APPLICATION OF OPERATIONAL RESEARCH IN THE HOSPITALITY INDUSTRY

Apurv Upadhyay[*1], Arnav Rastogi[*2], Arpit Bafna[*3], Aryaman Chandra[*4], Aryan Goyal[*5]

[*1,2,3,4,5]Students Of NMIMS, Anil Surendra Modi School Of Commerce, Mumbai Campus.

ABSTRACT

Operations Research is an analytical problem solving and decision-making method that is useful for managing organizations. This research paper focuses on the different operations research Methodologies that can be used for this purpose but with the Hospitality industry in context. Previous research has primarily focused on the use of operations research in the field of revenue management while areas like employee management, cost control, capacity management and ways to overcome the COVID -19 pandemic have not been as extensively researched into. The analysis focuses on these objectives of using operations research in allocation of space between rooms and restaurants, in Forecasting demand and overcoming emergency situations like the COVID-19 pandemic. Several operations research methods have been used for this research which include Simulation, Secondary Data Analysis, Linear Programming Problems and Demand Forecasting.

Keywords: Linear Programming Problems, Demand Forecasting, Bellman Ford Algorithm, Hospitality Industry, Covid-19.

I.   INTRODUCTION

It has been estimated that the hospitality industry accounts for 10.4% of the global GDP, and it has also been predicted that this percentage will rise by an astonishing 10% in the next 10 years. It is an essential industry for economies all around the world. The hotel industry is a part of the service industry that deals with accommodation or lodgings. According to most definitions, the hotel industry refers not only to hotels, but also to various other forms of accommodation, including inns, hostels and guest houses.

Operations Research is a systematic method of problem solving and decision making that is useful in the management of organizations. In operations research, problems are broken down into basic components and then solved in specific steps by mathematical analysis. It helps the managers in making effective and well-informed decisions. It is Operations Research that brings various options at the disposal of managers which they can then compare to find the best one. It also allows managers to study the effect of each option on the management. Therefore, Operation Research helps in making better decisions in a comparatively lesser amount of time.

In this study, we aim to display the use of Operations Research in these industries. This has been displayed by showing the use of Operations research in the said industries with the following situations, research methodologies designed to overcome the impact of COVID-19 on the hospitality industry with the help of simulation modelling, use of LPP (Linear Programming) to maximize profits subject constraints, minimize costs subject to constraints, find optimal combinations of variables and lastly application of various methods of forecasting in Demand Management.

II.   LITERATURE REVIEW

Operations Research in Hospitality Industry outlines a framework for determining the benefits that various operations research approaches can provide to the hospitality industry. For the advantages of various service sectors, assignment issues, transportation problems, linear programming problems, and replacement theories are commonly used. These ideas have been utilised to determine the advantages that the hotel business can gain from their application. The financial gains have been discovered. The economic benefits are adaptable and directly related to the services provided. These theories can also be used to discover ways to help experts in the hospitality sector by effectively applying these techniques to compete with competitors (Mehta, Mishra, Shah, Singh, & Fadia, 2019). Techniques have also been developed that focus on hotel and lodgings research (O'Neill & McGinley, 2014). In this regard two perspectives were considered to review the current capacity management approaches present in the hospitality industry, the long-term perspective and the short- term perspective. The long-term approach focusses on decision about usage of resources, capacity size and

expansion while the short-term approach focusses on ensuring the there is no hindrance in carrying out the long-term approach and all necessary conditions are there for the same (Pullman & Rodgers, 2017).

The most commonly talked about area where operations research can be applied in this industry is the area of revenue management. Some have tried to draw similarities between the airline and hotel businesses to apply the methods of revenue management to the latter that were applicable in the former. However, hotels have changing variables like period of stay of customers and the number of customers. Certain unforeseen circumstances may also arise in the case of hotels like early or late check ins/check outs. To solve the problem optimizations were made in a stochastic programming technique (Lai & Ng, 2012). A discount manipulating model was also explored for revenue management in hotels. Management has to choose from around 120000 different variables and finding their optimum combination requires a large amount of time and cost. The model aims to reduce the guess work required to find this optimal combination and also to reduce the no-show rate of customers. Other previously used methods which showed some degree of success include credit card guarantees and pre-payment methods (Meuwissen, Rosss, Narayan, & Gunter, 2011). Simulation models for finding the optimal combination of variables are also suggested. A simulation model allows analysts to grasp all the complexities that may arise in the application of any method as they can freely change variables and look at different results it provides (Feinstein & Parks, 2002). Moreover, the applicability of game theory was also looked into. It can be used to optimize the prices and hotel room rates which have a direct effect on the hotel's revenue (Schwartz, 1997). Linear Programming is yet another method that can be used here as it allows hotel to allocate their scarce resources effectively (Gupta & Griglani, 2014). The effects of pricing decisions on hotel yield management were delved into through a model that forecasts the demand in different segments of the market to capitalize on markets in which customers are willing to pay more than others. The model is considered to have an edge over other due to the fact it requires fewer assumptions about the demand process and the data required for it is very easily available through market research (Badinelli & Olsen, 1990). Revenue Management can be controlled by following the method of price differentiation which involves charging different prices for the same room from different guests. Tools like price segmentation and optimization were also used for the same (Zhechev & Ivanov, 2012).

Due to the recent pandemic cost control methods for hotels were brought into light to help reduce the losses caused by the economic slowdown. If effective cost control and waste removal techniques are implemented, they can go a long way in helping hotels reduce their losses and make their profits back. If companies can adopt new operational techniques or change existing ones then they can easily fight off such situation (Bhatt, 2018).

Employee management was another aspect in hotel management that cannot be overlooked. The use of staff scheduling and rostering methods has been done. Specifically, the impacts of nurse rostering and tour scheduling on the hospitality industry was looked into. (Rocha, Oliveira, & Carravilla, 2012)

In conclusion, most of the operational techniques used for hospitality industry have been to evaluate how hotels can manage their revenues in a better manner. While the other areas like employee management, cost control and capacity management have not been as extensively researched into.

III.   RESEARCH OBJECTIVES

- Use of Operations Research in allocation of space between rooms and restaurants
- Forecasting demand through OR techniques
- Operations Research methods that can be used to overcome emergency situations like the COVID pandemic.

IV.   RESEARCH METHODOLOGY

This Research Paper considers data and methodologies which are derived from various websites and research papers based on operations research. The aim is to find out the suitability of different mathematical models and show how they can be applied in the Hospitality Industry.

V.   ANALYSIS

Research methodologies designed to overcome the impact of COVID-19 on the hospitality industry Simulation and agent-based modelling: A simulation is a computer model on which experiments can be performed that provides a higher degree of integrity than a conventional experiment. Simulation models can

help with both complex and simple experiments and can be used in almost any social process. On researching, we found a lot of models that can be used under the methodology of simulation.

1. Agent-based model- An agent-based model can be used to determine the spread of the virus in tourism-oriented cities in order to discover sustainable and resilient strategies. This model represents the movement of simulated people and the spread of the contagious virus in an urban tourist area. This model evaluated the number of infectors within a touristic urban area over time and the number of visitors who return home being infected over time.(Davahli & Karwowski, 2020)This has appeared as an effective measure in places where the rates of infection are the highest.

2. Susceptible exposed infected recovered model- This model was created to calculate the primary reproduction number. The base reproduction number refers to the expected number of cases caused directly from one case in a population in which all individuals are susceptible to infection. (Mwalili, Kimathi, & Ojiambo, 2020)

$$S(t) = \frac{S(0)e^{-R_0(R(t) - R(0))}}{N}$$

S (0) = initial numbers of susceptible subjects

R (0) = initial numbers of removed subjects

N = constancy of population

Ro = basic reproduction number

S(t) = number of susceptible individuals as a function of time

R(t) = number of removed individuals as a function of time

3. Epidemiological model- This model was developed based on discrete-time integral equations and daily incidence series. It follows a similar formula as Susceptible exposed infected recovered model. Epidemiology is based on two fundamental assumptions. First, the occurrence of disease is not. Second, the study of populations enables the disease-related causes and preventive factors to be identified. (Bagaini & Ba, 2020)

4. Dynamic stochastic general equilibrium model- DSGE is a macroeconomic technique that describes economic phenomena based on the general equilibrium framework and studies their effects. They also explain and predict movements of aggregate time series over a business cycle and help in performing policy analysis. DSGE models can be used for three purposes: forecasting, storytelling, policy and guideline experimentation, as well as reviewing the forecast log. This method was adapted to the tourism sector, where the model included two indicators (health status and health disaster) and three categories of decision-makers (government), households and producers) The result of this model suggests that the duration of the pandemic is directly proportional to the catastrophic impact on the hospitality industry. (Alaminos & León-Gómez, 2020)

Methods to examine the Economic Impact of Covid-19

Seasonal autoregressive integrated moving average model (SARIMA)-

The seasonal autoregressive integrated moving average model is a linear model in statistical forecasting based on defining stationary, non-stationary, and seasonal processes of order. It follows time-series analysis. Seasonality also leads to considerable sales volatility in the hospitality industry. In the SARIMA model, to deal with multiple seasonality, external regressors need to be added. (Apostolos, 2021)

One such model was developed for the Filipino tourism and hospitality industry forecasting a total loss of $ 4 billion in revenue by September 2020.

Supply and Demand curve- This can be used to analyse the economic impact of COVID-19 on the hospitality industry. For this, the demand function is constructed using selected price factors for goods, customer tastes and preferences, customer expectations, the average income of specific countries, and the number of buyers. The supply function is developed using elements of production techniques, resource prices, price expectations, prices of related goods, supply stocks, and the number of sellers. The supply and demand curve then develops in the market equilibrium condition where the demand in the market is equal to the supply in the market. (Davahli & Karwowski, 2020)

Scenario analysis and Trend analysis- A scenario analysis technique was used to calculate the effects of COVID-19 on the tourism and hotel industries in Turkey. The model predicted an overall loss of revenue in the best and worst case. In the worst case, border closings for four months are without economic recovery. One article estimates the impact of COVID-19 on the Indian economy in a profit loss of around $ 28 billion in 2020. along with 70% job losses for hospitality and tourism workers and massive bankruptcies. (Fabien, 2021)The trend analysis has been used to study the impact of COVID-19 on the hospitality and tourism industries and global GDP. North America, Europe and Asia are predicted to suffer the most massive sales loss.

Using LPP in Hospitality Industry

Hotels can use linear programming to:

- maximize profits subject constraints
- minimize costs subject to constraints
- find optimal combinations of variables

Graphic Solution to the Problems

Linear programming is a mathematical programming method. In order to solve this LPP graphically, we have plotted all the constraints first. Then, feasible region for each constraint was found. Lastly, Region A was found which was a common feasible region for all constraints. (Saxena, Linear Programmimg Problem)

What's important in a room

Guests who walk in the hotel room generally expect the following things:

WIFI, room-service, cleanliness, friendly hotel staff, a comfortable bed, good view, ultimately value for money. In addition to these basic requirements, guests were also interested in getting concierge recommendations, regulating room lights/temperatures from a device, and using voice activation; accessing email, social networking sites, and entertainment from TV; connecting to Bluetooth speakers for music; and watching movies and shows from their own device, hinting that they want greater control over scheduling housekeeping services and being notified when their room is being serviced.

Hotels also need to keep in mind that different guests could want a different type of room. For example, a family of 4 may want the large room, a business group may want an executive room and a group of college students may want a room on sharing basis. Not being able to provide different types of rooms will result in the loss of potential revenue. (Sharly, 2019)

Importance of the restaurant in a hotel

Both hotels and their visitors benefit from a high-quality on-site restaurant. The restaurant's appropriate mix of fresh fare and eye-catching decor will make stays more convenient and memorable.

Examine your hotel's culinary options with a critical eye and consider how you can improve. What's more, how can you improve your hotel's dining experience to attract more guests? You'll be astonished by the benefits it provides to both you and your clients once you've done so.

It offers a memorable experience: Hotel guests want their stay to be an adventure in and of itself. A hotel is no longer only a place to sleep at night. Bookers want the entire event to be an event, right down to the on-site dining options. They'll typically spend top bucks to stay at your hotel if it provides everything they want.

Safe and practical: Having an on-site hotel implies that guests are more likely to stay for dinner, beverages, and dessert. As a result, no one needs to be concerned about getting to and from a nearby restaurant or pub. Instead, they can eat and drink safely before returning to their rooms without ever getting behind the wheel of an automobile. (Morch, aremorch.com, 2020)

LPP

A hotel has free area of 100 units of space and a budget of 100 units of money. It has to option, either make rooms out of it or make restaurant table area out of it. A room takes 5 units of space to make and a restaurant table takes 2 units of space to make. A room takes 3 units of money to make and a restaurant table area takes 4 units of money to make. A room yields a profit of 2 units of profit and the restaurant table yields a profit of 1 unit of money per day. Using this an LPP problem can be formulated to determine as to how many units of each

should be made so that the hotel can earn the maximum profit, assuming the rooms and restaurant will be fully occupied.

Constraints

- Space

A room takes 5 units of space to make and a restaurant table takes 2 units of space to make. It has a total of 100 units of space to use.

- Money

A room takes 3 units of money to make and a restaurant table area takes 4 units of money to make. It has a total of 100 units of money to use.

Objective function

To maximize profits by considering the best combinations of the two, rooms and restaurant seating to be made. A room yields a profit of 2 units of profit and the restaurant table yields a profit of 1 unit of money per day.

Formulation

Let x_1 be the quantity of rooms made & x_2

be the quantity of restaurant seating made

To Maximize $Z = 2X_1 + X_2$

Subject to constraints:

$5X_1 + 2X_2 <= 100$

$3X_1 + 4X_2 <= 100$

$X_1 > 0$

$X_2 > 0$

Solution

The management must take into account constraints and the objective function in order to maximise profits and identify the best combination of the two variables (Rooms and Restaurant table area). The best approach is to have 14 units of rooms and 14 units of restaurant table area, which will result in a maximum profit of 42 units. Region A being the feasible area
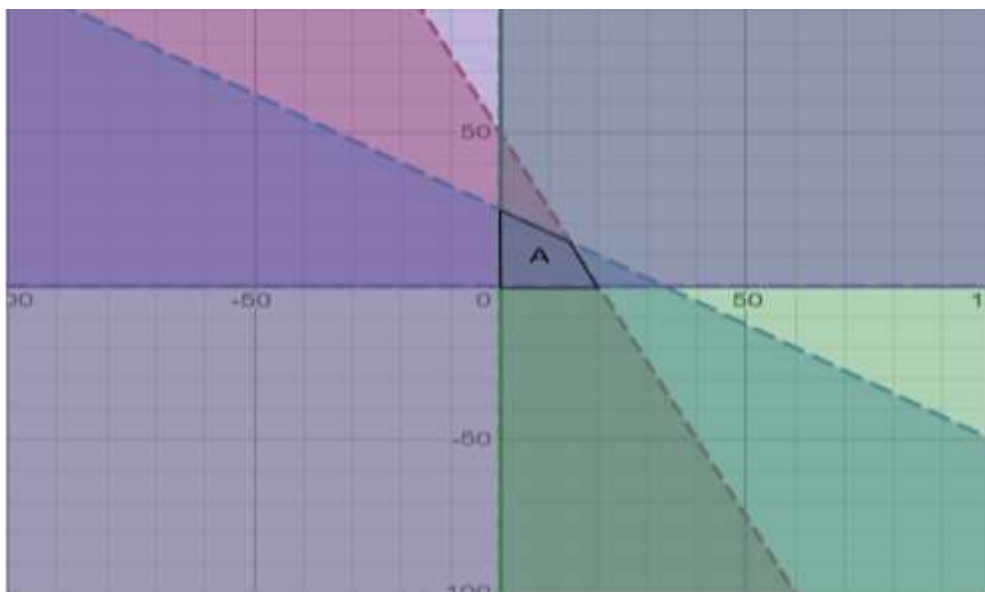
Demand Management

Demand Management refers to synchronization of the demand of a product with the its supply. It involves forecasting the demand for the product through the buying history of the customer and matching the supply of the product to the forecasted demand. Demand management also involves improving the performance indicators for demand.

In case of hotels which offer services of a staying facility in the form of rooms, the supply cannot be changed. Once the number of rooms in the building have been decided they will remain fixed. However, hotels can still control the customer's demand and ensure it is close to the supply but not equal to it. Doing so endures that if demand rises beyond the levels predicted then spare rooms will be present to fulfil such demand.

Various demand forecasting models have been developed, however their applicability in hotels remains largely unexplored. In this paper we have explored clustering analysis specifically (Wilson):

1) Clustering Analysis

This method involves analysing data by clustering the similar kinds of points or objects of a data set. The points clustered are based on their proximity to each other based on the parameters given in the data set. Even under clustering analysis different types exist out of which Density-Based Spatial "Clustering of Applications with noise(DBSCAN) has been identified to be more efficient for market segmentation" (Bose, Munir, & Shabani). "In this method different data variables are clustered based on their density which is determined by the distance of the data variables from each other (can be calculated using Euclidean Distance, City Block distance etc.). The DBSCAN method is also used to identify noise/outliers which refers to those data variables which cannot be mixed with the existing clusters as they are far apart from these clusters and are representative of abnormalities or extreme situations that may have occurred)" (Dobilas). Furthermore, the clustering analysis for hospitality industry will be different from other industries due to its uniqueness in terms of its coherency and predictability. Using this method will help hotels divide their customers into distinct homogenous clusters on the basis of a characteristic . A relationship between different observations under one cluster can be defined by taking the centroid of the cluster being looked into. For example, the figure given below has been plotted from the following data(it is to be noted that the data given is synthetic):

CUSTOMER NO.	AMOUNT SPENT(in dollars)	COUNTRY
1	60,000	USA
2	56,000	USA
3	15,000	Bangladesh
4	10,000	Bangladesh
5	40,000	India
6	37,000	India
7	18,000	Afghanistan

Source: The Authors
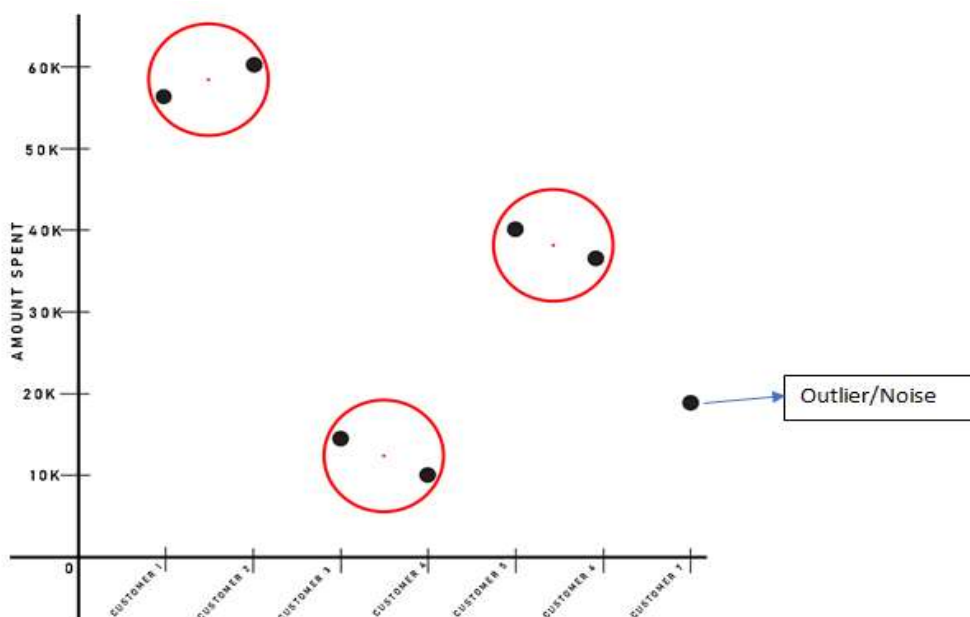
Source: Authors

In the figure the bigger red circles are considered to be the boundaries of the clusters. The clusters taken here are based on the assumption that at least 2 observations should be there in each cluster and the radius of the circle should be 5000 units as per the scale taken on Y axis. Each cluster has a centre point depicted by the smaller red circle which is representative of all the observations in one cluster. We can also see that customer 7 who belongs to Afghanistan is an outlier here because the cluster cannot be formed according to the given information. What this figure implies is that people belonging to US will spend 52K-62K dollars on hotels, consumers from India will spend around 33K-42K dollars, those from Bangladesh will spend 7K-17K dollars. Since customer 7 is an outlier observation and we cannot draw any concrete interpretations from it because of its uniqueness in the data set given. Thus, clustering can be useful for hotels to identify what their target consumers should be according to the amount they are willing to spend, which in other words is demand.

VI.   FINDINGS

On researching about the impact of COVID-19 pandemic on the hospitality industry, we came across the different models implemented by the different researchers to combat the impact of COVID-19 on the hospitality industry. These methods include:

1. Agent-based model
2. Susceptible exposed infected recovered model
3. Epidemiological model
4. Dynamic stochastic general equilibrium model
5. Seasonal autoregressive integrated moving average model
6. Scenario analysis
7. Trend analysis

All these methods have helped in forecasting the trend of the corona-virus in different parts of the world. Proposals for post-COVID-19 management have already been made in the tourism and hospitality industry.

These include:

(1) focus primarily on domestic tourism;

(2) ending mass tourism and pilgrimage tourism;

(3) focus more on conference tourism, virtual reality tourism and medical tourism

(4) building a more sustainable hotel and tourism industry rather than returning to normal.

Coming to the results of Linear Programming Problems it was found that hotels should have restaurant seating and hotel rooms in 1:1 ratio so that its easier for them to accommodate the guests and provide food and service. In the case the hotel is fully booked, everyone staying in the rooms will be able to dine in at the hotel restaurant. If the rooms are more than the restaurant seating capacity, it's likely that some guests will have to eat outside the hotel or will have to order in which has a higher cost due to service charges. If restaurant capacity is more than the number of rooms, the restaurant seating won't be optimally utilised. Talking about the various models and the various methods under these models which can be used to forecast demand for hotels to help hotels get an idea about their customer's preferences. All of the aforementioned models can definitely work in helping hotels ease and increase the accuracy of the process of forecasting demand. However, these models only provide a glimpse of the actual number of models available for forecasting and the other ones are just as if not more viable as these ones.

VII.   LIMITATIONS

1. In case of secondary data analysis, the researcher does not know exactly how the data collection process was done and how well it was done.
2. Since the researcher did not collect the data, he or she has no control over what is contained in the data set which can often times limit the analysis or alter the original questions the researcher sought out to answer.
3. There are a lot of variables that need to be considered while using different models and inaccuracy of any kind can lead to drastically different results.
4. No method exists that can give reliable results with 100% accuracy every time it is used.
5. Due to paucity of time all methods were not explored as extensively as they could have been.

6. Absence of extensive technical knowledge and skills in the fields of hospitality and operations research.

VIII. CONCLUSION

The hospitality industry is one of the biggest sources of employment in the world which needs effective and efficient management. With the help of various models provided by operational research, managers can increase the level of efficiency and productivity. The hospitality industry is among the hardest hit industries by covid-19 as people were restricted to go out and had to avoid going to public places. We have identified various models implemented by various researchers which helps in forecasting the trends, creating simulations, measuring the impact of Covid-19 in economic terms and providing proposals for post covid-19 management as it has had an irreversible impact on the world. For better accommodation it has been identified that hotels should have restaurant seating and hotel rooms in 1:1 ratio and various forecasting models have been identified to provide a better idea of consumer preferences which provide a better understanding of the demand and how to fulfil the consumer demand. Furthermore, utilising simulation models will help the hospitality industry minimise the damage they receive from uncertain events like the pandemic. Lastly, making methods sustainable is crucial for businesses and algorithms like the Bellman Ford Algorithm can be used to create a mathematically optimal model for ensuring sustainability in their daily operations.

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