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Application of Operations Research in Cruise Industry

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Abstract: *In this paper, we explore the power of Operation Research in maximising efficiency in the cruise-industry, an industry which is growing at a breath-taking pace and opening up new opportunities for managers to use OR to bring about a transformation in the modus-operandi of operations. Cruise Industry is called “the golden industry floating in the golden waterway” and signifies the future prospects of the industry. Our objective was to identify the problems in management of cruise-liners and then devising ways in which these issues could be alleviated through the use of quantitative techniques to arrive at a reliable solution. We identified ways in which the cruise-liners can make use of Linear Programming Model in Revenue Management, Analytical Hierarchy Process (AHP) in route selection and other prospective tools to aid inventory control, crew scheduling and waste management. All these tools facilitate decision making for the manager however no quantitative data has been used in this research paper to model the proposed solution*

I. INTRODUCTION

“High speeds, a fatal wrong turn, cut costs, weather conditions, a dismissed key iceberg warning and lack of binoculars and lifeboats all contributed to one of the worst maritime tragedies.” i Was the reason behind Titanic sinking inefficient management or lack of rescue resources or bad planning since the beginning? We can answer all these questions by doing an in-depth research about operations industry in the cruise industry. (Pruitt, 2018)

A cruise ship is a passenger ship used for pleasure voyages when the voyage itself, the ship's amenities, and sometimes the different destinations along the way form part of the passengers' experience. Transportation is not the only purpose of cruising, particularly on cruises that return passengers to their originating port.

The cruise industry of the world has gone through a number of changes in the past many years from the first cruise ship i.e. Prinzessin Victoria Luise of Germany built in 1900 to Harmony of the Seas built in 2016. Back in the day, cruise ships included features like a library or a gymnasium at most but today, cruising is all about a luxurious vacation for thalassophiles featuring amenities like a “snow room” on board or “skydiving simulators and observational pods”. ii (Williamson, 2016)

There are several aspects to the functioning of a cruise ship like on-board facilities, funding and financing, crew, safety and security, environmental impact etc and to make sure that there is smooth sailing of such processes it is necessary to have a well planned operations system which is implemented only after conducting an industry wide deep operations research.

The central objective of operations research is optimization, i.e., “to do things best under the given circumstances.” This general concept has great many applications, for instance, in agricultural planning, biotechnology, data analysis, distribution of goods and resources, emergency and rescue operations, engineering systems design, environmental management, financial planning, health care management, inventory control, manpower and resource allocation, manufacturing of goods.

Through this research paper we aim to understand how cruise liners plan their operations, the various models of management science used in the planning and how they can achieve maximum profits with minimum costs without compromising on factors like safety etc. (Preble, 2017)

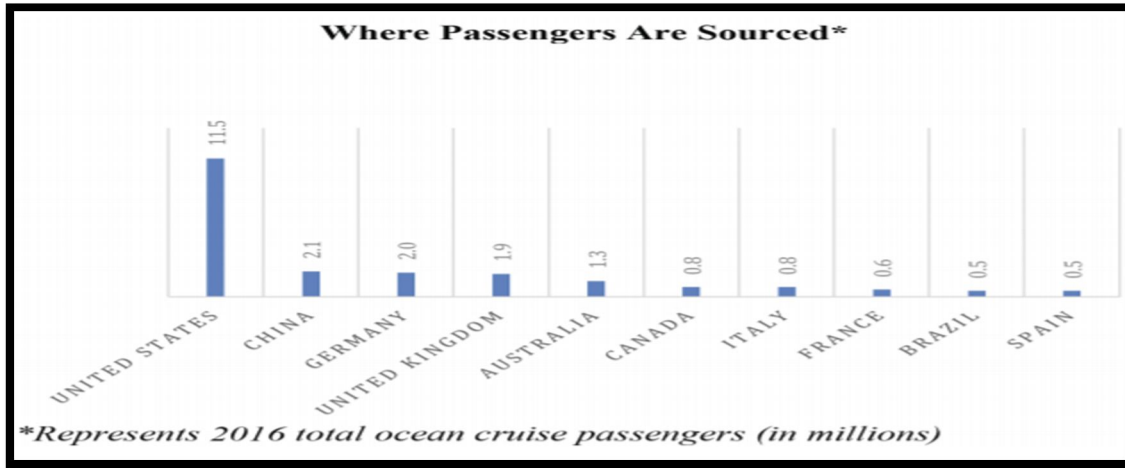
II. OVERVIEW OF THE INDUSTRY

From recent data, it is found that the CRUISE INDUSTRY is the fastest growing industry in the leisure travel market or the tourism industry. The industry is still young in its current stage and has strong potential to boom. The industry suffered a major revenue fall during the 2009 global recession but it made a significant recovery soon.

The changing pattern of vacations of travelers, the cruise lines have started offering different and new themes and packages to attract more people to come on board.

The following data is about the cruise industry in the year 2018: (Cruise Lines International Association (CLIA), 2019)

- 1) Revenue of Cruise Industry Worldwide – 35.5bn USD
- 2) Number of lower berths in the global cruise industry – 520,000
- 3) Average revenue per passenger worldwide – 1,779 USD

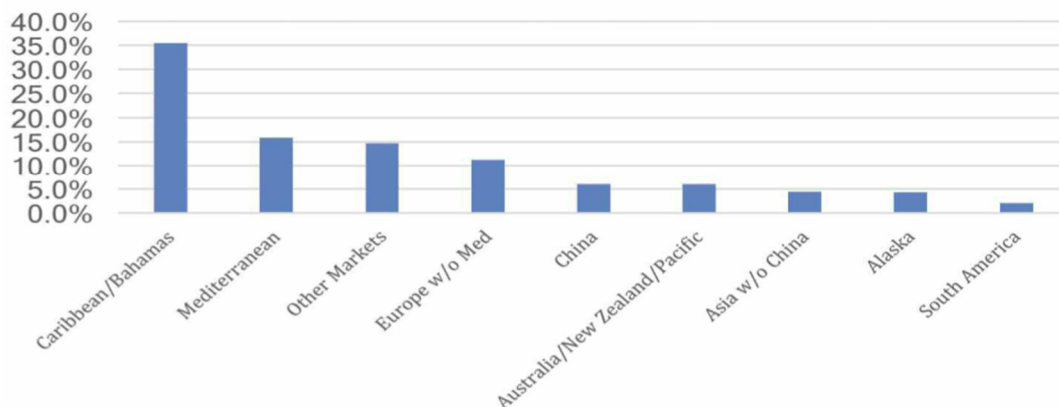


Cruise ships are the passenger ships which make voyages pleasurable because of the ship’s amenities and the ports (stops during the voyage). All these add to the passenger’s experience. The main purpose of these cruise ships is not transportation. In closed-loop voyages, cruises take the passage back to their originating ports. But the dedicated transport-oriented ocean liners on the contrary do not undertake round trips. They typically transport passengers from one place to another. The only dedicated transatlantic ocean liner in operation as a liner as of December 2013 is Queen Mary 2 of the Cruise Line. She also has the amenities of contemporary cruise ships and sees significant service on cruises. As of 2019 the world’s largest cruise-ship was Royal Caribbean International’s Symphony of the Seas along with its three sister ships Harmony of the Seas, Allure of the Seas, and Oasis of the Seas which round out the top 4 largest cruise ships in the world.

Some statistics showing the Cruise industry overview: (The Florida- Caribbean Cruise Association, 2018)

- a) 25.8 million passengers cruised globally in the year 2017 and this was a record in comparison to the previous years. This record led to the passengers’ estimation for 2018, which was an all-time high of 27.2 million.
- b) In 2016, the cruise industry made \$126 billion in total economic impact. There was high employment generation and there were 1 million jobs paying \$41 billion in wages and
- c) salaries. Demand for cruising increased 20.5% from 2013-2018.
- d) From a capacity standpoint, utilization is consistently over 100%.
- e) The cruise ship order book from 2018-2025 includes 50 new ocean-going vessels from FCCA/CLIA member cruise lines, representing 220,000 lower berths and an investment value of \$51 billion.
- f) 8 out of 10 CLIA-certified travel agents expect increased cruise sales in 2018. (Kai Wang, 2016)

2017 Deployed Capacity Share



The cruise business aims to provide cruise passengers with an inexpensive and fun vacation on cruise ships. To scale down cruising value and thenceforth slow down cruising price tag value, huge investments have been made and are incessantly made by cruise lines to boost their cruise ships' waste-disposal systems, fuel potency, back-up power systems, propulsion and safety generally.

Some of the essential aspects which we need to look to know more about the management of the cruise industry are:

- 1) *Regional Analysis*: The situation, development and trends in the cruise industry are studied for different regions and then do the analysis that helps in identifying the regions that are having higher demands for cruise liners than other regions.
- 2) *Risk Management*: This is critical for the safety of the crew members, the passengers and the cruise. If some accidents happen, then thousands of passengers travelling in cruise ships would fall prey to an unpredictable disaster. Proper and frequent assessments to avoid human error to the limit possible.
- 3) *Environmental Concerns*: It is not ecotourism. This industry incurs some environmental concerns like pollution cases: ship emissions, oil leakage and waste water. Thus, regulations have been made by the IMO (International Maritime Organization) to limit the pollution by the cruise industry. (Lock, 2018)

There is a broad scope in this industry to do research on areas like Cruise Fleet Management, Cruise Ship Deployment, Cruise Itinerary Design, Cruise Service Planning.

III. RESEARCH OBJECTIVES

- 1) To understand the growth in Cruise Industry, which in the last five years alone has grown by over 20%, coupled with an annual occupancy percentage exceeding 100 percent. This passenger growth shows sustained consumer interest in cruising and an industry where demand continues to outpace its supply.
- 2) To find out operation techniques that can help better key areas in the cruise industry such as revenue management, crew scheduling, waste management, inventory control, price fixing, disaster management and other various functions. (Thompson, 2011)
- 3) To Elaborate on how Cruise industry has some similarities with other industries like aviation and hospitality. We will amalgamate the techniques used in all these industries to develop a structure that can help in increasing the efficiency of the cruise in terms of human capital and cost effectiveness. (Etschmaier, 1974)
- 4) To outline the research questions which were explored in this research paper:
 - a) Can the efficiency of the cruise industry be increased or is it at its optimal level?
 - b) Can other industries be integrated together to form a single industry which has the benefits of both of them?
 - c) Can such techniques be employed that will not only be cost effective for the organization but also provide a greater service to the consumers?
 - d) How does the future of the cruise industry look in such a competitive travel market?
- 5) To describe the relevant operation technique and figuring out how can they be implemented in the operations and functions of the cruise industry.

IV. RESEARCH METHODOLOGY

The research was conducted with the objective of analysing the cruise-liner industry in depth and deploying ways in which the industry can improve its efficiency. To aid this analysis, various research papers were used along with articles from various websites and reports released by consulting firms. These credible sources formed the foundation on which we have built this research paper helping us analyse some critical elements in the cruise industry and understand the nitty-gritties and peculiarity of cruise industry.

- 1) *Tools*: Operations Research technique to maximise revenue by implementing Linear Programming Problem (LPP) in Revenue Management and AHP technique for route selection decisions
- 2) *Analysis*: In this section of the paper, we aim to analyse the aforementioned tools and describe them in detail to get a crystal clear idea of how to implement these tools in the real world especially in the cruise industry.

A. Using Analytic Hierarchy Process (AHP) for Cruise Route Selection

Cruise route selection aims to select those routes that yield the maximum revenue for the company in light of the available time window and the duration of the voyage. In recent years, the cruise industry has garnered the attention of the tourists and has shown a growth rate of approximately 8%. An optimal cruise route selection can contribute in developing more practical routes, attracting more tourists and increasing the rate of use of ports. We use Analytical Hierarchy Process (AHP) for devising plans for cruise routes.

Cruise route planning involves three problems that need to be addressed, the selection of ports of call, the sequence of ports of call and the route revenue management.

Analytical Hierarchy Process is suitable for complex decisions which involve the comparison of decision elements which are difficult to quantify. It involves building a hierarchy (Ranking) of decision elements and then making comparisons between each possible pair in each cluster (as a matrix). This gives a weighting for each element within a cluster (or level of the hierarchy) and also a consistency ratio. By using fuzzy comprehensive evaluation based on AHP to evaluate the coastal ports, we can obtain a ranking for each port. Then, based on the principles of asymmetric links, shortest path, and maximum flow, practical routes are obtained using MATLAB modelling. Lastly, for small and large – scale port collections, the paper uses the traversal algorithm and the randomised algorithm respectively to obtain the practical routes.

The objective function of the model consists of income and cost, wherein income needs to be maximized and cost needs to be minimized. Income consists of the revenue generated from the sale of tickets to the passengers, while cost comprise of cost of fuel, port charges, tourism cost etc.

The Objective Function:

$$\max f(c_{pi}, \sum_i \sum_j x_{ij} \cdot d_{ij}) \cdot Q - \sum_i C_{pi} \sum_j x_{ij} - C_{r1}$$

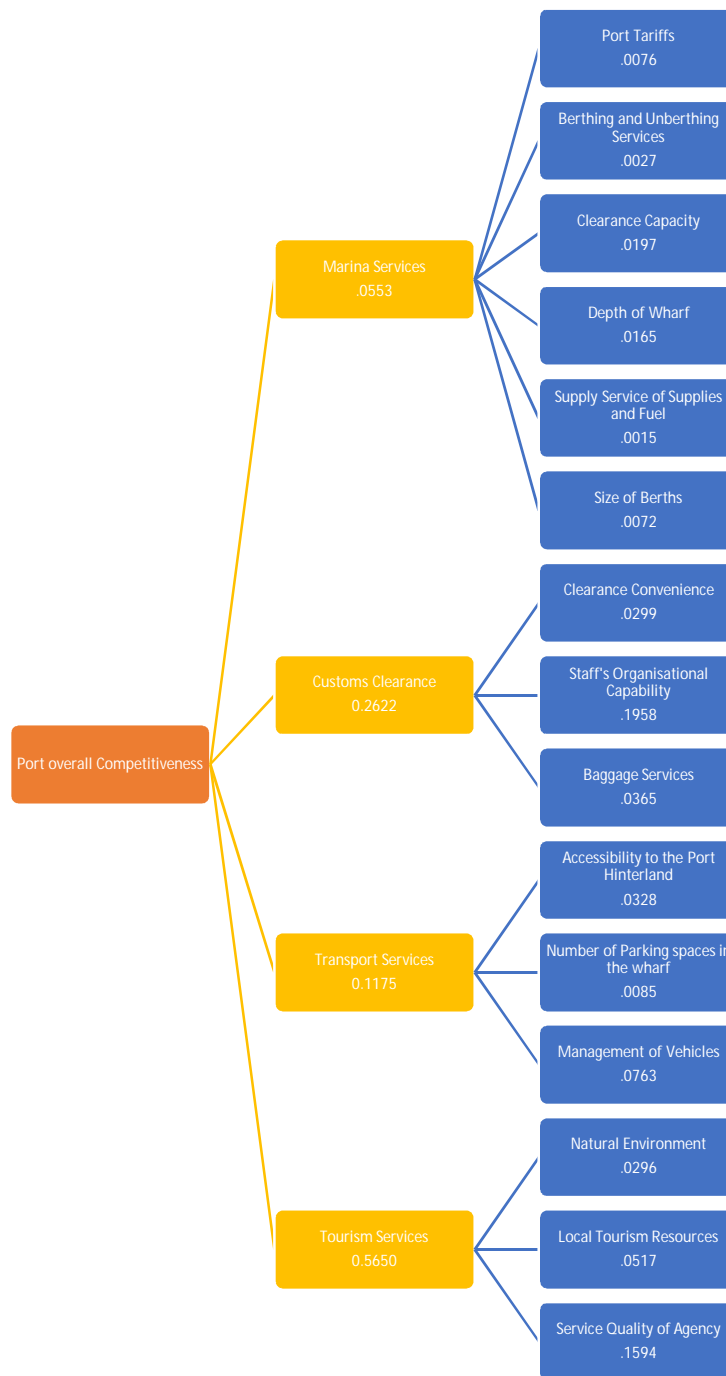
$$\frac{\sum_i \sum_j x_{ij} \cdot d_{ij}}{v \cdot 24} - C_{r2} \cdot \frac{\sum_i t_i \sum_j x_{ij}}{24} - C_c \cdot \frac{\sum_i t_i \sum_j x_{ij}}{24} - C_l \cdot Q_s$$

$$\left(\frac{\sum_i \sum_j x_{ij} \cdot d_{ij}}{v \cdot 24} + \frac{\sum_i t_i \sum_j x_{ij}}{24} \right) - C_f$$

$$\left(\frac{\sum_i \sum_j x_{ij} \cdot d_{ij}}{v \cdot 24} + \frac{\sum_i t_i \sum_j x_{ij}}{24} \right)$$

B. Process of Using Analytic Hierarchy Process for Route Selection

- 1) Firstly, the port of call is selected based on the following factors – The marine services, customer clearance services, transport services and tourism services.
- 2) For selection of the cruise port, fuzzy comprehensive evaluation method based on AHP is used to assess the alternative ports. The elements of port selection are first classified by AHP and the last layer of elements is regarded of consisting the calculated indices.
- 3) Formulation of Design Principles based as per the problem that needs to be solved. The Design Principles for the cruise route selection involves the following:
 - a) The port of call needs to be chosen by considering various factors such as depth of the wharf, maximum tonnage and port charges.
 - b) Clearance convience and organising ability is considered while assessing customs services
 - c) Parking space and traffic while assessing the transport services.
 - d) Availability of travel agencies, local scenery and tourism policy are to be considered while assessing the tourism services.
 - e) It is assumed that the ship will only travel at night while the passengers are sleeping because if the ship arrives at the port of call at night, then most of the tourist attractions will be closed and the tourist would waste their time on board.
- 4) Finally, an index is prepared which takes into consideration all the parameters on which all the ports of call have to be evaluated. Following which the ports are ranked in order of maximum points scored by each port. (L.Olson, 1988)



C. Limitations of Using Analytic Hierarchy Process

- 1) **Problem Structuring:** A different structure may lead to different rankings. Several authors have observed that a criterion with a large number of sub categories tends to get more weight than a criterion with less details.
- 2) **Lack of Consistency:** It has been observed over the years that the model tends to give contractor results to an input. These contradictions are not observed at the time of designing the model but sometime later when the results are not as they were expected.

It can just settle direct models that is one whose yield is specifically corresponding to its information and it cannot unravel non-straight models that are whose yields are not straightforwardly corresponding to its information. (Olson, 1988)

D. Using Linear Problem Programming (LPP) for Revenue Management

Revenue management aims to maximize a company’s revenue by optimally allocating customer requests to a limited capacity. The airline industry strives to perfect this technology and still constitutes RM’s most important application area. Although, Revenue Management is predominantly used in Airline Industry to maximise revenues, the Cruise Liner industry has not yet adopted RM techniques to maximise their revenues. Linear Problem Programming in one such way in which firms can make use of Revenue Management. (Rao)

The basic question arises during application of OR (Operational Research on RM (Revenue Management) are as follows:

1. Is the current method which we use for revenue management gives optimal output?
2. Is the resource available with us for applying linear programming is sufficient for revenue management?

A typical mathematical problem consists of a single objective function, representing either profits to be maximized or costs to be minimized, and a set of constraints that describe the decision variables. In case of a linear program (LP), the objective function and constraints are linear functions of the decision variables. Objective Function (Maximize or Minimize) (Xiaodong Suna, 2009)

The Objective Function (Maximise or Minimize)

$$Z = C_1X_1 + C_2X_2 + C_3X_3 + \dots + C_nX_n$$

Non – Negative Linear Constraints

$$a_{11}X_1 + a_{12}X_2 + \dots + a_{1n}X_n (\leq \text{ or } \geq) b_1$$

$$a_{21}X_1 + a_{22}X_2 + \dots + a_{2n}X_n (\leq \text{ or } \geq) b_2$$

$$a_{m1}X_1 + a_{m2}X_2 + \dots + a_{mn}X_n (\leq \text{ or } \geq) b_m$$

Linear programming is widely used in mathematical model that can solve various problems with thousands of variables. For a linear program, the objective functions and constraints are required to be linearly related to the variables of the problem. (Kashyap M. Gupta, 2014)

Elements of Linear Programming Problem

Objective Function:

The objective function in case of cruise liner will be to maximise the revenues by setting an appropriate price for various categories of rooms namely Interior, Ocean View, Balcony and Suites. The goal will be to set a price based on the forecasted demand for the rooms and thus enabling companies to maximise their revenue. For example if there are 500 interior rooms, 1000 Ocean View rooms, 150 Balcony Rooms and 50 Suite rooms with decision variable set as price for these rooms as x1, x2, x3, x4.

Maximise $Z = 500X_1 + 1000X_2 + 150X_3 + 50X_4$.

E. Constraints

In mathematics, a constraint is a condition of an optimization problem that the solution must satisfy. Based on all the constraints, we get a feasible region, which is a set of points which satisfy all the constraints. Important component of using LPP model is able to forecast demand for the cruise ships so that appropriate pricing is possible in peak season and off-season. Since cruise ships forms a part of tourism industry, the demand is highly seasonal with spurt in demand during summer breaks and slump in demand during other periods. The best approach is to charge a significantly higher price for rooms when there is a surge in demand and lowering down the prices in other periods to stimulate demand. A pre-requisite to using LPP efficiently is having well-structured models and techniques to forecast demand in the future. Forecasting techniques play a crucial in determining whether we achieve success in pricing the rooms correctly based on a scientific OR approach. Traditionally, the prices for the rooms were based on the notions and beliefs of the managers of the ships and there were times when the pricing went horribly wrong because of some preconceived notions of the managers. This was a very subjective approach to pricing the rooms. In the 21st century, with the advent of highly powered digital computers and employing a set of people who are having the skill-set to deploy OR in real world, organisations can take various decisions objectively which increases the probability of greater revenue and increases the reliability and accuracy of the forecasts.

V. LITERATURE REVIEW

Based on various research papers and research done from a wide array of sources, it was observed that Cruise-industry is an industry which is growing at a brisk pace and is setting new trends for 21st century tourists. Despite experiencing growth, the operations of a cruise-liner are fraught with complexities and uncertainty forms a part of day-to-day routine. The manager has to work under massive stress trying to balance out superior customer experience and cost incurred to offer the service. Our analysis below highlights some of the areas where Operation Research can be used in cruise liners. Inventory control is a major requirement in cruise-liners. (Anonymous, 2017) Inventory in cruise-liners comprises of stocking liquor in the bars to having enough groceries and

perishables in stock to cook food for thousands of tourists and crew members for multiple days to having on-board linen for state-rooms. Inventory Control technique like Economic Order Quantity can be applied to balance out the cost of ordering the merchandise and the cost of storing the merchandise. It helps the managers to identify the amount of inventory to be carried on-board. (TARVER, 2019) OR can also be deployed for having a safe and environment-friendly waste management procedures. It includes using proper flow diagrams to analyse how should the waste be transferred to appropriate centres for treatment. Classification of waste gets imperative so that waste can be treated at the incinerator as per the best means to get it disposed with minimal harm to the environment. (Valentina-Mariana, 2018) Important aspects of management in cruise-industry is the process of housekeeping, supplying necessary inputs, guest arrivals and departures and producing food and beverage. Other areas of Application of Operation Research include Crew scheduling, Revenue Management and Route decisions and these are dealt with detail later on in the research paper. (Stanisic, 2015)

Cruise industry is in fact setting benchmark for various other customer-facing industries like hospitality when it comes to providing customers with a mind-blowing experience. When it comes to the future of customer experience, there are few better businesses to watch than cruises: Once at the forefront of compelling passenger experiences, operators now seek reinvention in an increasingly competitive market. (Toporek, 2013)

Cruise operators not only must inject digitally enabled passenger experiences into existing large-scale capital investments, but they should also forge ecosystems via co-opetition (cooperative competition), where cruise operators collaborate with travel, hospitality, and tourism competitors in their ecosystem. Customer experience will influence how cruise operators either flourish or die.

Today's competitive market is heightened as operators navigate changing cruise passenger demographics. Younger generations, who rate cruises as their favorite type of vacation, are demanding enhanced features and a wider array of unique experiences. As millennials embark on their first cruises, they have an appetite for heightened personalization and customization as compared to prior generations. In response, cruise operators are seeking to one-up the competition by adding more and more unique attributes to ships. High-quality restaurants, modern fitness facilities, and even sustainable practices are no longer enough to earn cruises a five-star rating. This cruise industry analysis explores how cruise operators can raise the bar on passenger experience to attract new demographics of passengers to the cruise industry. (Deloitte.)

The passenger-first framework



VI. FINDINGS

Extensive research conducted on the cruise industry and various Operations research technique helped to derive few critical trends and patterns in the industry overall. Findings from this paper would prove to be quintessential to ensure that cruise-liner companies can flourish in this fast-growing yet competitive industry with few players dominating the market.

Since this is a relatively new industry, the managers have still not been able to decode ways in which service can be provided with least-possible cost. Thus, there is a great potential to implement OR in this industry and reap the benefits of the same and attain a sustainable competitive advantage. Major areas of operations in a cruise-liners includes housekeeping, inventory management in restaurant and bars, crew scheduling, route selection, disaster and waste management. Some of the ways in which OR can be used has been explained in detail in the prior part of this research paper.

The managers are making constant efforts to make progress in the aforementioned fields so that it can pave way for future profits of the organisation and help them capture a significant portion of the market by providing top-notch service. Potential to become the market leader is huge, but can the managers make guided efforts in the field of Operation Research to achieve this feat?

VII. CONCLUSIONS

Based on the information collated, it is very evident that there are immense opportunities available to unleash the true potential of Operation Research in day-to-day business activities. Managers can use sophisticated and scientifically proven quantitative techniques to ensure that efficiency is embedded in the culture of the organisation enabling them to reach new height. Operation Research can help managers identify and deploy unique techniques to save costs and maximise revenue in ways that were almost impossible to recognize and implement otherwise.

Although the cruise industry is growing at a breath-taking pace and attracting thousands of tourists from all over the world, the C-Suite executives have still not adopted Operation Research extensively to bring about a transformation in the way they do things. Operations of cruise involves a culmination of various different activities which ensures that each and every customer has a memorable relationship with the cruise-liner. (WARTSILA)

From the above analysis and research, we can understand the ways in which Operation Research is applicable in almost each and every field and has no bounds. From analysing sweet-spots to find oil and thus facilitate mining to space exploration to Formula-One races to Inventory Control to energy efficiency. OR is everywhere. (Jain, 2017)

This research paper also eludes to the fact that the managers of the cruise industry are positioned at a pivotal stage of their growth journey wherein the future of their company depends on how effectively and efficiently they apply Operation Research. It will either make them or break them!

The aim of this paper was to analyse how operations research can be applied in cruise industry, especially by demonstrating ways in which efficiency can be built into the operations of the cruise right from choosing the appropriate route to disaster and waste management and how decisions on that basis can be made. We have proposed a small problem with certain assumptions and how the OR can be applied in that problem so that business can achieve its various objectives. However due to lack of quantitative data available the extent of change that will be achieved and increase in efficiency attained, we cannot be determined and thus further analysis is required to decide whether this model is helpful for the business or not and its impacts. (Megha Gera, 2018)

A. Limitations of Operation Research

Throughout our journey of making this research paper, several challenges were encountered and the same are mentioned below: (AdminMDN, 2018)

- 1) Inadequate technical knowledge about some of the OR techniques
- 2) Difficulty in getting quantitative data to test our model
- 3) Difficulties in dealing with complexity of Operation Research
- 4) Access to digital and powerful computers
- 5) Qualitative factors like the prejudice and preconceived notions of the manager couldn't be considered.
- 6) The primary data was unavailable for some of the research tools

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