“This chapter looks insight into the related literature to yield management. The purpose of this chapter is to find out what has already been done in past, and what could be done in future. This chapter helps to identify how one could proceed to meet the objectives. First of all the YM along with its purpose is explained as found in literature. Then the major part of this chapter is based on the various aspects of YM. The various aspects such as segmentation, price management, capacity management, demand forecasting, customer management, availability and overbooking are also discussed from the literature point of view. A number of methodologies and techniques are discussed for dealing with yield management. A number of applications such as airlines, hotels, sea-cargo, restaurants, stadiums, telecommunication, grid computing, cloud computing, etc. has been found in the literature and discussed by various authors. The two major techniques i.e. use of simulation and genetic algorithm, for implementing YM has been specially looked upon from the literature as these forms the basis of present thesis. Overall, this chapter forms the layout for the future work on the basis of past laurels.”
4.1 Yield Management

In literature, many authors use the term revenue management (RM) interchangeably with yield management (YM). Some consider YM only to be related with revenue derived from accommodation whereas RM may encompass all areas of hotel revenue [Burgess and Bryant, (2001)]. Therefore, it is important to highlight the term YM and clarify its meaning for the purpose of this thesis.

Jaucey, Mitchell and Slamet (1995) summarize YM as: ‘yield management is an integrated, continuous and systematic approach to maximizing room revenue through the manipulation of room rates in response to forecasted patterns of demand’. According to Kimes (2002) yield management can be defined as ‘a method that can help a form sell the right inventory to the right customer at the right time and for the right price’, Kimes (1989) however also suggested that this should be done in order to maximize the yield or revenue.

A description of YM, according to Jones and Val (1993), is to apply basic economic principles to pricing and to control the supply of rooms for the purpose of maximizing room revenue. This would mean that in order to have an effective YM system in place one would need to understand the basic economics of supply and demand so that the right price could be set and increase room revenue for the company.

Yield management is used in many different areas of the service industry. It can be used in every situation where the following conditions are met (Kimes, 1989): a relatively fixed capacity, segmentation into different market segments is possible, the inventory of the product is perishable, the products can be sold in advance (before they are actually consumed), there is a fluctuating demand, the marginal sales cost is low and the marginal production cost is high. Examples of industries where yield management can be used are given by Kimes (1998) and include: hotels, airlines, rental cars, cruise lines, convention centers, stadiums/arenas, movie and other theatres, internet service providers and golf courses.

4.2 Purpose of Yield Management

Information technology has enabled YM to be effective since it can store and analyze historical data necessary for accurate demand forecasting and the monitoring of actual demand in relation to the forecasted. Also, in combination with the communication of rate availability and restrictions to those making reservations, technology plays an essential role. [Jauncey et al., (1995)].
YM is a procedure that attempts to maximize profits by using information about buying behaviour and sales to create pricing and inventory controls [Lee-Ross and Johns (1997)]. The system consists of techniques that allow managers to gain more insight into customers’ buying behaviour and consequently, to make adjustments in the marketing mix to maximize revenue and achieve significant increase in profitability through customer preferences [Siguaw et al. (2001)]. Hence, the ability to control rates is dependent on correct predictions of future patterns of demand. This involves modelling the rate and volume of predicted reservations over time, based on historical data.

It is stated in literature that YM consists of two separate but interrelated parts, room inventory management and pricing [Kimes (1989); Brotherton and Mooney (1992); Writs et al. (2003)]. Inventory management deals with how different rooms are to be allocated according to demand. Weatherford et al., (2001) suggested that the two interrelated strategies that should be used in order to influence room revenue are pricing and duration of customer use. Duration of customer use involves controlling the length of stay. Also, price can be fixed or varied and duration is either predictable or unpredictable and involves controlling, predicting length of stay or service.

Further, policies regarding pricing, discounting, overbooking reservation pick-ups, incentives, cancellations, advance payments, deposits and the setting of maximum and minimum length of stay must be developed in order for YM to be successful.

4.3 Aspects of Yield Management

Companies often have the problem that they have a product with a fixed capacity and they have to sell this within a fixed period. According to Goksen (2011), if the market is characterized by customers who are sensitive to price and those who are insensitive to price, this creates an opportunity to sell the product to different customer segments for different prices. Airlines have done a good job of segmenting their passengers by willingness to pay. So there is a difference in price for customers who book ahead and customers who book a few days or weeks before departure. Segmentation is not only based on charging different prices at different points in time, but also on offering a higher service level for a higher price. For instance, in a plane the passenger could choose a seat with extra legroom or in a hotel the customer could choose for a room with street view, pool view or sea view or, back to a time-based example, you could choose for travelling during the weekend which is much more expensive than travelling during the week. This is because of the higher demand in the weekend. Another important point is that business travellers are generally charged the higher price than the leisure travellers because the availability of seats is more important for
business travellers and that is mostly why they are willing to pay the higher price. Each of these necessary ingredients will be discussed in the following sections.

4.4 Segmentation

Segmentation can be defined as the process of classifying customers into different groups or segments based on their observed or inferred characteristics. The objective of segmentation is to identify who is buying the product, how the customers buy it, when do they buy and what type of attributes they prefer. Based on their own preferences, some customers will value the product proposed by the company more than other customers. Based on this, they will be willing to spend more money on the product [Cento, A. (2006)]. In order to be successful, it is necessary for a company to segment its customers into groups. Some of them can be classified by price sensitivity (youngsters, leisure travellers), others by time sensitivity (business travellers, emergency travellers). More segmentation is presented in table 4.1.

Another important group of the customers can be classified according to industry as different industries offer dissimilar service charges to students, families, groups, tourists and business travellers. Table 4.2 gives an overview of some of these classifications according to industry.

4.5 Price management

Price is one of the most effective variables that managers can manipulate to encourage or discourage demand in the short run. It is a tool that helps to regulate inventory and production pressures [Verginis (1999); Bitran and Caldentey (2003)]. The application of YM often provides the operator with a series of rates to offer to prospective customers, based on forecasted demand [Jauncey et al. (1995)]. At times of high demand only high rates are open in combination with restrictions on length of stay and possibly pre-payment, as opposed to lower rates and fewer restrictions in periods of low demands in order to stimulate demand.

There are in general two main approaches to pricing, cost-based or market based. In cost-based pricing, the price is set in line with the cost of the product. In market-based pricing, the price could be set in line with competition and possibly according to demand. Often the term rack rate is used within hotels and it is the term given to the regular published room rate [Morrison (1999)]. Nevertheless, rack rate has become a starting point for price negotiation between client and staff. Therefore, tactic or differential pricing has become more common and is used as a means of effectively managing the overall financial yield from hotel accommodation.
### Table 4.1 Some common segment bases used in Revenue Management [Talluri, K.T. (2004)]

<table>
<thead>
<tr>
<th>Basis of Segments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Purchase</td>
<td>Used in airlines, retail, cruise, etc. Separate low and high valuation customers depending on the value of buying early or late.</td>
</tr>
<tr>
<td>Time of Reservation</td>
<td>Need not to be same as the time of purchase. One can reserve early and purchase by deadline. The firms take the risk that you would not purchase by the deadline but cancel. Hotels, airlines let this thing to happen.</td>
</tr>
<tr>
<td>Day of week</td>
<td>Hotel and airlines have peak demand during week-days. Weekend and week-days also separates the leisure and business travellers.</td>
</tr>
<tr>
<td>Cancellation likelihood</td>
<td>In reservation based industry, the service is used in future. Customers differ in their uncertainty that they will use the service. This uncertainty is sometimes connected with willingness to pay. Customers can be provided the option of choosing between high cost and penalty for cancellation.</td>
</tr>
<tr>
<td>Trip length and Stay of length</td>
<td>Used by airlines, hotels, and car-rental companies. Longer stay or trip length means leisure traveller.</td>
</tr>
<tr>
<td>Group discount</td>
<td>Groups are generally considered as leisure customers. It is basically the volume discounting as the firm lessens the risk of unused inventory by selling a large block.</td>
</tr>
<tr>
<td>Package</td>
<td>Package holiday combined with some trip restrictions limits the product to leisure customers in case of airlines, hotels and car-rentals</td>
</tr>
<tr>
<td>Business or individual</td>
<td>Used in telecommunication, retail, or energy industries.</td>
</tr>
<tr>
<td>Loyalty</td>
<td>Repeat customers have a higher lifetime value for the firm. By using store discount cards or frequent flier card, customers can be separated based on their loyalty.</td>
</tr>
<tr>
<td>Frequency</td>
<td>Frequent customers are not only loyal; they also provide more information about their preferences. Based on past purchasing habits and frequency of purchases, the firm can separate the frequent buyers from infrequent buyers.</td>
</tr>
<tr>
<td>Delivery Time</td>
<td>Used in manufacturing, freight and package delivery system. Customers with express orders are willing to pay more. The value of the service to the customers in a rush is much higher than normal. This is easily implementable segmentation in most cases.</td>
</tr>
</tbody>
</table>
### Table 4.2 Customer Segments classified according to industry [Cento, A. (2006)]

<table>
<thead>
<tr>
<th>Industry</th>
<th>Customer Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotels</td>
<td>Leisure, meetings, location, single or double occupancy, facilities</td>
</tr>
<tr>
<td>Airline</td>
<td>Business, leisure, students, children, youth, seniors, groups, military</td>
</tr>
<tr>
<td>Freight</td>
<td>Small, medium, large volumes</td>
</tr>
<tr>
<td>Energy</td>
<td>Office, retail, restaurant, grocery, school, guaranteed, controlled lighting</td>
</tr>
</tbody>
</table>

Pricing also needs to be supported by a market segmentation strategy which identifies the varying needs and expectations of market sectors [Donaghy et al. (1995)]. The challenge is to take advantage of these market characteristics when provisioning, packaging and pricing the hotel product by matching different rates against different purchase behaviour. Thus, hoteliers have to implement rational restrictions which prevent inelastic price keeping. Therefore, the critical point is the manager’s precision in establishing the respective needs of each market [Donaghy et al. (1995)]. Those willing to pay a high rate will receive accommodation in periods of high demand and through this the company will receive higher revenues. This could be seen as unfair by those willing to pay less during the same period. Kimes (1994) explained that most customers feel that they are entitled to a reasonable price and that companies are entitled to a reasonable profit. From that principle Kimes (1994) stated three hypotheses:

- If price needs to be increased by a company in order to maintain a profit, this is fair - so if costs increase so should the price.
- If the price is raised in order to increase profit, the customer thinks it is unfair.
- If costs decrease, customers think that it is reasonable for an organisation to maintain the same price.

This illustrates how customers perceive price and it is important for hotels to understand how their customers perceive prices if they are to run and use YM successfully. Luxury hotels, for example, have been able to increase occupancy rates during slow periods by offering profound discounts. Nevertheless, these efforts have frequently had a negative impact on the perceived quality of the experience [Marmorstein et al. (2003)].

According to Jones and Hamilton (1992), YM in the hotel business context tries to maximize guest room rates when demand exceeds supply and maximize occupancy even at the expense of average rate when supply exceeds demand.

It could be summarized that the overall strategy for a successful YM system is that price is dictated by demand [Donaghy et al. (1995)]. For management this involves activities such as
setting the most effective pricing structure, limiting the number of reservations accepted for a
given room night or room type, reviewing reservation activity to determine whether inventory
control action is needed, negotiating volume discounts with wholesalers and groups,
providing customers with the right product – both room type and room rate, and enabling
reservation agents to be effective sales managers rather than order takers. Subsequently, in
order for YM to be effective, managers and personnel must adopt a proactive approach to
managing the transition from traditional accommodation techniques [Donaghy et al. (1997)].
Yield Management has been seen by some researches as a form of price discrimination - the
application of the different prices for similar products to different customer groups. By
offering multiple rates to different customer groups, firms hope to diversify and increase their
revenue or retain their current revenue level. Furthermore, price management has been seen
as systematic offering different prices to different customer groups in response to changes in
demand and its characteristics [Ingold, A. (2000)]. For instance, some passengers who are
quality-oriented can influence the demand for the certain company product by their personal
characteristics and willingness to pay as well as they their price elasticity. The price elasticity
gives the percentage change in quantity demanded in response to a one percent change in
price, by holding constant all the other determinants of demand. This result can be used to
estimate or a price change leads to an increase in sales or just a revenue decline. Leisure
travellers may be very price elastic, and the business traveller may be more time sensitive and
less price elastic.

Other examples of using price management are early booking discounts for those customers
who are booking early at the company as well as offering the supplements for travellers in the
on weekend. By doing so, the company can cover some major costs and can concentrate on
more expensive offers (charging higher price) to receive more revenue. By doing so, it is
important that a company realizes which products (or services) it can offer at profitable price
for each specific customer segment. Hence, price management plays an important role for the

4.6 Capacity Management

According to Kotas (1986), most of the service operations have sales instability as a specific
characteristic. The fluctuations, which occur in the volume of business, are according to the
same source, of three kinds:

• The annual pattern. Seasonality is in general regarded as a problem within various
  industries.

• The weekly pattern. The volume of business fluctuates according to day of the week.
• Daily pattern. To narrow it down even more there are even differences between the levels of business depending on the hour of the day.

Thus, demand fluctuates annually, weekly, and daily posing difficulties in predicting demand. Capacity management places an emphasis on considerable understanding of the nature of demand by forecasting, and the options for managing capacity to meet the expected demand. According to Armistead and Clard (1994) “Capacity management is the ability to balance demand from customers and the capability of the service system to satisfy demand. “

When managing service operations, the heart of the planning and control process is the interaction between capacity management, quality management and resource productivity or efficiency management. With that, managers are confronted with contingencies in managing supply and demand. These barriers will in return affect the ability to maintain quality standards while at the same time achieving productivity targets. The issues are:

• The limited ability of the organization to alter capacity in terms of the extent of the change and the response time to make the change while at the same time having to deal with rapid fluctuations in demand.

• The need to deliver consistent levels of customer service.

There are four general strategies to manage these issues: altering capacity, holding inventory in anticipation of demand, requiring customers to wait for the service or influencing demand and holding it as an inventory. Hence, it is this element of service production that makes the matching of supply and demand very important, especially in hotels where the profitability of the operation is closely linked to the use of the current capacity and the prices charged [Armistead and Clard (1994)].

Hence, management must understand the composition of their capacity, the degree to which it can be changed, the speed of reaction, and the costs involved. Hotels are generally said to have relatively fixed capacity as the number of rooms cannot be changed according to demand. Further, as a result of fixed capacity and high marginal costs, hoteliers may determine the optimal guest mix by addressing the extent of demand from existing markets, the potential demand from additional segments and the compatibility of hotel resources with market demand [Donaghy et al. (1995)].

A further strategy when striving to utilize capacity fully is to identify and characterise demand variables per sector over time in order to forecast demand. To do this efficiently, historical data should preferably cover at least two years in order to predict peaks and off-peaks in demand, and to determine demand sensitivity relative to microeconomic and external factors. The more fragmented the data becomes the more useful is the information.
No-show data is important in order to determine a sufficient overbooking policy [Donaghy et al. (1995)].

In order to utilize capacity fully, there is a need to find ways of controlling as well as stimulating demand. Consequently, when dealing with the issue of fixed capacity, a balance between occupancy rate and average room rate must be achieved in order to achieve optimal revenue. The focus must not only be on high occupancy rates, attention must also be paid to the revenue that is generated. Selling too many rooms at a low rate may not be a good solution [Inkpen (1998)].

Capacity management has been identified as an important tool within YM with the purpose of allocating rooms according to demand. Although capacity management has been separately discussed, it is clear that the management tools and strategies are similar to those of YM. Nonetheless, capacity management could be used without the use of YM. While effectively resolving the short-term problem of excess capacity, YM also has in some cases influenced the perceived quality of the service and hence, the long-term image of the firm [Marmorstein et al. (2003)].

Further, capacity management in service operations could be explained as a difficult activity for managers because of the complex nature of the hotel product and the involvement of the customers in the process. This restricts the options open for controlling the process and matching supply with demand. Hence, managers need to encourage the development of products and services to match customers’ needs more accurately or to focus operational and/or marketing activities on customers whose needs match the hotel’s resources [Vinod (2004)].

4.7 Demand forecasting

Each industry faces specific difficulties in the forecasting of demand. For instance, in the airline industry it is important to take into account the period of seasonal peaks and off-peaks in demand for flights. The tour operators and travel agencies have sales peaks around holiday periods. The restaurants and theatres have higher sales in the weekends. In the certain industries the price for the products or services may influence the demand. Therefore, it is essential for all companies and establishments to adjust to these seasonal periods or price changes in order to be able to correctly predict the demand for their products or services and gain the maximum feasible revenue [Cross (1997)].

The accurate demand forecasts are essential to a Revenue Management system. Ingold (2000) argues that by forecasting potential demand based on the historical sales data and special future events, the companies can predict both: the size of targeted market segments and the
price that each segment will be willing to pay for the product or service. For example, in the airline industry, the widespread information on demand and booking patterns are necessary for the future revenue forecasting. If the company knows about the demand for the certain destinations in the previous years, it can estimate the demand for the coming year(s) for the similar products/services, taking into account the market situation and the economic situation in the country or in the world. Further, a company can use obtained demand information to classify its customers and assign the concrete price for each specific customer class in the most optimal way that increases the company revenue.

Kimberley (2010) defined forecasting as an act of estimating, calculating, or predicting conditions in the future. When forecasting demand in any industry, the firms follow different forecasting methods in order to catch as many customers as possible. According to Gabor (2010) these methods are short-term forecasting, long-term forecasting, constrained and unconstrained demand. He stated that a long-term forecast serves as a framework and a compass to anticipate which direction to turn to and how far one can expect to go. Structure of long-term forecasting is less detailed than short term forecasting. Long-term forecasting consists of current economic situations, growth rate, inflation etc. Jonathan (2011) adds that long-term forecasts, which are not as detailed as weekly and quarterly forecast, but are intended to give the general direction of expected business operations in the future.

4.8 Availability and Overbooking

Capacity allocation and overbooking are two main strategies used by revenue management specialists. While capacity allocation deals with reserving seats for different fare classes, overbooking as stated above is concerned with the number of additional booking requests to be accepted above the physical capacity. Overbooking is used by the airline companies to protect themselves against vacant seats due to no-shows and late cancellations. On the other hand, it may also happen that some of the reservations are denied boarding due to the lack of capacity at the departure time. In such a case, the airline faces penalties like monetary compensations, and even worse, suffers from bad public relations. Even though the overbooking decision involves uncertainties regarding the no-shows and cancellations, accepting more booking requests than the available capacity is still a commonly-used, profitable strategy because the revenue collected by overbooking usually exceeds the penalties for denied boarding. [Rothstein (1985)].

Limiting or shifting the availability of certain products or services according to customer demand in a specific period is important for Revenue Management [Andersen, A. (1997)]. For instance, if there is no supply for a deluxe room, while demand for the standard room
exceeds supply, the company can sell the deluxe rooms for the same price as the standards. Otherwise the rooms are empty and will not be sold. This is because of selling something is better rather than nothing. In this situation is the demand high and the company has the possibility to make their capacity high as well. It is vital for companies to sell a product before the expiration date, otherwise it is worthless. As stated above one cannot sell an empty seat on an airplane that has already taken off or you cannot sell last night’s empty hotel room. On the other hand, it may be that all the products have sold out before the expiration and to other customers the company has to say no. In that case it can occur that the airlines may sell out the flight, but on the departure day the plane takes off with empty seats. These passengers, who book a seat, but do not show-up at the departure time, for whatever reason, are called no-show passengers. This is not the case for just the airlines, hotels and restaurants have the same problem with customers who make a reservation and do not show up. Another possibility is that they cancel the reservation within a few hours before expiration. The airlines and hotel industry have good cancellation policies to protect themselves, for restaurants is this not always the case. One of the methods that companies apply to protect themselves against the no-show passengers and the possibility that a reserved capacity can later be cancelled is by overbooking. It is also possible to develop other methods to avoid no-shows, like customer reminders, deposits, standby passengers, overselling or no money back guarantees. Standby passengers are arriving at the airport and they do not know before the take off time if they will be go with that flight [Shaw, S. (2004)]. The only way that they will travel is if there will be an empty seat, caused by a no-show passenger.

However, overbooking can also cause problems if everyone who had made a reservation comes. Mostly in such a situation like this, there are also standard policies, one of them is that the passengers will be served by others or given compensations [Cento, A. (2006)]. In addition, employees have to be trained in how to handle in situations of overbooking because, both customer and employee satisfaction may suffer. Finally, this means that companies selling perishable products carry a high revenue risk. Revenue Management can be used as a technique to reduce this risk by creating a certainty about the demand for those products and by using overbooking policies.

The overbooking limit, which is also referred to as virtual capacity or total booking limit, is the maximum number of booking requests an airline company is willing to accept. An allocation policy specifies how to allocate this virtual capacity to each fare class. Although a common practice is first setting the virtual capacity and then doing the allocations [Belobaba (2006)], this heuristic approach in fact undermines the effects of these two decisions on each
other. Therefore, it is natural to study the joint capacity allocation and overbooking problem which is, in general, difficult to solve largely because of the uncertainty in the class dependent no-show and cancellation parameters.

Overbooking means that more products are reserved than there is capacity. Thereby it is essential that companies develop an overbooking policy, to develop this, a firm must have more information about the number of no-show passengers and cancellations on a flight over time. Overselling means that customers who pay the high price are reserved despite of the capacity and customers who pay a low price are advised to take an alternative product [Koole, G. (2010)]. The alternative could be depart of another airport or depart one day before or one day later.

Companies in a variety of industries (e.g., airlines, hotels, theaters) often use last-minute sales to dispose of unsold capacity. Although this may generate incremental revenues in a short term, the long-term consequences of such a strategy are not immediately obvious: more discounted last-minute tickets may lead to more consumers anticipating the discount and delaying the purchase rather than buying at the regular (higher) prices, and hence potentially reducing revenues for the company. To mitigate such behaviour, many service providers have turned to opaque intermediaries that hide many descriptive attributes of the service (e.g., departure times for airline tickets) so that the buyer cannot fully predict the ultimate service provider. Using a stylized economic model, a paper by Jerath et.al. (2010) attempts to explain and compare the benefits of last-minute sales directly to consumers vs. through an opaque intermediary.

Lan et al. (2011) formulated a joint overbooking and seat allocation model, where both the random demand and no-shows are characterized using interval uncertainty. They focus on the seller’s regret in not being able to find the optimal policy due to the lack of information. The regret of the seller is quantified by comparing the net revenues associated with the policy obtained before observing the actual demand and the optimal policy obtained under perfect information. The model aims to find a policy which minimizes the maximum relative regret.

**Static Overbooking:** In the first part of his thesis, Chi (1995) studied a static overbooking problem with multiple fare classes and formulates it as a dynamic programming model. However, when cancellations and no-shows are considered, the model suffers from the curse of dimensionality because one needs to keep track of the number of reservations for each class. To overcome this difficulty, Chi proposed an approximate model that can be solved in polynomial time. Coughlan (1999) also considered an overbooking problem with multiple fare classes, but he assumed that the go-show passengers are given the empty seats at the
same price as in. Unlike the majority of the studies in the literature, Coughlan does not use a Poisson distribution to model the demand but makes the simplifying assumption that both the demand and the number of bookings for each fare class are independent and normally distributed. Coughlan’s discussion also supposed implicitly that the minimum of the demand and the number of bookings is also normally distributed. Overall, the author provides a closed form formula for the revenue function and applies heuristic search methods to find a maximizer.

**Dynamic Overbooking:** Several researchers have addressed dynamic overbooking models for single-leg problems. Generally, the dynamic overbooking problem is modelled as a Markov Decision Process (MDP). Rothstein (1971) proposed two such models, where only one fare class is considered. In the first model, the objective is to find the optimal expected revenue after deducting the cost of denied boarding. Following the work of Thompson (1961), the second model added a constraint to limit the proportion of denied boarding. Alstrup et al. (1986) also used a MDP to solve an overbooking model but this time with two fare classes and the cost of downgrading. In the second part of his thesis, Chi (1995) discussed two dynamic models with multiple fare classes. Although the first model incorporates the realistic setting of cancellations occurring in time, it is computationally intractable. To ease the computational burden, Chi then assumes in his second model that the cancellations occur right before the departure time. This assumption allows him to solve the resulting model with an approximation similar to the one he uses in the static case. Chatwin (1998) analyzed the optimal solution structure of a discrete time dynamic single fare class overbooking model and discusses the conditions, under which a booking limit policy is optimal. Subramanian et al. (1999) studied a more general setting than Chatwin, where they analyzed the overbooking problem with multiple fare classes. The authors considered the arrival of a cancellation, the arrival of a booking request and no arrival of any type as a combined stream and assume that at most one of these events can occur at any discrete time epoch. Under this setting they present two models. In the first model, the cancellation and no-show probabilities do not depend on the fare classes. They show that the resulting problem can be equivalently modelled as a queuing system discussed in the literature [Lippman and Stidham (1977)]. In their second model, they relax the class independence assumption and model a more general problem with class dependent cancellations and no-shows.

Chatwin (1999) examined a continuous-time single fare class overbooking problem, where fares and refunds vary over time according to piecewise constant functions. In his model the arrival process of requests is assumed to be a homogeneous Poisson process, and the
probabilities to identify the type of a request are independent of time. He assumes that the reservations cancel independently according to an exponential distribution with a common rate, and the arrival process of requests depends on the number of reservations. Under these assumptions, the author formulates the problem as a homogeneous birth-and-death process and shows that a piecewise constant overbooking limit policy is optimal. A closely related study is given by Feng et al. (2002). They considered a continuous-time model with cancellations and no-shows. They derived a threshold type optimal control policy, which simply states that a request should be admitted only if the corresponding fare is above the expected marginal seat revenue (EMSR). Karaesmen and van Ryzin (2004) examined the overbooking problem differently. Their model permits that fare classes can substitute for one another. They formulated the overbooking model as a two-period optimization problem. In the first period the reservations are made by using only the probabilistic information of cancellations. In the second period, after observing the cancellations and no-shows, all the remaining customers are either assigned to a reserved seat or denied by considering the substitution options. They give the structural properties of the overall optimization problem, which turns out to be highly nonlinear. Therefore, they propose to apply a simulation based optimization method using stochastic gradients to solve the problem.

In all of the above models probability distributions are used to model uncertainty in demand and cancellations. Recent studies in revenue management focus on the availability of information. Adaptive methods are used when there exists no or limited information about the demand. Most of these methods assume that there is access only to samples from demand distributions. They mainly compute the booking limits based on the past information but also react to the possible inaccuracies related to the estimates of demand [van Ryzin and McGill (2000); Huh and Rusmevichientong (2006)]. Kunnumkal and Topaloglu (2009) considered a capacity allocation problem with limited demand information and develop a stochastic approximation method to compute the optimal protection levels iteratively. They proved that the sequence of protection levels computed by using their approach converge to the optimal ones. Birbil et al. (2009) presented a robust version of static and dynamic single leg problems. In their model, they took into account the inaccuracies associated with the estimated probability distributions of the demand for different fare classes. Ball and Queyranne (2009) used online algorithms to treat also a robust problem. In this way, they eliminated the need for estimating the demand and present the closed-form optimal booking limits.
4.9 Reservation negotiation

In many tourism businesses the management is implementing its decisions into the systems about pricing the capacity. That means they create opportunities to negotiate [Andersen, A. (1997)]. These negotiations are mostly intended to increase revenue, and on the other hand, if the company do it right, do they have a satisfied customer. Negotiation exists of up-selling and cross-selling. “Up selling” or “up-grading” is when the costumer has made a reservation and the agent is asking the customer if he or she want a room with sea view or the agent is asking for a travel insurance. The agent is trying to sell you more than just the holiday. When have chosen an accommodation and it is already fully booked, the agent can say two things:

• Sorry, there is no place.
• This one is fully booked, but I have a better accommodation on offer for you.

This means that the first answer is no entry and the second one is a possibility. Option two, where the agent suggests an alternative product, is called “cross-selling”. Usually there is some probability that a customer, when denied a booking at a lower rate class, will agree to buy the requested service at the applicable rate for a higher rate class. These kinds of sale techniques are very important. This is because of selling something rather than nothing. In the book of Andersen (1997) and in the paper presented by IDeaS (2005), they have shown the above functional aspects and then the characteristics which are the basics for implementing Revenue Management are described.

4.10 Customer Management

Some authors argue that YM is not in line with sufficient customer management and point out that there are downsides to the use of YM, such as a decrease in guest satisfaction and loss in brand recognition, if the system is not used carefully. According to Lieberman (1993), consistent pricing is often more important for repeat business than for occasional customers in order to sustain guest satisfaction. Kimes (1994) also recognizes that consistency in price is important although it is more important for repeat businesses than for occasional customers. Since YM often results in fluctuating prices, it is therefore important even when demand is high not to refuse a loyal customer’s request for a normally available discounted rate since that guest might represent future sales [Lieberman (1993)]. However, as illustrated by Donaghy et al. (1995), different market segments (business and leisure) respond differently to changes in price and price elasticity is therefore not the same. When customers decide accommodation based on price and if prices fluctuate a hotel could loose its brand recognition or incur a decrease in guest satisfaction.
To maintain and gain a competitive advantage the practice of YM has become a major tactic. Customer satisfaction is the leading decisive factor for determining the quality that is actually delivered to customers through the product/service [Pizam and Ellis (1999)]. Several studies have found that it costs about five times as much in time, money and resources, to attract new customers as it do to retain existing customers. Simply stated, customer satisfaction is essential for corporate survival. This creates the complexity of maintaining high levels of service, awareness of customer expectations, and improvement in services and product.

There are several ways to assess the quality of services and customer satisfaction through subjective, or soft, measures of quality, which focus on perceptions and attitudes of the customer rather than more concrete objective criteria [Pizam and Ellis (1999)]. These soft measures include customer satisfaction surveys and questionnaires to determine customer attitudes and perceptions of the quality of the service they are receiving. Understanding consumers’ service quality expectations is the key to delivering service quality [Bebko, (2000)]. Because the extent to which goods or services meet the customer’s needs and requirements is the index by which quality is determined, customers’ perceptions of service is vital in identifying customer needs and satisfaction [Pizam and Ellis (1999)]. The key to success is customer satisfaction, and the satisfaction also depends to a large extent on the comfort a customer is given in a hotel [Adamo (1999); Pizam and Ellis (1999)]. In general there are two types of comfort: physical and psychological, physical being things such as access, heating, ventilation, light, etc., and psychological being safety, privacy and hygiene [Adamo (1999)].

It is suggested that hotel markets are characterised by an intolerance of room rate fluctuations and that any application of YM will therefore result in dissatisfied guests [Jauncey et al. (1995)]. Such opposing views may reflect the need to consider the characteristics of specific market segments, for different segments may differ in terms of their willingness and ability to pay different rates. Therefore, one important issue lies in that the business needs to segment their customers and recognize their differences and differentiate their products accordingly, an example being the recognition that not all customers has the same price elasticity [Vinod (2004)].

The goal is to align business processes and customer strategies for long-term customer loyalty and profitability [Noon et al. (2003)]. Strategies include binding the customer to the organization through, for example, clubs and loyalty cards. An organization must also establish a means of ranking their customers, identify the most valuable ones and service them differently, this being a fundamental component of CRM.
As the practice of YM can lead to a decrease in guest satisfaction it is important to have a good service recovery system which takes into account the possible failures. Service recovery is defined as “the actions taken by an organisation in response to a service failure” [Zeithaml and Bitner (2003)]. A service failure results in negative feelings and responses from customers and must be resolved efficiently to prevent this. In relation to YM, Bitner and Zeithaml explained that customers may perceive pricing as unfair and that they may feel alienated if they fall victim to for example overbooking practices. This must be addressed by having good compensation policies.

Further, it is stated that good customer education is crucial for an YM system. Therefore, having good service recovery policies that are in line with the YM system is essential for good customer management. If YM is managed correctly, the use of the system does not have to lead to unsatisfied guests.

**4.11 YM in Network Environment**

In network seat inventory control, the complete network of flights offered by the airline is optimized simultaneously. One way to do this is to distribute the revenue of an origin-destination itinerary over its legs, which are called prorating, and apply single leg seat inventory control to the individual legs. Williamson (1992) investigates different prorating strategies, such as prorating based on mileage and on the ratio of the local fare levels. This approach provides a heuristic to extend the existing single leg solution methods to a network setting. However, only a mathematical programming formulation of the problem can be capable of fully capturing the combinatorial aspects of the network.

Bertsimas (2003) investigated dynamic policies for allocating scarce inventory to stochastic demand for multiple fare classes, in a network environment so as to maximize total expected revenues. Typical applications include sequential reservations for an network, hotel, or car rental service. He proposed and analyzed a new algorithm based on approximate dynamic programming, both theoretically and computationally. This algorithm uses adaptive, nonadditive bid prices from a linear programming relaxation. He provided computational results that give insight into the performance of the new algorithm and the widely used bid-price control, for several networks and demand scenarios. He extended the proposed algorithm to handle cancellations and no-shows by incorporating oversales decisions in the underlying linear programming formulation. Encouraging computational results that show that the new algorithm leads to higher revenues and more robust performance than bid-price control were reported.
4.12 Methodologies and Model in YM

Littlewood (1972) was the first to propose a solution method for the seat inventory control problem for a single leg flight with two fare classes. The idea of his scheme is to equate the marginal revenues in each of the two fare classes. He suggested closing down the low fare class when the certain revenue from selling another low fare seat is exceeded by the expected revenue of selling the same seat at the higher fare. Belobaba (1987) extended Littlewood’s rule to multiple nested fare classes and introduces the term expected marginal seat revenue (EMSR) for the general approach. His method is known as the EMSRa method and produces nested protection levels, i.e. they are defined as the number of seats protected for the fare class and all higher classes. The EMSRa method does, however, not yield optimal booking limits when more than two fare classes are considered.

Optimal policies for more than two classes have been presented independently by Curry (1990), Wollmer (1992) and Brumelle and McGill (1993). Curry used continuous demand distributions and Wollmer uses discrete demand distributions. The approach Brumelle and McGill proposed, is based on subdifferential optimization and admits either discrete or continuous demand distributions. Van Ryzin and McGill (2000) introduced a simple adaptive approach for finding protection levels for multiple nested fare classes, which has the distinctive advantage that it does not need any demand forecasting. Instead, the method uses historical observations to guide adjustments of the protection levels. They suggested adjusting the protection level $p_i$ upwards after each flight if all the fare classes $i$ and higher reached their protection levels, and downwards if this has not occurred. They prove that under reasonable regularity conditions, the algorithm converges to the optimal nested protection levels. This scheme of continuously adjusting the protection levels has the advantage that it does not need any demand forecasting and therefore is a way to get around all the difficulties involving this practice. However the updating scheme does need a sufficiently large sequence of flights to converge to a good set of protection levels. In practice, such a start-up period can not always be granted when there are profits to be made.

The solution methods in the above paragraph are all static. This class of solution methods is optimal under the sequential arrival assumption as long as no change in the probability distributions of the demand is foreseen. However, information on the actual demand process can reduce the uncertainty associated with the estimates of demand. Hence, repetitive use of a static method over the booking period based on the most recent demand and capacity information is the general way to proceed.
Dynamic solution methods for the seat inventory control problem do not determine a booking control policy at the start of the booking period as the static solution methods do. Instead, they monitor the state of the booking process over time and decide on acceptance of a particular booking request when it arrives, based on the state of the booking process at that point in time.

Lee and Hersh (1993) considered a discrete-time dynamic programming model, where demand for each fare class is modelled by a nonhomogeneous Poisson process. Using a Poisson process gives rise to the use of a Markov decision model in such a way that, at any given time \( t \), the booking requests before time \( t \) do not affect the decision to be made at time \( t \) except in the form of less available capacity. The states of the Markov decision model are only dependent on the time until the departure of the flight and on the remaining capacity. The booking period is divided into a number of decision periods. These decision periods are sufficiently small such that not more than one booking request arrives within such a period. The state of the process changes every time a decision period elapses or the available capacity changes. Kleywegt and Papastavrou (1998) demonstrated that the problem can also be formulated as a dynamic and stochastic knapsack problem (DSKP). Their work was aimed at a broader class of problems than only the single leg seat inventory control problem considered here, and includes the possibility of stopping the process before time 0 with a given terminal value for the remaining capacity, waiting costs for capacity unused and a penalty for rejecting an item. Their model is a continuous-time model, but they do, however, only consider homogeneous arrival processes for the booking requests. In a recent paper Kleywegt and Papastavrou (2001) extend their model to allow for batch arrivals.

Subramanian et al. (1999) extend the model proposed by Lee and Hersh to incorporate cancellations, no-shows and overbooking. They also consider a continuous-time arrival process as a limit to the discrete-time model by increasing the number of decision periods. Liang (1999) reformulates and solves the Lee and Hersh model in continuous-time. Van Slyke and Young (2000) also obtain continuous-time versions of Lee and Hersh’ results. They do this by simplifying the DSKP model to the more standard single leg seat inventory control problem and extending it for nonhomogeneous arrival processes. They also allow for batch arrivals. Lautenbacher and Stidham (1999) link the dynamic and static approaches. They demonstrate that a common Markov decision process underlies both approaches and formulate an omnibus model which encompasses the static and dynamic models as special cases.
According to James (1999), traditional peak-load and stochastic peak-load models assume firms have prior information about when peak demand occurs. However, price dispersion, such as is typically used by firms practicing yield management, can achieve some of the same efficient demand shifting even when the peak time is unknown. Equilibrium price dispersion arises because of stochastic demand and price rigidities, but a previously unexplored benefit of price dispersion is its ability to reduce equilibrium capacity costs through demand shifting. The model also suggests how yield management (now more commonly called revenue management) might actually benefit business travellers, contrary to the popular prejudice.

4.13 YM in various applications

Airlines

One successful application of revenue management is the airline industry. The airline industry is actually the pioneer in this field. Smith et al. (1992) reported that American Airlines begin research in managing revenue from its inventory in the early 1960s. One of the earliest published works in revenue management, Littlewood (1972) looked at how airplane seats should be allocated in a two fare system. Although the model was presented more than 40 years ago, the allocation rule proposed in the model (Littlewood’s rule) is still widely used in the airline industry now. After the deregulation of domestic and international airlines in the United States during the mid 20th century, more intensive researches in revenue management were conducted as airlines faced tougher competition.

The research works done in airline revenue management may be divided into four major areas: forecasting, overbooking, seat inventory control and pricing. As the success of revenue management depends heavily on the accurate forecasting of customer demand, several research works in revenue management look at how the forecasting methods can be improved to give more accurate and reliable prediction. The practice of overbooking refers to the acceptance of booking requests well above the capacity of the plane. The intention to accept requests above capacity is to reduce the possible revenue loss caused by passenger cancellations and no-shows. A closely related area to overbooking is the seat inventory control. In seat inventory control, the emphasis is to look at how the limited airplane seats should be allocated across the multiple fare classes. Most early works in the area of seat inventory control focused on the single-leg problem. Due to the much simpler problem setting, many interesting and important structural properties were obtained for this class of problem. In recent years, research in the airline inventory control problem looks at a more realistic setting with multiple segments. The emphasis in these research works is to find an
efficient method to determine the approximate optimal seat allocation. In overbooking and seat inventory control problems, the price of each airline seat is assumed to be predetermined. The research in pricing goes a step further by using price as the variable in maximizing the profit for the airline carriers. This area of pricing is gaining its relevance in the airline industry now as many airline companies are implementing “name-your-price” strategy via the internet to attract the budget travellers. A more detailed overview of revenue management in airline industry is given in McGill and Van Ryzin (1999).

**Hotels**

Another successful example of revenue management is the hotel industry. Research works on hotel revenue management starts as early as 1970s. The research direction in hotel revenue management was more or less similar to that of the airline revenue management in the beginning. For example, Rothstein (1974) considered the hotel overbooking problem in his paper. Although some works [Bitran and Mondschein (1995) and Badinelli (2000)] focus on the mathematical aspect of the problem, most research works in hotel revenue management take a different approach and focus more on the “human aspect” of the problem. While revenue management may give a company the competitive edge, it could also result in many problems such as [Kimes (1989)]: a loss of competitive focus, customer alienation, severe employee, morale problems, a change in reward systems and a need for intensive employee training. Kimes (1989) also pointed out that there is a lack of research in the managerial implication of revenue management. In order to gain more from revenue management, we need to look at how the revenue management methodology can be integrated into an organization.

Hansen and Eringa (1998) identified 11 people related critical success factors for the application of revenue management in hotels. They also suggested that the approach should be both qualitative and quantitative. Furthermore, it must be cross-functional and combines information and resources from different departments in the hotel.

Jones (1999) also observed that although the revenue management systems interact with various divisions within the hotel chain, little system analysis has been conducted in the hotel sector. He proposed a systems model for hotel revenue management that will better integrate various key departments in a hotel chain.

**Cargo transportation industry**

Compared to the airline and the hotel industries, the cargo industry is a new entrant in revenue management. In an article by Pompeo and Sapountzis (2002), they pointed out that most freight companies offer a standard service to all customers, with prices based on a vague
understanding of the competitive situation. With revenue management, they can better understand the market’s dynamics and the needs of the customers. They can divide the customer into various segments and offer different services and prices for each segment. Although the largest air cargo companies have begun to practice this concept, the container shipping industry has yet to apply this.

Kasilingam (1996) compared the differences between the air cargo revenue management and the airline passenger revenue management. He listed four main differences between these two applications: Uncertain capacity, Three-dimensional capacity, Itinerary control, Allotments. Due to these differences, the air cargo revenue management problem is considered far more complex than the airline passenger revenue management problem.

Saranathan et al. (1999) presented an operational model for the air cargo revenue management at United Airlines. However, no mathematical model for the air cargo revenue management problem is discussed so far.

Kleywegt (2002) also presented two models: Contract planning and Booking control, specifically for the application to the sea cargo industry. The Contract planning model is meant for the carriers to make long-term planning. Given the economical situation and the available capacity on certain voyages, the model seeks to determine a contract that maximizes the carriers’ return. With the inputs from the Contract planning model, the Booking control model is used for short-term allocation of capacity in the ship.

**Some other Applications**

Bertsimas and Shioda (2003) developed a revenue management model for a restaurant. In a restaurant, the floor manager has to decide where and when to seat each group of arriving customers daily, in order to maximize the revenue. Assuming that the total bill increases with the group size, the floor manager would arrange the group to the table where its seating capacity is close to the group size. However, restaurant also needs to consider seating smaller groups at large tables when the larger groups are not expected to arrive in the near future. This is because some revenue will still be generated from the smaller groups, compared with zero revenue generated from an empty table. The restaurant revenue management model is made complicated by the fact that the customers are only willing to wait for the seats for a limited time period.

Bertsimas and Shioda (2003) used integer programming, stochastic programming and approximate dynamic programming methods to study the problem. The integer programming approach is the most basic approach and uses expected demand in the formulation. To take advantage of the stochastic nature of the problem, the stochastic programming approach is
implemented in the second formulation. The dynamic programming approach is used in the third model, to take into account of the dynamic nature of the problem. The three optimization models are compared with the first-come-first-serve policy. They observed that the three models produce higher revenue without sacrificing the waiting time of the customer. Overall, as the sophistication of the model increases, it will result in better revenue.

Nair and Bapna (2001) applied the revenue management technique to the internet service providers. With growing demand from an expanding customer base, it is not uncommon that some internet users are disconnected from the network during peak hours. This is undesirable as competition between the internet service providers is stiff. Although the internet service providers can improve their service by purchasing more modems, this is not a good option as this involves huge capital cost. Currently, the internet service providers depend on the modems to users’ ratio (MUR) to decide the number of modems for a particular location. With fixed modems available, Nair and Bapna (2001) studied the optimal strategies for utilizing the network capacity of the internet service providers when they are faced with stochastic arrivals and departures of customers.

Unlike airlines and other industries discussed so far, the internet service providers do not at present differentiate their customers. In order to apply the concept of revenue management here, Nair and Bapna (2001) proposed to segment their customers into two classes namely Platinum and Gold, based on the quality of service. They defined the quality of service as the probability of getting access to the internet when the customers attempt to dial-in. As such, the Platinum customers, who pay a higher rate, will be guaranteed a higher quality of service here.

While revenue management is widely implemented in the service sector, this is rarely observed in the manufacturing sector. Barut and Sridharan (2004) is one of the first few papers that discussed the application of revenue management in a make-to-order (MTO) manufacturing setting. In the MTO manufacturing company, inventories are not stocked up to act as buffer for demand uncertainty. According to Barut and Sridharan (2004), the MTO manufacturing company needs to establish capacity management policies in order to solve the short-run capacity allocation problem when the demand exceeds the capacity. The chief capacity management issue is to ensure that the company utilizes the available capacity in the most effective and efficient manner to satisfy the current demand.

To apply revenue management in this context, they considered the setting where the MTO manufacturing company faces a fixed planning horizon. They noted that when the company faces a relatively high production lead time to sale period time ratio, its planning horizon is
rather fixed. Seasonal products, short product life-cycle goods and products near the end of their life cycle are some examples that share this characteristic. They proposed a customer segmentation policy that charges different prices for products based on order lead-time. They used a heuristic, similar to the idea introduced in Belobaba (1987) for the airline industry, to select the group of customers for production.

Few others reported the use of yield management in other industries such as health care e.g., [Chapman and Carmel (1992)], broadcasting [Cross (1998)], golf course industry [Kimes (2000)], internet service provision [Paschalidis and Tsitiklis (1998)] and nonprofits sector [Metters and Vargas (1999)]. Some of the latest applications of yield management are grid computing and cloud computing and are discussed below:

Buyya et al. (2005) introduced a Grid economy concept that provides a mechanism for regulating demand and supply of resources, and calculates pricing policies based on these criteria. With this concept, it offers an incentive for resource owners to be part of the Grid, and encourages users to utilize resources optimally and effectively, especially to meet the needs of critical applications.

[Siddique et.al (2006) and Sulistio et.al. 2007a)] provided a simple pricing model to determine the usage cost of each reservation. Resources might need to adopt a more complex method to increase their incentives or profits. In order to address this problem, Sulistio et.al.(2007a) have incorporated revenue management (RM) techniques for determining the pricing model in our on-line algorithm for elastic Grid reservation-based systems.

In a paper by Sulistio et.al.(2007b), a novel approach of using Revenue Management (RM) to determine pricing of reservations in Grids in order to increase profits has been proposed. The effectiveness of RM is evaluated and it is shown that by segmenting customers, charging them with different pricing schemes and protecting resources for them who are willing to pay more, will result in an increase of total revenue for that resource. Moreover, using RM techniques ensure that resources are allocated to applications that are highly valued by the users.

In the thesis of Anthony Sulistio(2008), the application of YM in grid system has been taken care of. According to him in most Grid systems, submitted jobs are initially placed into a queue if there are no available computer nodes. Therefore, there is no guarantee as to when these jobs will be executed. This usage policy may cause a problem for time-critical applications or task graphs where jobs have inter-dependencies. To address this issue, using advance reservation (AR) in Grid systems would allow users to secure or guarantee resources prior to executing their jobs. This thesis investigates how AR can be incorporated and
deployed in Grid systems, and determines how to increase the resource utilization. This thesis investigates how to increase resource revenue, and examines how to regulate resource supplies and reservation demands. Towards accomplishing these inquests, this thesis suggests the use of Revenue Management to determine the pricing of reservations, increase resource revenue, and regulate supply and demand. Moreover, this thesis looks into overbooking models to protect resources against unexpected cancellations and no-shows of reservations. In a paper by Puschel (2012), the research question of increasing revenue by adapting admission control for cloud service providers both under certainty and uncertainty has been considered. A novel service acceptance models has been proposed, which maximize the revenue of the cloud service providers with respect to the acceptance decision, thus contributing to service management innovation. Typically, customers have only vague estimates with respect to the resources that are needed for running the job on the cloud. Classical forecasting models have failed to predict the resources adequately due to the inherent complexity. In their approach the cloud service provider has no longer reserve the maximum amount of resources but can include this uncertainty into his optimization. After discussing how revenue management is applied in various industries, we note that some industries do not naturally have the characteristics required for the application of revenue management. However, we see some innovative approaches to modify the problem so that the concept of revenue management can be applied.

4.14 Simulation Approach in YM

In a study, Bertsimas and de Boer (2000) introduced a simulation based solution method for the network seat inventory control problem. They define the expected revenue function as a function of the booking limits and their aim is to find those booking limits that optimize the function. The DLP (Deterministic Linear Programming) model is used to generate an initial solution which takes the combinatorial aspects of the network into account and by which a nesting order can be determined. After that, the solution is gradually improved to make up for factors such as the stochastic nature of demand and nesting. Bertsimas and de Boer also provided a method to derive bid-prices from their booking limits by use of simulation. The bid-price for each leg is set equal to an approximation of the opportunity costs of reducing the capacity on the leg. They simulate a sequence of demand realizations and for each simulation calculate the revenue resulting from using the booking limits. To obtain an approximation of the opportunity costs, they subtract from this revenue the revenue generated by the same booking limits if the capacity on the leg would have been
decreased by one seat. The bid-price is defined as the average of the approximated opportunity costs over the simulations.

Gosavi (2007) developed a model-free simulation based optimization model to solve a seat-allocation problem in airlines. The model is designed to accommodate a number of realistic assumptions for the real world airlines system allowing cancellations of tickets and overbooking of seats. The simulation model is designed to solve single-leg and multi-leg problems. Results shows that the solution produced by using the simulation models are better than heuristic model mostly used by industry EMSR (Expected Marginal Seat Revenue) and DAVN (Displacement Adjusted Virtual Nesting).

4.15 Use of Evolutionary Approaches in YM

It has been observed that for the purpose of optimization evolutionary approaches has proven to be very effective in YM. The use of some these approaches are shown below:

4.15.1 Genetic Algorithms

So far not much of the work has been found in literature which applies GA in YM. But still some of the work that has been identified from literature has been described below:

A decision support tool for yield management using GA has been suggested by Pulugurtha et al. in 2003. This tool helps to decide about number of seats, number of fare classes, amount of overbooking, segments of flights, etc. GA has been used for the implementation purposes and the results obtained are on expected lines i.e. optimized solution has been achieved. Another application of GA has been found [Xiao-Bing Hu and Ezequiel Di Paolo (2007)] to be in the air traffic control system with the special emphasis on the uniform crossover. The basic aim of this paper was to identify an appropriate schedule to for aeroplanes and control their sequence of arrival. The reported GA exhibits a good potential of real-time implementation in the air traffic sequencing and selection problem.

A GA has been designed for choice based network revenue model has been suggested by Etebari, F., et.al. (2011). The customers were divided into segments and then GA was applied. The performance of GA was compared with CDLP i.e. Choice Based Deterministic Linear Programming and the results of GA were found to be encouraging.

Another tool has been suggested by Chi Ruey Jeng (2011), which can be employed as a real-time decision supporting tool for practical complex airline operations to save operation cost, increase passengers’ convenience and reduce air pollution. For designing of this tool GA has been utilized.

A crop yield management has been proposed in a thesis by Maxwell Martin in 2009 with the help of GA. The prediction has been found to be quite useful in US maize yield production.
A GA based airline booking terminal opening and closing system has also been proposed by A.George et.al. in 2012. In the proposed system, in order to maximize the revenue of airline, an optimized flight booking and transportation terminal open/close decision system is presented using Genetic Algorithm.

A pricing-inventory model with multiple interdependent products and stochastic demand is implemented with the help of GA by Alireza Inanlou Ganji and Hassan Shavandi (2013). Models with additive and multiplicative demand uncertainty were developed. Then a genetic algorithm was used to solve the models. Results were good and satisfying.

A GA has been developed by Reza Alaei and Farhad Ghassemi-Tari (2011) for the advertising time allocation problems. The advertising is the main source of income for TV channels and the allocation of time slots is an important issue to be taken into account. With the help of GA the revenue can be maximized.

Another important application of GA is found for Project Planning by Milena Karova, Julka Petkova and Vassil Smarkov (2008). As there are strict requirements to timeframes and budget costs for projects, GA can act as a very good tool for this type of planning.

4.15.2 Ant Colony Optimization

The importance of achieving optimality or near optimality in supply routing is on the rise as globalization leads to scenarios in which multiple, heterogeneous and highly spatially distributed demands have to be satisfied under stringent constraints. However, there is no consensus concerning what constitutes an all-encompassing objective function for the supply planner, who faces what can easily constitute a problem requiring Non-deterministic Polynomial time for determining the solution even in its simplest formulations. The work presented in an article by Nicolescu et al. (2013), proposes that a mathematically grounded approach which uses Ant Colony Optimisation to yield near optimal results across a large set of problem formulations and objective functions. The latter were designed to capture real-world goals such as cost reduction, optimal transportation management, flexibility and minimal lead-time. This study added a new dimension to topics traditionally encountered in the literature, namely that of the cultural differences between partners engaged in international trade relations.

4.15.3 Particle Swarm Optimization

In recent years, many of the developments in supply chain revenue management are connected to the need of information of efficient supply chain flow; modelling and optimisation, are most important in order to maximise the profit of supply chain because the cost of material, manufacturing and distribution and inventory accounts for 70-80% value of
the product. Hence, tactical supply chain design has become a major challenge for firms so as to improve the revenue of the organisation. According to Kedadevaramath et al. (2009) Particle swarm optimisation is used to optimise the supply chain operations with the objective of maximising the profit of the supply chain revenue.

The retail market is governed by customer behaviour, demand pattern and inventory replenishment policies. It is also observed that any decision would prove to be full of errors, and objective of enhancing the market share could not be achieved, without inclusion of these factors and policies. The work by Gandhi et al. (2011) primarily tries to bridge this research gap by addressing dual objectives of revenue maximization and reduction of salvaging losses. In this paper an inter-temporal dynamic pricing model for multiple products is developed under a market setup with price-sensitive demand. The formulated objective function is found to be tractable for deriving prices and procurement quantities of large product portfolios. A multi-objective problem has been devised to handle the optimization of normal and clearance revenue by satisfying several pragmatic constraints. Subsequently, an effective algorithm deriving its traits from Particle Swarm Optimization has been proposed to address this problem.

A paper by Niu et al. (2013) examines optimization of revenue of power plants facing stochastic demand with varied prices. A network optimization model is proposed for power plant revenue management under an uncertain environment. The network optimization has a stochastic programming formulation designed to capture the randomness of the unknown demand. A novel approach of robust optimization and PSO are applied to solve the problem on a scenario-basis. Decision-makers risk aversion is considered in the objective function. Mean absolute value is used to measure risk of deviation of revenue from its expected value.

4.16 Summary

It has been established that YM is a tool used with the intention to increase revenue. The system has been adopted from the airline industry into hotels and other industry and is now used as a base to make informed decisions by managers within various industries. It has also been established that YM consists of three interrelated management parts: price, inventory, and duration of customer use. The management of these parts should increase revenue but it should also be considered that the system could have boundaries such as decreasing guest satisfaction, loss of brand image, and a decrease in revenue if the system is not managed effectively.
There are a number of aspects of YM such as segmentation, capacity management, price management, customer management, demand forecasting, availability, overbooking and reservation negotiation.

Segmentation is a very important aspect in YM. If proper segmentation of customers is not available YM is very difficult to implement. Segmentation is the process of classifying customers into different groups or segments based on their observed or inferred characteristics. The objective of segmentation is to identify who is buying the product, how the customers buy it, when do they buy and what type of attributes they prefer. Based on their own preferences, some customers will value the product proposed by the company more than other customers. Based on this, they will be willing to spend more money on the product. In order to be successful, it is necessary for a company to segment its customers into groups.

Capacity management is clearly interlinked to YM through the management of inventory and strategies such as allocation of capacity. Nevertheless, the management of capacity could take place without the practice and use of a complete YM system. When managing capacity, managers should have a clear understanding of their product in order to apply strategies for the best utilisation of rooms. Further, demand should be understood in terms of how it can be influenced as well as the time of reaction since it is demand that determines how supply can be maximised and greater revenue can be expected.

Price is clearly an instrument which could be used to manipulate demand. However, price is also a delicate matter since it has an impact on customers and therefore impacts on demand in various ways. Price differentiation would capture greater revenue but this also implies that each market segment’s needs, wants, and willingness to pay are fully understood. Regardless, prices must be justified in a fair way to customers. Hence, strategies have been suggested in how to manage this. It is also highlighted that if these strategies are not managed correctly, an increase in occupancy at a lower price might lead to a decrease in revenue. Pricing tactics could, as capacity management, be interlinked to YM. Nevertheless, the practice of YM in relation to only lowering prices could be questioned. Consequently, managers must adopt a proactive management style in order to match demand with supply without jeopardizing revenue.

Within customer management literature, it is highlighted that all service managers should know that guest satisfaction is the leading key factor which is linked to the product sold. Strategies have been suggested in order to evaluate service quality and guest satisfaction. Also, the practice of customer relationship management has increased as a strategy to maintain guests. It is also clear that YM could be incompatible with customer management
since literature presents a variety of areas where the system could fail. Nevertheless, there is no direct correlation and if YM and customer management are managed in close connection to each other, revenue should be gained.

If the demand is not forecasted properly, then the firm may lose a lot of revenue or customers may return unsatisfied. Forecasting is an act of estimating, calculating, or predicting conditions in the future. When forecasting demand in any industry, the firms follow different forecasting methods in order to catch as many customers as possible.

Limiting or shifting the availability of certain products or services according to customer demand in a specific period is important for Revenue Management. Overbooking means that more products are reserved than there is capacity. Thereby it is essential that companies develop an overbooking policy, to develop this, a firm must have more information about the number of no-show passengers and cancellations on a flight over time.

A number of methods and models have been suggested in the literature for solving YM. Starting from Littlewood’s model for single-leg, a number of models not only for single-leg but also for multi-leg have been suggested. Belobaba’s EMSR has gained a lot of popularity in YM. The models are categorised into static models and dynamic models. Various mathematical based solutions have been proposed.

A number of applications of YM have also been considered in this chapter. Along with some common applications such as airlines and hotel industry, a few uncommon applications like sea-cargo, restaurants, internet service providers, health care, golf course industry, grid computing and cloud computing has also been discussed from the literature.

In the end use of simulation and GA in YM has been taken care of. A few aspects of YM such as network inventory, bid-price problem and seat allocation problems has been considered through simulation. Some applications like airlines, air-traffic control, time allocation, crop YM and project planning using GA have been discussed from literature.