Dynamic Pricing for Hotel Revenue Management

By Disha Katyal

Date: 20/07/2022

Abstract

This paper addresses the problem of room pricing in hotels. We propose a hotel revenue management model based on dynamic pricing to provide hotel managers with a flexible and efficient decision support tool for room revenue maximization. The two pillars of the proposed framework are a novel optimization model, and a multi-class scheme similar to the one implemented in airlines. Our hypothesis is that this framework can overcome the limitations associated with the research gaps in pricing literature; and can also contribute significantly in increasing the revenue of hotels. We test this
hypothesis on three different approaches, and the results show an increase in revenue compared to the classical model used in literature.

In this article I propose a new dynamic pricing approach for the hotel revenue management problem. The proposed model is a hotel revenue management model based on dynamic pricing to provide hotel managers with a flexible and efficient decision support tool for room revenue maximization. The proposed approach is based on having 'price multipliers' that vary around '1' and provide a varying discount/premium over some seasonal reference price. The price multipliers are a function of certain influencing variables (for example, hotel occupancy, time until arrival). In this paper I propose a novel dynamic pricing approach. It is based on having a seasonal reference price, and control variables in the form of multipliers. Each multiplier will adjust the price up or down around the reference price based on certain influencing variables (for example, hotel occupancy, time until arrival). The parameters of these multipliers are optimized. The goal is to maximize the revenue, taking into count current demand, and the demand-price sensitivity of the hotel's guest.

The proposed dynamic pricing model has the advantage of framing the price in terms of carefully optimized premiums and discounts control over a time-varying or seasonal reference price set by the hotel. This could conquer some of the hurdles that make some mid-range hotels reluctant in adopting revenue management ed to the systems. Our proposed model allows the hotel manager to give his input that he gained through his long experience. Moreover, this will reduce the uncertainty of where to expect the price, and hence improve the willingness of managers to king into adopt it.

1.0 Problem statement

This paper addresses the problem of room pricing in hotels. I propose a hotel revenue management model based on dynamic pricing to provide hotel managers with a flexible and efficient decision support tool for room revenue maximization.

Using a qualitative approach, the study analyses how dynamic pricing is currently implemented in hotel RM. By doing so, this research shows empirical evidence of the use of recent concepts in the industry like “open pricing” and identifies the opportunities and challenges of a customer-centric approach to pricing

2.0 Introduction

Revenue management is the science of managing a limited amount of supply to maximize revenue, by dynamically controlling the price/ quality offered. Revenue management systems have recently gained significant worldwide adoption in the hotel industry, at least for higher-rated hotels. The typical hotel guest has probably noticed in the past few years a progressively evolving level of dynamism in quoted room prices. This is indicative of the sophisticated nature of algorithms behind these reservation systems. However, the hotel revenue management models are still in their infancy, and there is a need for further development and improvement of these systems. Because of the sheer number of worldwide hotels every per cent of revenue improvement will add up considerably for the top line and much more so line because of the thin margin.

Hotel revenue systems can be partitioned into two major groups. In the first group, the quantity control approach, the rooms are segmented by categories, such as by rate, guest type, room type and/or length of stay. Each category has a fixed price, but the number of rooms allocated to the category is dynamically controlled in a way that maximizes revenue. The other group, the dynamic pricing approach, groups all similar rooms in one category, and applies a price that is continually adjusted with time based on the supply and demand variations. The dynamic price is set so as to maximize revenue, taking into account the hotel occupancy, and the current and expected demand. The dynamic pricing approach is particularly prevalent in some online hotel reservations. The online nature makes updating the price periodically quite manageable. Dynamic pricing is an important part of revenue management. It offers variable room rates based on demand and supply. This allows hotels to quickly react to changing market values maximizing revenue and occupancy rates. Customer segmentation, demand, and supply insights allow hotels to apply different pricing strategies. Thus, it is expected that the dynamic pricing approach will in the future overcome the quantity-based approach in adoption.

Hotel Pricing Strategies

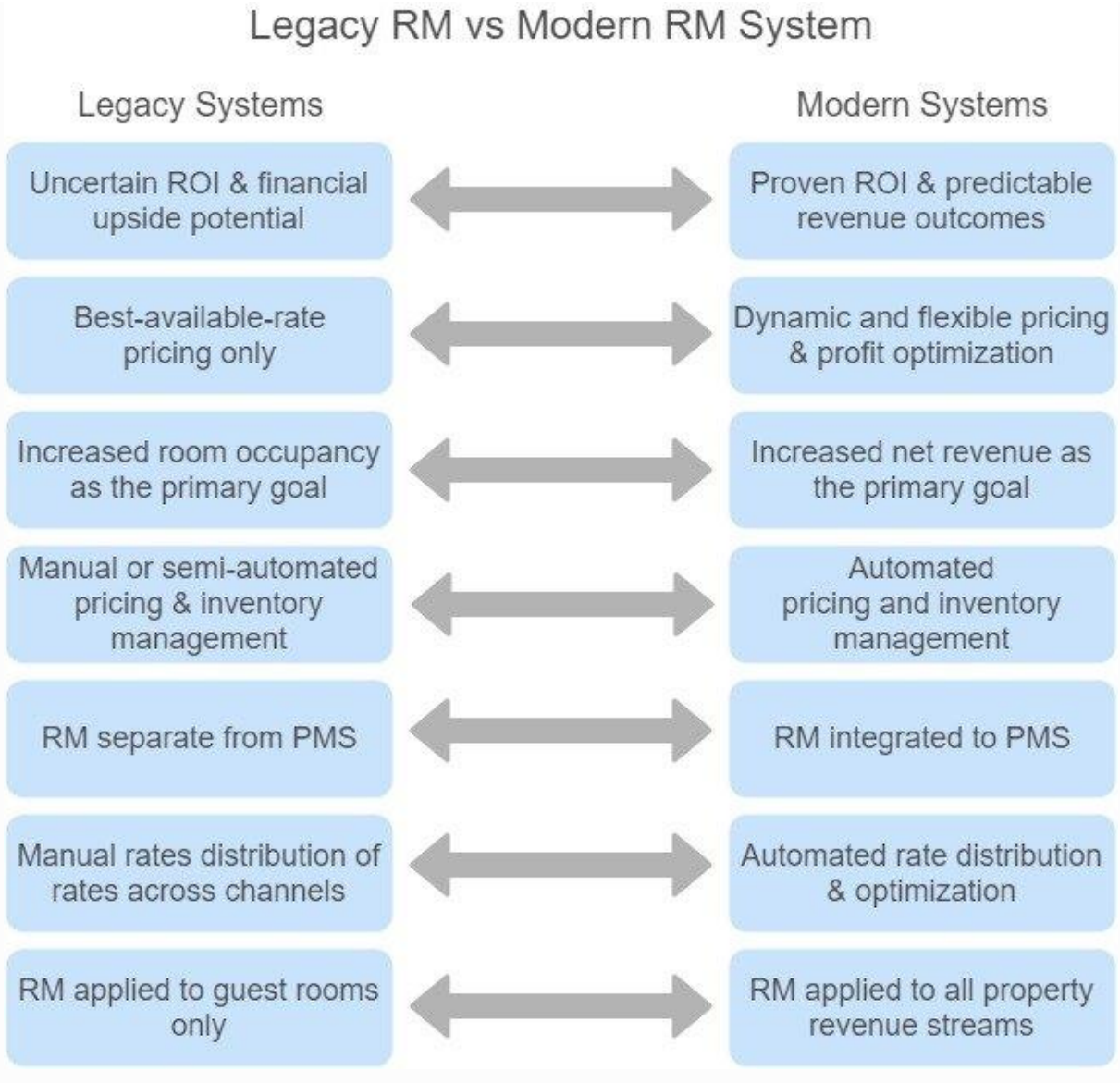
Approach	Explanations	Pros	Cons
Cost – based pricing	Occurs when pricing is driven by financial motives, such as equitable profit beyond all costs associated with the sales of the product.	Ensures that hotel achieves contribution margins targeted by financial executives.	Hard to price correctly to costs, because costs change with the volume. This leads to underpricing when demand is strong and over-pricing in times of weak demand.
Value-based pricing	Initiated before investments, and then customers are provided with a certain value.	Correctly implemented can bring higher revenues than competitors, because of a higher perceived value of products and services.	The biggest challenge is to raise customer willingness to pay a price that reflects product true value, rather than passively accept their will.
Customer-driven pricing	Demand-driven for a service at a certain time. Demand can change very rapidly.	Pricing is fitted to customers' willingness to pay – the biggest possible revenue.	Customers are not honest with their willingness to pay and the purpose of RM should not only be listening to customers preferences but also raise their willingness to pay a product's true value.
Competition-driven pricing	Occurs when hotel wants to achieve a targeted market-share and price their services to achieve this level.	it usually comes together with big revenue and high occupancy	Focus on market share can lead to inappropriate price cutting and when followed by competitors will create a downward spiral of prices.

2.1 Legacy vs next generation revenue management

Hotel legacy systems are often complicated and technically deficient. For instance, revenue managers must manually tweak prices, limiting the agility of the dynamic pricing approach. The problem extends to other operations as well. Guests may be segmented only by the purpose or length of travel. Demand forecasting may be based on simple methods like "the-last-year-demand."

Due to old software performance, data processing is delayed. The information on inventories is frequently inconsistent because the revenue management function is often separated from the property management system.

These problems lead to inefficient pricing and timing, which results in low occupancy and significant revenue losses for hoteliers. The modernization of revenue management systems can significantly change the situation. By linking new modules with a property management system, you can prevent overbooking and selling below costs.



3.0 Business Need Assessment

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4.0 Target Specification and characterization

Hotels and other players in the hospitality industry use dynamic pricing to adjust the cost of rooms and packages based on the supply and demand needs at a particular moment. The goal of dynamic pricing in this industry is to find the highest price that consumers are willing to pay. This form of price discrimination is used to try to maximize revenue based on the willingness to pay of different market segments. It features price increases when demand is high and decreases to stimulate demand when it is low. Having a variety of prices based on the demand at each point in the day makes it possible for hotels to generate more revenue by bringing in customers at the different price points they are willing to pay.

5.0 What is a dynamic pricing algorithm?

A dynamic pricing algorithm is the set of inputs and instructions underlying any dynamic pricing strategy. Dynamic pricing algorithms input data about a product/service, and output what would be an optimal price for it within given circumstances in order to maximize the vendor's profits while maintaining customers.

Dynamic pricing algorithms leverage historical data about:

- Product prices
- Production costs
- Market trends
- Customers' purchase behaviour

5.1 How does a dynamic pricing algorithm work?

Dynamic pricing algorithms work by estimating the dependency of a price on-demand in the following manner:

1. Processing historical sales and prices data, pricing points, and current market demand (e.g. data about wrapping paper during Christmas)
2. Identifying significant parameters that the price depends on. For example, "school opening" is a parameter that affects stationery sales.
3. Generating a mathematical model based on significant parameters.
4. Rerun the model using new data (when available)

5.2 What are the models of dynamic pricing algorithms?

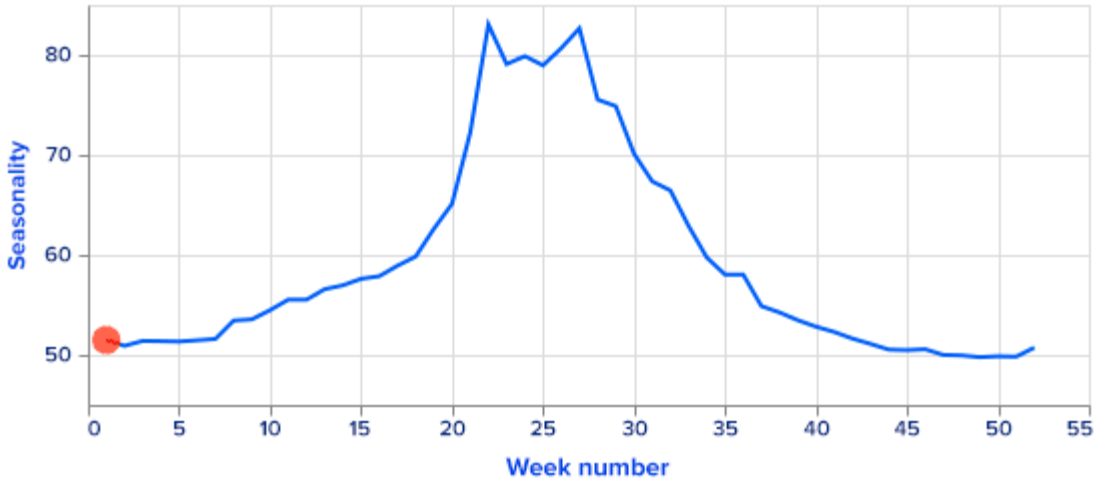
Depending on the mathematical model, businesses can create numerous algorithms that fit their dynamic pricing strategy. Here are a few approaches compiled from research articles:

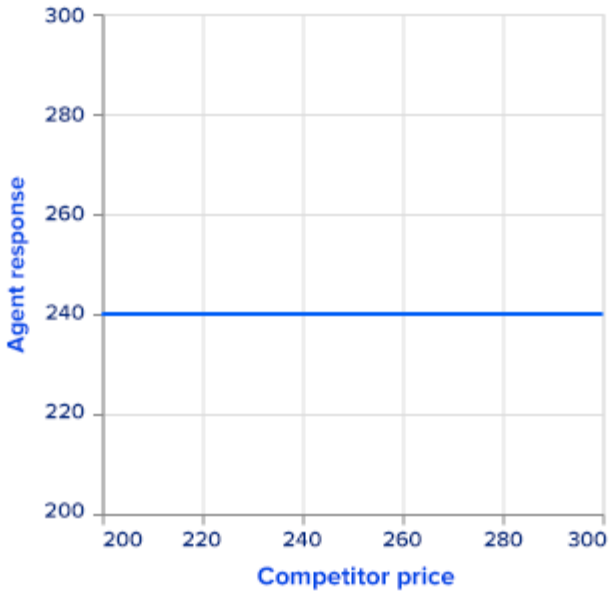
1. Bayesian model

In a Bayesian model, the user picks a prior value indicating the initial belief about the possible price. Then, whenever a new data point is entered into the algorithm, the initial belief shifts either higher or lower. Most Bayesian models use historical pricing data as the most important feature to decide on the final price.

2. Reinforcement learning model

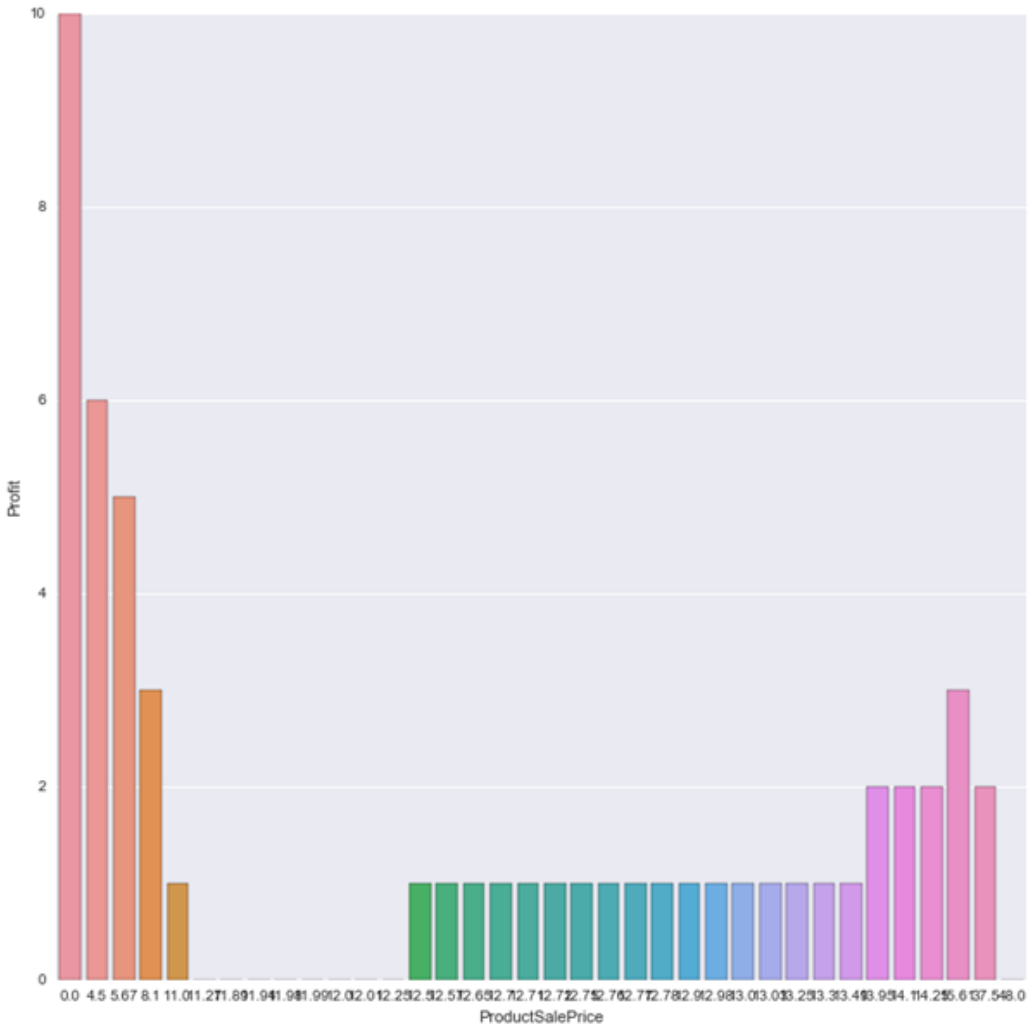
Reinforcement learning (RL) is a goal-directed machine learning model which aims to achieve the highest rewards by learning from environment data. An RL dynamic pricing model explores data about customers' demand, taking into account seasonality, competitors' prices, and the uncertainty of the market, with high revenue being the final goal.





3. Decision tree model

Decision trees are classification machine learning models that output a tree-like model of decisions and their possible consequences, including the possibility of a certain outcome, resource costs, and utility. Decision tree dynamic pricing algorithms help businesses understand which parameters have the most effect on the prices, and which of these price ranges predicts the highest revenues, and using this information, the algorithm predicts the best price range for each product.



5.3 How to choose the best dynamic pricing algorithm?

To choose the best dynamic pricing algorithm, businesses need to take into account that the algorithm should be able to provide prices which:

1. Maximize the profit
2. Minimize customer churn
3. Attract competitors' customers
4. Improve customers' experience and maintain loyalty

5.4What are the different types of dynamic pricing?

According to industry requirements, businesses can leverage one or a combination of different dynamic pricing types, which are:

1. Segmented pricing

Segmented pricing, also known as price discrimination, is where businesses set different prices for the same product based on customer data (e.g. age, job, location, purchasing channel, willingness to pay) . For example:

- A plane ticket can be priced lower if the customer is a student because they are less likely to make money at the time.
- A product can be priced higher in wealthy geographical locations where people can afford to buy it.
- A product can be cheaper if you buy it online instead of in-store.
- A product that comes with a coupon can be cheaper because people who use coupons are typically sensitive to higher prices.

2. Time-based pricing

Time-based pricing is where businesses determine the price of a product/service according to a specific time of the month, year, or season. For instance:

- Flight or train tickets are more expensive during the holiday season because people are more likely to travel in holidays.
- Stationery can be priced higher in September at the time where schools and universities start.
- Retailers and ecommerce companies tend to price older products at lower prices to encourage customers to buy them before they expire or go out of style.

3. Peak pricing

Peak pricing relies on market data. It is similar to time-based data such that businesses determine the price according to high demand times, however, businesses also leverage data about competitors, such as inventory or availability. For example:

- Prices can be set higher if a business understands that their competitors are out of stock.
- During heatwaves, electricity suppliers can set higher prices on power consumption.
- Uber sometimes sets higher prices on rides when there are less drivers around.

4. Penetration pricing

Penetration pricing is typically used by businesses that are just entering the market or introducing a new product. In this pricing method, businesses set lower prices compared to competitors in order to attract customers and encourage them to try their product/service. Prices are destined to get higher as the product gets more popular among customers.

5. Competitive pricing

Competitive pricing is the practice of setting prices of business products/services according to market and competitor prices. In a 2019 survey, 70% of respondents stated that competitive

pricing was the most important factor that influenced them to shop with a particular online retailer. Businesses can set the prices:

- Above the competitor prices to imply that their product/service is better than their competitors.
- Below competitor prices in hopes that more customers will purchase their product once they compare prices of different vendors.
- At competitor price to avoid loss. Businesses who set their prices at the same rate of the market tend to market their products in versatile ways to differentiate their product from competitor products.

6.0 Applicable Patents

The US Patent granted to Allotz.com Limited, covers the technology the company began developing in 2006. The technology has since been used in a variety of industries, including, travel, retail and transport. President and founder Martin McConnachie said the patent for this unique cloud-based application uses real time data, based on supply and demand, including time to expiry, to maximise a vendor's distribution, turnover and profit. The Allotz technology is available under licencing or a royalty agreement to companies in potential breach of the patent -and also as a plugin for any transactional application. These companies include ride share operators, hotel owners, airlines, online shopping sites, freight companies and fuel suppliers to name just a few.

7.0 Applicable Constraints

1. Specification of the following input data:
    - The demand categories defined by attributes like the time of the booking, time and length of the stay, and the room type defined by the tariff class
    - For each category its reference price (with its lower and upper limits as 50% deviations)
    - The operational cost for each room type
    - Planning horizon.
2. Forecasting the demand for the reference price based on
    - Historical data on the check-ins and associated lengths of stay for each demand category
    - Forecast for each demand category the number of check-ins and length of stay for each day of the planning horizon

- Calculation of the number of occupied rooms for each demand category and day in the planning horizon.

3. Determination of the demand-price relations as linear non-increasing demand functions for each category
    - Calculation of the slope of the function by a linear regression based on the past demand-price values
    - Calculation of the constant of the demand function using the reference price, the slope of the demand function and the forecasted demand for the reference price.
4. Calculating an optimal price for each category *c* and each day in the planning horizon by solving a mathematical programming problem with a concave quadratic objective function and linear constraints on the price values.

8.0 Concept Selection

The COVID-19 pandemic has caused an unprecedented level of disruption to the global hotel industry. A combination of local lockdowns and travel restrictions has resulted in many hotels having to close temporarily or operate at a fraction of their available capacity. During the COVID-19 crisis hotels needed to be reactive and flexible. The suggested revenue management approach allows to audit reservations and calculate different future demand scenarios. The choice of the hotel for a traveller is based on several factors such as long period reduction, room upgrades, high season offers, special cancellation offers, etc., which can be accounted in the demand categories. The approach offers the hotel business the opportunities of an improved price management for various scenarios and a quick reaction on market and demand changes. It can support the recovery of small hotels from the economic consequences of COVID-19.

9.0 Final Product Prototype

Machine learning algorithms can be used to influence nearly every component of RM.

The proposed idea is based on having a seasonal reference price that is possibly a piecewise constant function that varies according to the major seasons classification This reference price is typically set by the hotel managers. Moreover, we have four multipliers that represent the control variable. They will be multiplied by the reference price, to obtain the final price. They vary around the value of 1, where value that is lower than one corresponds to discount with respect to the reference price (for example, 0.9 means the price is 10 per cent lower) Conversely, a value that is higher than 1 represents a premium over the reference price The advantage of this formulation is that it will give the hotel manager or the revenue manager a suggested price that has some relation to the price that he has determined during his experience. Therefore, he can relate to the new price by observing its discount/premium in relation to his reference price. Each of the four multipliers corresponds to a variable that is known to have an influencing effect on pricing decisions. Specifically, the four variables that we selected are as follows:

1. Time from reservation until arrival date;
2. The hotel's remaining capacity at the time of the reservation;
3. The length of stay, abbreviated as LOS;
4. The number of rooms to be reserved (group size)

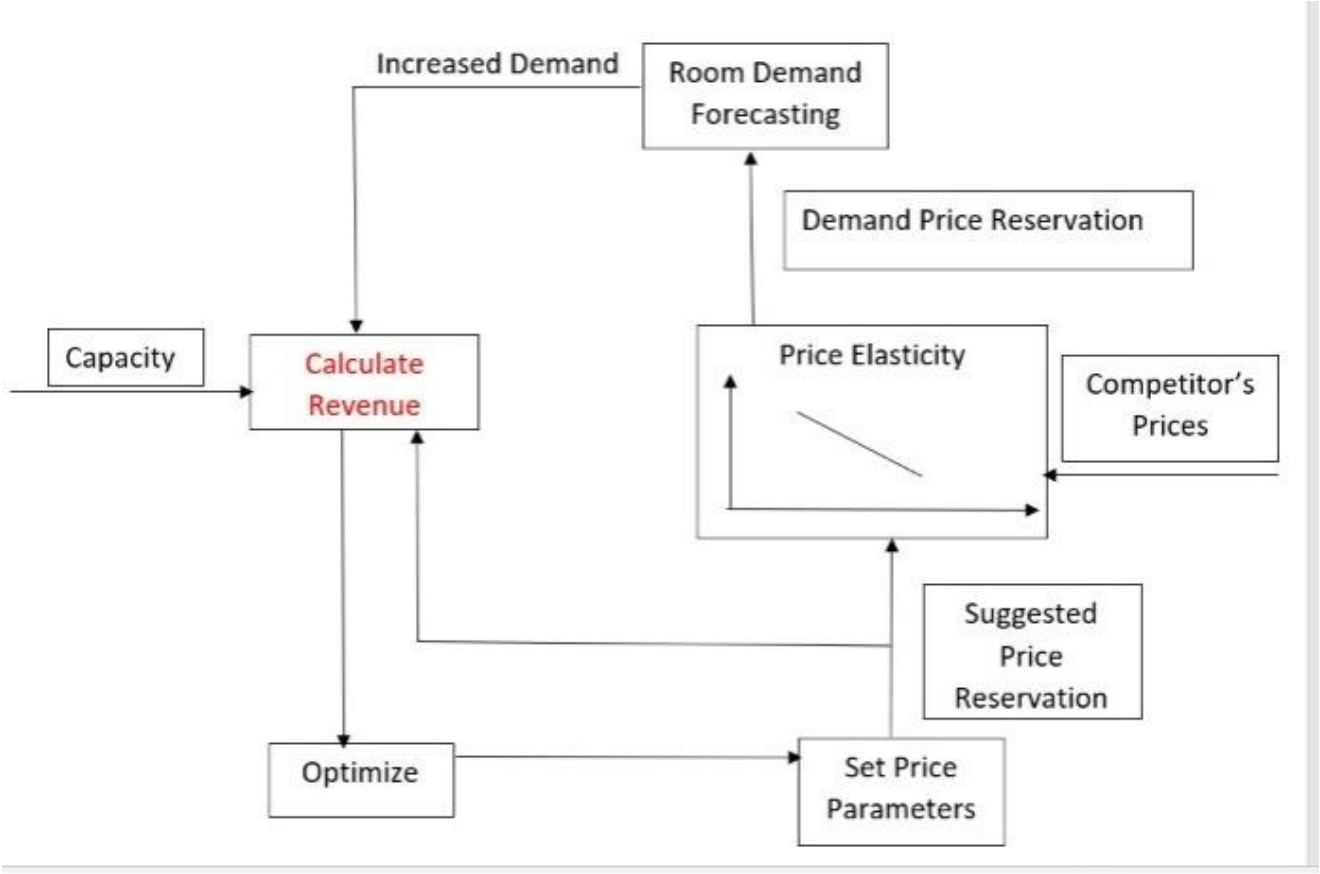
We construct a multiplier for each of these. four influencing variables. To simplify the problem formulation, these multipliers are usually taken linear or piecewise linear functions of the influencing variables, whose levels and slope are determined by the optimization algorithm.

The piecewise linear functions are selected based on logically expected relations identified by experts. For instance, if the remaining capacity is high, then the multi should be low in order to attract more customers using the lower price (or else more rooms will stay un-booked) Conversely, if the remaining capacity is small, the hotel prices the rooms higher to better save the remaining for higher paying customers few rooms for Therefore, we use a linear function that is monotonically decreasing with remaining capacity. Similar arguments apply for the other multipliers. We emphasize that these multi pliers alter the price relative to the reference price set by the hotel manager, which typically varies with time according to the season.

$$Price = Seasonal\ Reference\ Price * Time\ multiplier * Capacity\ multiplier * LoS\ multiplier * Group\ Size\ multiplier \quad (1)$$

The resulting price will reflect the discounts/premiums resulting from the different values of the influencing variables.

9.1 Framework Overview



9.2 Price multipliers

The following are the four multipliers that determine the final price.

1. **Time multiplier-** The time from the reservation date until the arrival date can be a very important controlling variable for the room's price. At the beginning of the booking horizon room prices should be low in order to quickly fill up the rooms, and thus the time multiplier will start from a low level. This can be considered as early bird discount. As time goes by and arrival time becomes closer, the discount is gradually lifted, and thus the multiplier's value increases. This is until a few days before arrival. At this point we are confronted with several vacant rooms that have little prospect to be filled up in the remaining short time. For such a situation, it is prudent to price them low, in order to avoid them going non booked as the target date approaches. Thus, the multiplier's value decreases until it reaches its minimum value y, on the arrival day.
2. **Capacity multiplier-** If there are many vacant rooms, then one has to offer some incentives and therefore the capacity multiplier is at its lowest value. The multiplier's value increases as the remaining capacity of the hotel is decreased, until it reaches the maximum value when there are no remaining rooms to be sold**.**

3. **Length of stay (LOS) multiplier-** The pricing should be monotonically decreasing with the length of stay, in order to attract longer stays (which therefore yield larger and more guaranteed revenue).

Yield Tactics in Revenue Management

Yield Tactic	Primary Application
Maximum Length of Stay (MaxLOS)	A reservation is restricted to a maximum duration. Often used to limit the availability of discounted or promotional rates.
Minimum Length of Stay (MinLOS)	A reservation is restricted to a minimum duration. Often used during high demand dates to optimize on demand for longer lengths of stay.
Closed to Arrival	No reservations are permitted with arrival on a particular day. Often used to encourage stays into shoulder dates, but risks turning away long stay bookings.
Allocations	Partners are given an allocated number of rooms to sell within the hotel, often at a discounted rate.
Last Room Availability	Key accounts are guaranteed availability within the hotel; on the room type they have contracted rates for, as long as that room type is still available for sale.

4. **Group size multiplier-** A large amount of tourism travel nowadays through pre-arranged tour package the tour packages. This way the tour operator can achieve block reservations. In my model I also consider group size on pricing.

The prototype can be implemented in the following three ways:

1. The first approach is to obtain different scenarios of the forecasted demand, and then calculate different percentiles of these forecasted scenarios. Then use each percentile as the estimated demand to solve the dynamic model. The output of this approach is different prices for each day along the forecasted horizon; each price is related to the amount of demand, i.e. if the demand is low, so will be the price associated with it. The problem with this approach is that we must generate several demand forecasts from the simulator.
2. For the second approach, we obtain only one scenario for the estimated demand and we divide it into m overlapping segments; each of which is used as the estimated demand. This approach also generates different prices for each day, where each price is related to the percentage of the total demand used.

   The third approach manipulates the capacity of the hotel, it partitions the total capacity of the hotel into overlapping segments; and for each segment the proposed model is solved to obtain a different set of prices. So each price set is related to the occupancy level in the hotel, ie when the hotel is not fully occupied, the price will

be low and it will increase as long as the number of available rooms in the hotel decreases

10.0 Conclusion

This paper describes a dynamic pricing approach for a hotel revenue management problem with multi-products. The demand is divided into several categories, the forecast can be made for each category and the optimal prices for the categories can be found by solving mathematical programming problem. After determining the optimal prices, demand function can be used to determine the number of rooms that should be assigned to each category. One decision strategy is to accept any booking in a category if a suitable room is available. Another strategy is to only accept the number of bookings determined by the demand function and optimal prices. This approach can take into account the prices of competitors as these are included in the reference prices of the demand categories. The approach can be used to plan prices for the period up to a year in advance. It can be used to manage a single hotel or a hotel chain, provided that the season periods of all hotels in the chain are the same.

The special features of our approach are:

- Handling multiple products;
- Addressing the lengths of stays;
- Addressing the hotel capacity;
- The flexibility of shifting a room from one tariff class into a different tariff class;
- No limits on the number of price changes;
- The planning horizon is up to a year;
- The demand-price function allows a short-term modelling in times of a crisis like COVID-19 pandemic.

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