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A study on applications of operation research in the airline industry

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ABSTRACT

Operations research is the application of scientific and mathematical methods to study the problem-solving and decision-making aspect which is useful for the management of organizations. The discipline of operations research has greatly contributed to the aviation sector. It is one of the fastest growing sectors globally, adding a lot of value to the economy. This paper is an effort to study and analyze the various problems faced by the airline industry using the applications of operations research. The most common problems are fleet assignment, tail assignment, airline scheduling, airline overbooking, disruption management, airline maintenance planning, demand management, operational performance, airport de- icing. We'll analyze, review and give suggestions for the operations research tools and models used by various researchers across the world to solve the problems. This paper also talks about the lack of management system, efficiency of various airlines in India, minimizing the operational cost in fleet operation and the evaluation of Brazilian airlines. The data for this research paper has been collected usingsecondary research, by means of existing research papers, articles, reliable websites like Statista, economictimes etc.

Keywords: *Operations research, Airline industry, Fleet assignment, Tail assignment, Airline scheduling, Overbooking, Disruption management, Demand management, Airport de-icing, Integer LP, rolling horizon algorithm, benders master problem, set partitioning model, column generation, LEA model, CPM, Fuzzy critical path analysis, DEA, Queuing method, TP model, MODI, Hungarian method.*

1. INTRODUCTION

The airline industry provides the only rapid air transportation network to essentially every cornerof the globe, making it an integral part of global economy and business. The global airline industry is estimated to grow at a CAGR value of25.5% from 2022 to 2027. The sector was severely impacted by the COVID-19 pandemic and lockdowns, but as per International Air Transport Association (IATA) the losses in 2022are expected to narrow to $9.7 billion from $42.1billion last year. Employment in this sector will grow by 10.8% in 2022, owing to increased government support in form of investing capital,lowering tax liabilities etc. So, the sector is an important facilitator of economic growth and development, also making it one of the mostcompetitive in the world.

A lot of problems are faced by airline companiesas well as its passengers in the industry.Operations research as a field of study has made major contributions to the industry by giving its several tools and models for the important aspectsand problems like fleet and tail assignment, airline scheduling and overbooking, maintenance and demand management, etc. The OR tools usedby researchers to work on these problems are Integer LP, benders master's program and set partitioning model using CG, Queuing method, DEA, LEA, VAM, MODI, CPM and others. In comparison to previous times, airline companies are getting more profitable as well as the overall flight experience has been improved greatly for passengers, still we should give deep focus to theaforementioned problems and look how we can use operations research tools and models to overcome these issues and make flight experience great for everyone.

2. LITERATURE REVIEW

There have been many O.R tools utilized to solvethe problems of the aviation industry such as - airline crew scheduling, overbooking, fleet assignment, tail assignment, aircraft maintenancerouting, airline revenue management,overbooking models, disruption management, airline delays, minimization of operational costs, etc. It has been also observed that measuring the efficiencies of the airlines is also a major

challenge of the industry that Operations research have addressed.

Airline scheduling

One of the major problems- integrated Airline Scheduling consists of fleet assignment, aircraft maintenance routing and crew scheduling. The paper (1) discusses about several semi-integratedmodels to optimize the same. The scheduling starts with fleet assignment maintenance routing and crew pairing. Although different models were discussed RHA+SP (heuristic approach) approach is concluded to be superior as it could provide the optimal solution in a significantly shorter computational time compared to the method of using only branch-and-cut and heuristics approaches used by commercial solvers.

Airline scheduling has also been discussed in (2)with respect to Air India airline. AIRINDIA's main concern was the lack of a managementsystem. The problem is solved by developing four separate cases (namely, Route Selection, Crew Scheduling, Air India-Transporting numerous items in a one plane, Aircraft Maintenance problem). After using Critical Path Analysis to analyses the airline's aircraft maintenance activities, it has been concluded that CPM is a valuable tool for reducing time elapsed and increasing flying hours, which increases the airline's profits.

The paper (3) deals with the "airline crew scheduling" problem. Since there are certain fixed cost like fuel which cannot be reduced so cutting down the crew cost expenses becomes even more crucial. This problem is divided into two parts- crew pairing and crew assignment. The operations research model proposes in the paper is the Set partitioning model that is solved via column generation (CG). The results show minimizing the total cost of the schedules and penalty cost of uncovered flights using the proposed OR technique.

Fleet assignment optimization

Fleet Assignment Optimization, is a great burdenon the costs of many airline companies.

In fleet assignment, profit is maximized by minimizing two types of costs: operational and spill costs. Here (4) an assignment model is set up, using the linear integer programming, to solvethe optimal fleet assignment problem of the largest airline Company in Turkey, Turkish Airlines. This optimization model helped in minimizing the assignment costs and the numberof aircrafts grounded at each airport, while assigning the right aircraft to the right.

Another paper (5) paper aims to minimize the operational cost of a budget airline's fleet operation. The study used the analytic hierarchy process in selecting the aircraft to be used in the daily operations. And then, the linear programming was applied to find the optimal solution to the flight frequency distribution per aircraft type per route to the proposeddestinations with the goal of minimizing the cost.the paper analyzes the best aircraft to use in the airline's domestic operations in the Philippines, using the analytical hierarchy process as a decision-making tool.

Fleet assignment is also discussed in (6) with respect to the linear programming (LP) method toreduce the airline's daily operational costs while utilizing a fleet of three aircraft types. To optimize daily fleet operations, linear programming (LP) is used. The LP model assignsa flight frequency per aircraft type to a specific route in order to minimize operational costs while taking into account operational restrictions orconstraints.

Tail assignment

(7) Proposed a model for the problem of tail assignments where specific aircrafts (tails) are assigned to flights in a given flight schedule. Hence all individual operations are considered inthe model proposed. The research solves thisproblem of Vueling Airlines – main airlines in Spain, through a mathematical model and a solution approach by identifying optimal solutions in short computational timings.

Overbooking problem

The OR group (8) studied various models and reviewed them before they developed their own model for the overbooking problem of the industry. That OR model maximizes the revenue from passengers, subject to constraint on the proportion of oversales based on the theory of Markovian sequential decision process.Therefore, this simplified Taylor's model was a success and American Airlines adopted it within a year (Rothstein, 2001).

Disruption management

The paper (9) discusses about "disruption management" for commercial airlines, presentedby Amadeus for the ROADEF 2008/2009 Challenge. Disruption management as described in (9) is an approach to the rescheduling of operations following an unanticipated eventoccurring that has been applied in a wide range ofapplications, including airline scheduling and project management. The paper reviewed the most prominent methods proposed by the participants and provided optimal results. The best method is a large neighborhood search method which used operations research applications to carefully handle problems, alternating in an intelligent way various ad-hoc subproblem solving subroutines as well asdescent and diversification phases, which was proposed by proposed by Bisaillon, Cordeau, Laporte, Pasin.

The paper (10) discusses how to minimize delaysand minimize airport congestion, taking in consideration passenger satisfaction and demand; integer linear programming is used which showed room for improvement in congestion in the existing structure, and helped in differentiating between delays caused by insufficient capacity orinsufficient utilization.

Airline schedule and maintenance planning

Other airline industry problems like scheduling and maintenance planning; which are contributing to flight delays; uses fuzzy critical path analysis by using an example of Aircraft GasTurbine Engine to explain this method. The outcome was in favor, and this method resulted inincreasing the efficiency of the workers, and the efficiency of aircraft maintenance services. (11)

To improve on-time performance, without increasing crew costs; schedule perturbation method is used. (12) The study uses 2 different fleets data, solving through different methods of perturbing the schedule. Results show improvement of airline's on-time performance, and showing improvement in operationalperformance under push-back recovery.

Airline efficiencies

The paper (13) about the airline efficiencies. Thisstudy employs linear programming and data envelopment analysis to determine the efficiencyof different airlines operating in the Indian aviation market. This particular study investigated the impact of numerous variables onairline company efficiency, including budget, scaling, and others.

Even the paper (14) talks about the inefficienciesof the Brazil airlines using O.R. To analyze the Brazilian airline industry and provide alternatives for inefficient airlines; a different DEA method (using non-radial index) was used. This study observed a lot of negative efficiencies because the most efficient are extremely scale-size (eithervery big or small), thus, due to this, this method has not managed to adequately deal with the sizeof firms.

Airport De-icing

To tackle difficulties caused by snow and ice conditions that airports and airlines encounter; resulting in considerable financial losses;researchers advise creating a de-icing queuing system model using the queuing method to address the issue. The paper (15) presented a study conducted at an airport in western China that experiences winter snowfall. The outcome was favorable, and this method assisted in reducing operating expenses for airports and airlines as well as saving time.

Therefore, the purpose of writing this research paper is to formulate and answer problems usingOperations Research (OR) approaches-pertaining to fleet, route management, andchoosing prices for the same. Exploration of additional opportunities for dynamic decision- making, integrated aircraft, crew, and passenger recovery planning, and inter-airline capacity exchange mechanisms are all research areas with significant potential impact. Additionally, it aimsto analyze and assess the benefits and drawbacksof employing such a method in various situations.

3. FINDINGS AND ANALYSIS

It can be observed that integrated integer linear programming is the most frequently used tool to solve problems in the airline industry, such as fleet assignment, tail assignment, demand management strategies, fleet operational cost minimization, and many others. It must be noted that LPP in conjunction with rolling horizon methods provides feasible solutions in a short computational time. These solutions are then improved using a heuristic-based approach.

Airline scheduling is among the most pressing airline issues. Column generation is used to solvethe problem. Subproblems of airline scheduling, on the other hand, are solved using various methods such as the benders-masters problem, set partitioning models, and so on.

When different types of goods are transported across the same network, the airline industry benefits by lowering costs and increasing revenues, as well as allowing them to transport multiple items at the same time, reducing travel time. Iterative Dijkstra's algorithm finds the shortest path between any two nodes in a graph.

CPM scheduling is also a popular O.R tool for disruption management and aircraft maintenance planning. The CPM approach is used to calculatethe network's "critical route," which is the sequence of project operations that determines the shortest project time required. CPM is typically used in conjunction with the program evaluation and review technique (PERT) to eliminate the problem of imprecise data (fuzzy sets of data), obtain the critical path, and improve and secure aircraft maintenance services. As a result, CPM is a valuable tool for decreasing elapsed time and increasing flying hours, which increases airline profits, and we also solve the airline problem with various cases. The algorithms can help any aviation industry save time and money while increasing profits.

Airport de-icing can be accomplished using O.R tools such as the queuing method. De-icing and snow removal during ice storms have a significant impact on flight and air service punctuality. The theory of queuing is - icing usedto estimate the number of de-icing machines. Theairport de-icing problem, like the previously mentioned disruptive management problem, is a path optimization problem. The two most common goals associated with de-icing are to find the shortest path between line de-icing devices, the shortest delay path, and the optimal number of de-icing machines to open.

The main advantage of using a queuing model tofind an optimal path over the previously mentioned CPM model is due to two major reasons:

- The nature of the problem: disruption management and maintenance planning deal withambiguous and imprecise data.
- The need to determine the optimal number of de-icing machines to be installed.

However, both the methods used to improve pathefficiencies have effectively reduced the airport'soperating costs.

The VAM and TP models can also be used effectively to solve the problem of disruptionmanagement. The TP Model aims to reduce costsby optimizing available routes from a given origin to a given destination. The Vogel's Approximation Method (VAM) is an iterativeapproach that uses penalties to determine the initial basic feasible solution (IBFS) of a transportation problem.

The DEA O.R tool is also used to assess airline efficiency. There are several methods for measuring efficiency, but Data Envelopment Analysis (DEA) is a non-parametric approach. This O.R tool is typically implemented using theminimization and maximization models, and it can be used to measure the airline efficiencies ofconverting inputs into outputs as well as the scale efficiency. Brazilian and Indian airlines were evaluated using the same O.R. in the research paper. When compared to financial data, the DEAmodel is a simpler way to measure airline efficiency.

Schedule perturbations method are used to improve the operational performances of the crewschedules.

4. CONCLUSION

Operation research techniques can greatly enhance the use of resource. These methods offer easy and effective ways for businesses to make better decisions while saving money, time, and resources.

This research paper provided examples of severalissues that the airline business encounters on a daily basis. The study examines how varioustechniques for operation research can be utilized to pinpoint issues and offer the most effective solutions. The research finds that the linear programming method is quite versatile and may be applied to a variety of issues, including demand management, fleet assignment, tail assignment, and airline efficiency analysis. Schedule perturbation is one of the best techniques for enhancing operational performance, according to this study. The most effective approach for using defrost machines to effectively de-ice airports was the queuing system, which significantly increased the effectiveness of airports during the winter. For aircraft scheduling, the RHA+SP (heuristic method) is seen to be the ideal option because it offers

the greatest result in a noticeably lower amount of computing time. The critical path analysis (CPM) tool is a very useful tool for shortening travel times and extending flight times, which increases airline revenue. Since disruption management is one of the crucial tasksfor the efficient operation of the airline sector, thelarge neighborhood search (LEA) model is a widespread and effective approach for dealing with disruption problems.

Based solely on estimates, these systems create an extremely intelligent and seamless planning process. The input data is a key component of the techniques stated in the study article. Therefore, it can be said that one of the key elements for obtaining the greatest outcomes and solutionswhile employing operation research tools is acquiring reliable data.

5. LIMITATIONS AND SUGGESTIONS

Limitations: The following drawbacks are observed in the above-mentioned methods. And some suggestions are provided to overcome them.

- ***Lack of proper data and numerous assumptions***: While doing extensiveresearch for this paper, we found that the data used to explain the model is partiallyborrowed from the web. Except a few, rest of the data's borrowed have no source mentioned. This leads to making numerous assumptions about the data.The more assumptions taken means that the data is uncertain and should not ideally be used for developing a model inreality.
- ***Costs and revenues for route fluctuates***: Due to high competition and many hosts of costs involved airlines cannot predict the perfect cost. Airline turbine fuel prices are subject to change and due to aneconomic environment, this is leading tolow cost, few crew members. The above presented models are, in some cases, increasing the complexity of it.
- ***Consideration of different environments***: The airline industry is surrounded by Political, Economic, Social and Technological environments, with which comes many contradicting points like shortage of crew members and fuel prices fluctuating etc. The above- mentioned analytical models don't necessarily take these into consideration.

Suggestions:

- The future upcoming research should back the assumptions with qualitative data and should use a more knowledgeable platform for pertinent data. They should keep this in consideration that the cost and revenue fluctuate accordingly.
- Relaxing the walls between different stages of aircraft and crew schedule planning, so that the aircraft problems like: fleet assignment, crew scheduling etc.; can be implemented in an integratedmanner.
- The future studies should reflect the standpoint of customers and the opinionsof outsiders. Air passengers who are sensitive to service quality may have different opinions from those of securitypractitioners.

There are many areas in which research/study canbe improved. There are many additional areas which can be taken into consideration while studying the methods.

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