes :

$$\text{min } \sum_{m \in M} \sum_{n \in N} c_{mn} x_{mn}$$

$$\text{s.to } \sum_{n \in N} x_{mn} \leq s_m, \quad m \in M,$$

$$\sum_{m \in M} x_{mn} \geq d_n, \quad n \in N,$$

$$x_{mn} \geq 0, \quad m \in M, \quad n \in N.$$

---

### Syllabus Topic : Logistic and Production Models : Revenue Management Systems

---

#### 4.5 Revenue Management Systems

**Q. 4.5.1** List revenue management systems. Explain any one in detail.

(Ref. Sec. 4.5)

**(5 Marks)**

- Revenue management is a policy to manage and its main objective is to maximize the profits for the company by maintaining the balance between demand and supply.
- It is usually created for marketing and logistic criteria and has also gained interest in service industries responsible for transport, tourist and hotels.
- Eventually it was been accepted by manufacturing and distribution companies. It was expected to grow as the basic idea was related to the revenue and every company thinks about maximizing their profit to the max.
- But the revenue management needs to be planned according to the strategies and decision making patterns and models of the company and so it becomes complex when data is feed to it.

##### 4.5.1 Decision Processes in Revenue Management

- When it comes to revenue management the models that are involved have mathematical models which are used to determine the actions of the customers at every level so the availability of the product and its price can be optimized to have maximum of the profits out of the sales.

- The aim of revenue management is not only maximizing profit but also managing various offers on products and services to increase the demand which will have different ideas of marketing strategies to promote the offers and logistics.
- It gives focus on fulfilling the requirements with minimum expenditure on the cost for the transport.
- Since it is a managerial policies most of the companies have taken up this policy and working over it. It is been notices that this policy have become the favourite and growing successfully and the fields that are actively implementing this policy are automotive rental companies, entertainment companies, hotel chains, airlines and so on.
- The common features among these fields are they have low margin sales cost and the possibility of imposing dynamic policies for public and also violating various sales channels.

---

### Syllabus Topic : Data Envelopment Analysis : Efficiency Measures

---

#### 4.6 Efficiency Measures

**Q. 4.6.1 List and explain efficiency measures associated with Data Envelopment analysis. (Ref. Sec. 4.6)**

**(5 Marks)**

- When it comes to data development analysis the units which are being compared are known as decision making units also known as DMUs as they have decisions that are self governed.
- To calculate the efficiency of  $n$  units  $N = \{1, 2, \dots, n\}$  are the set of units being compared. If these units are able to produce one single output from one single input only the effect of  $j^{\text{th}}$  decision making unit  $DMU_j, j \in N$  which is given as :

$$\theta_j = \frac{y_j}{x_j}$$

- In that  $y_j$  will be the output value generated by  $DMU_j$  and  $x_j$  is input that is been used. And if output is generated using different input factors, the efficiency of  $DMU_j$  will be defined as ratio between weighted sum of outputs and inputs.
- Given by  $H = \{1, 2, \dots, s\}$  is set of production factors and  $K = \{1, 2, \dots, m\}$  which are the outputs. In  $x_{ij}, i \in H$  which gives quantity of inputs  $I$  which are been used in  $DMU_j$  and  $v_{rj}, r \in K$  which is the quantity of output  $r$  that is been gained and the efficiency of  $DMU_j$  is given as :

$$\theta_j = \frac{u_1 y_{1j} + u_2 y_{2j} + \dots + u_m y_{mj}}{v_1 x_{1j} + v_2 x_{2j} + \dots + v_s x_{sj}} = \frac{\sum_{r \in K} u_r y_r}{\sum_{i \in H} v_i x_{ij}}$$

- Where weights  $u_1, u_2, \dots, u_m$  are been associated by outputs and  $v_1, v_2, \dots, v_s$  is been assigned to inputs.
- Whereas when it comes to second case, the ability value may have different variations also when it becomes difficult to fix single structure of weights which can be shared by different units.
- So to avoid different problems that can be raised by units to represent a unit of weights that will give advantage to few DMUs instead of benefiting to all.
- Data envelopment analysis calculates the ability for every unit on bases of this weigh mechanism which is good for DMU where the efficiency of system will be maximized.
- Also by doing additional analysis the aim of data envelopment analysis are efficient or not.

---

### **Syllabus Topic : Data Envelopment Analysis : Efficient Frontier**

---

#### **4.7 Efficient Frontier**

**Q. 4.7.1 Explain in brief efficient frontier. (Ref. Sec. 4.7)**

**(5 Marks)**

- It is also known as production function which shows the relation between the inputs that are been used and the outputs that are been produced using those inputs. It also shows the maximum amount of outputs that can be generated by given combination of inputs.
- Also it showed the minimum quantity of inputs that would be required to obtain the required output level.
- And hence efficient frontier is directly proportional to technical efficiency of operating methods. Efficient frontier can easily be gained by having set of observations which shows the output level of given set of combination of input level production factor.
- When it comes to data envelopment analysis the observations that are been obtained responds to the units that are been evaluated. Statistical methods which use instances to calculate regression curve give predefined hypotheses on shape of production functions.
- Data envelopment analysis considers assumptions on functional form of efficient frontier and is non parametric in nature.
- The only condition is that the units which are been compared should not be placed on production function depending on its ability value.

**Syllabus Topic : Data Envelopment Analysis : The CCR Model****4.8 The CCR Model****Q. 4.8.1 Explain in brief CCR model. (Ref. Sec. 4.8)****(5 Marks)**

- When data envelopment analysis model is used the option of choosing the optimal weights of generic  $DMU_j$  included solving mathematical optimization model whose decision variables are given by weights  $u_r, r \in K$  and  $v_i, i \in H$  that is been associated with every input and output.
- There are various formulas to get the efficiency score both the well known is Charnes-Cooper-Rhodes (CCR) model which is given by formula :

$$\max \quad v = \frac{\sum_{r \in K} u_r y_{rj}}{\sum_{i \in H} v_i x_{ij}}$$

$$\text{s.to} \quad \frac{\sum_{i \in H} u_r y_{rj}}{\sum_{i \in H} v_i x_{ij}} \leq 1, \quad j \in N,$$

$$u_r, v_i \geq 0, \quad r \in K, i \in H.$$

- The aim is to maximize the capability measures for  $DMU_j$ .

$$\max \quad v = \sum_{r \in K} u_r y_{rj},$$

$$\text{s.to} \quad \sum_{i \in H} v_i x_{ij} = 1,$$

$$\sum_{r \in K} u_r y_{rj} - \sum_{i \in H} v_i x_{ij} \leq 0, \quad j \in N,$$

$$u_r, v_i \geq 0, \quad r \in K, i \in H.$$

- Let  $\theta^*$  be the optimum value of the objective function corresponding to the optimal solution  $(v^*, u^*)$  of  $DMU_j$  is said to be efficient if  $\theta^* = 1$  and if there exists at least one optimal solution  $(v^*, u^*)$  such that  $v^* > 0$  and  $u^* > 0$ .
- By solving a similar optimization model for each of the  $n$  units being compared, one obtains  $n$  systems of weights.

- The flexibility enjoyed by the units in choosing the weights represents an undisputed advantage, in that if a unit turns out to be inefficient based on the most favourable system of weights, its inefficiency cannot be traced back to an inappropriate evaluation process.
- However, given a unit that scores  $\theta^* = 1$ , it is important to determine whether its efficiency value should be attributed to an actual high-level performance or simply to an optimal selection of the weights structure.

#### 4.8.1 Dual of the CCR Model

- CCR model that is been associated with input oriented dual problem which has interpretation as follows :

$$\begin{aligned} \min \quad & v, \\ \text{s.to} \quad & \sum_{j \in N} \lambda_j x_{ij} - v x_{ij} \leq 0, \quad i \in H, \\ & \sum_{j \in N} \lambda_j y_{rj} - y_{rj} \geq 0, \quad i \in K \\ & \lambda_j \geq 0, \quad j \in N. \end{aligned}$$

#### 4.8.2 Definition of Target Objectives

- When it comes to real world applications it is always favourable to set improvement aims for inefficient units for both input utilized and output generated.
- Data envelopment analysis gives important suggestions in this case as it can identify at which levels of the input and output the not so capable units will give ability values.
- The ability scores of unit show the highest proportion of inputs that are been utilized and given current output levels.
- The opposite of ability score shows the factors the factor by which current level of output must be multiplied to make unit capable which constantly holds the level of utilized inputs.
- Based on capability values data envelopment analysis gives a account for every unit that will be compared to savings that is been done in inputs or what has increased in output to make unit capable.
- To analyses target values input output strategy can be followed where the first case is the improvement aims that ate to be considered for resources to be used and target values of input and output are given below :

$$\begin{aligned} x_{ij}^{\text{target}} &= v^* x_{ij} - s_i^- * , \quad i \in H, \\ y_{rj}^{\text{target}} &= y_{rj} + s_r^+ * , \quad r \in K. \end{aligned}$$

- Whereas in second case, target values for inputs and outputs are given by,

$$x_{ij}^{\text{target}} = x_{ij} - \frac{s_i^-}{v^*}, \quad i \in H;$$

$$y_{rj}^{\text{target}} = \frac{y_{rj} + s_r^+}{v^*}, \quad r \in K.$$

#### 4.8.3 Peer Groups

- Data envelopment analysis demonstrates every unit that is not capable from the set of best units which are said to be peer group which have both capable units that contribute in excellence and the units that are not capable.
- This group is made up of multiple DMUs which are differentiated based on operating methods which are same as inefficient units that are been checked in real environment where the unit should show its best capability so as to improve the operating practices and its performance.
- The units that are present in peer group the given unit  $DMU_j$  can be identified by following and DMUs for first and second conditions are :

$$E_j = \left\{ j : \sum_{r \in K} u_r^* y_{rj} = \sum_{i \in H} v_i^* x_{ij} \right\}$$

---

### Syllabus Topic : Data Envelopment Analysis : Identification of Good Operating Practices

---

#### 4.9 Identification of Good Operating Practices

**Q. 4.9.1** Explain basic factors associated with Identification of good operating practices.  
(Ref. Sec. 4.9)

**(5 Marks)**

- Having good operating practices is important as it helps to improve the performance given by unit when compared.
- The units that are said to be capable in terms of data envelopment analysis demonstrate to compare and also examples that are associated with other units.
- Also between all the most efficient units there might be some which will help to improve the existing ability. It is important to search for most capable unit so that the ability of existing operating practices is improved.

- So to identify great operating practices the units that are actually capable needs to be recognized and their score also demonstration depends on system of weights that are been selected.
- To distinguish between these units we can use different methods like: cross-efficiency analysis, evaluation of virtual inputs and virtual outputs, and weight restrictions.

#### 4.9.1 Cross-Efficiency Analysis

- Cross efficiency analysis is done with the help of efficiency matrix that gives information about the nature of weights systems which are been implemented by units for their ability calculation.
- The square efficiency matrix contains multiple rows and columns that have units that are been compared. The element  $\theta_{ij}$  of matrix denotes ability of  $DMU_j$  calculated with optimal weights structure for  $DMU_j$  and  $\theta_{ij}$  ability of  $DMU_j$  which is evaluated using optimal weights.
- If  $DMU_j$  is efficient ie  $\theta_{ij} = 1$  even if it shows behaviour which is to be sustained to special dimension along with units the ability value in column related to  $DMU_j$  that should be less than 1.
- The quantities of interest can be derived from efficiency matrix. In which first is the average ability which is obtained from  $j^{\text{th}}$  column whereas second is average efficiency obtained by measuring unit of optimal system of weights to other units.
- Later is gained by averaging values in rows which is been associated with units that are been examined.
- The difference between  $\theta_{ij}$  and  $DMU_j$  and ability gained as average value of  $j^{\text{th}}$  column gives the result of how much the unit relies on system weights that is been used by units to calculate the process.
- If the difference obtained between the two terms is relevant,  $DMU_j$  will choose structure that is not been shared by other DMU in order to given all the privilege of analysis for efficient functioning.

#### 4.9.2 Virtual Inputs and Virtual Outputs

- Virtual inputs and virtual outputs gives information about importance of every units features for every input and output for the reason to maximize its ability score.
- And hence allows some specific capability of every unit identified, highlighted and also its weaknesses are been presented at same time. The virtual inputs that are of DMU are said to be the product of inputs that are been used by unit and its interrelated weights.



- Also virtual outputs are denoted as product of outputs of unit and linked with optimal weights. The pair of input outputs pair for which unit shows maximum high score provides idea of activities in which unit occurs efficient.
- There can be a scenario where two units have same virtual score but have different combinations of inputs and outputs which means there are two different operating practices. So here each unit has got two different ways in which it can function to gain maximum output.

#### 4.9.3 Weight Restrictions

- When the units that are really efficient are to be separated from efficiency score majorly depends on the weights system that is been selected.
- Conditions are been implied on the values of weights which will be related to inputs and outputs. These conditions are the converted into definition of maximum threshold of specific output for a particular weight or minimum threshold for specific inputs of weights.
- Even when different conditions are imposed on weights they still have some resilience in choosing multiplicative factors of inputs and outputs.
- And due to this reason it will be helpful to sort evaluation of virtual inputs and outputs to identify units that are more efficient operating practices related to usage of specific input resources or generation of outputs.

### 4.10 Exam Pack (Review Questions)

#### ☛ Syllabus Topic : Marketing Models : Relational Marketing

**Q. 1** Explain Relational marketing and various factor associated with it.  
(Refer Section 4.1) (5 Marks)

**Q. 2** Explain the concept of acquisition. (Refer Section 4.1.5) (5 Marks)

#### ☛ Syllabus Topic : Marketing Models : Sales Force Management

**Q. 3** Explain sales force management and various factor associated with it.  
(Refer Section 4.2) (5 Marks)

#### ☛ Syllabus Topic : Logistic and Production Models : Supply Chain Optimization

**Q. 4** Describe Supply chain optimization. (Refer Section 4.3) (5 Marks)



☛ **Syllabus Topic : Logistic and Production Models : Optimization Models for Logistics Planning**

**Q. 5** Explain optimization logistics planning in Logistic and production models.  
(Refer Section 4.4) (5 Marks)

☛ **Syllabus Topic : Logistic and Production Models : Revenue Management Systems**

**Q. 6** List Revenue management systems. Explain any one in detail.  
(Refer Section 4.5) (5 Marks)

☛ **Syllabus Topic : Data Envelopment Analysis : Efficiency Measures**

**Q. 7** List and explain efficiency measures associated with Data Envelopment analysis.  
(Ref. Sec. 4.6) (5 Marks)

☛ **Syllabus Topic : Data Envelopment Analysis : Efficient Frontier**

**Q. 8** Explain in brief efficient frontier. (Refer Section 4.7) (5 Marks)

☛ **Syllabus Topic : Data Envelopment Analysis : The CCR Model**

**Q. 9** Explain in brief CCR model. (Refer Section 4.8) (5 Marks)

☛ **Syllabus Topic : Data Envelopment Analysis : Identification of Good Operating Practices**

**Q. 10** Explain basic factors associated with Identification of good operating practices.  
(Refer Section 4.9) (5 Marks)



*Chapter Ends...*