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MAXIMIZING TOTAL AIRPLANE PROFITABILITY THROUGH JOINT YIELD MANAGEMENT

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ABSTRACT

Yield management, alternatively known as revenue management, can be defined as the integrated management of price and inventory to maximize the profitability of a company. A joint-yield management system for combination air carriers seeks a trade-off between the profitability of passengers and cargo in order to maximize the total airplane profitability, subject to a given payload and belly volume. The objectives of this paper are to introduce the concept of a joint-yield management system and to develop a framework for designing and implementing such a system for combination air carriers.

INTRODUCTION

Yield management, alternatively known as revenue management, can be defined as the integrated management of price and inventory to maximize the profitability of a company. In the case of combination air carriers, or airlines operating airplanes that carry passengers as well as cargo, it is applied to passenger inventory or the number of seats, and cargo space or the payload/belly volume after passenger and bag weight and volume. Passenger yield management is concerned with the management of various passenger fare classes and the available number of seats. Cargo yield management is the management of available space and weight for cargo and cargo rates.

A typical yield management system is expected to generate 3-5% additional revenue. The implementation of a passenger yield management system (called DINAMO) at American Airlines generated an estimated total of $1.4 billion in incremental revenue in 1988, 1989, and 1990. American Airlines estimates that DINAMO will generate at least $500 million annually (Smith, et al. 1992). American Airlines Cargo Division has realized similar benefits (at least 3% additional revenue) after the implementation of a cargo yield management system. Other airlines have reported similar results. Thus, the impact of an effective yield management system on an airline's revenue and profitability is quite substantial.

In practice, the concepts of airline yield management are applied in a hierarchical manner. The hierarchical practice of yield management assumes that passenger profitability is higher than cargo profitability for the equivalent weight. This may not be true in certain segments of a carrier's route network, however. For instance, intense competition from smaller carriers in certain segments may push down the passenger fares, resulting in losses for some larger carriers. The cargo shipping rates may be higher due to the need for several businesses to ship certain perishable items on time. The growing popularity of express or priority shipping services, such as overnight, same day, and next day delivery is another reason.

With substantially low passenger yields and relatively saturated passenger traffic, the ability of cargo to provide additional revenue is becoming important these days. Industry forecasts predict a tremendous growth in cargo demand; world cargo volumes will almost double by year 2005. Hence, it is important to address the issue of jointly managing the total lift capacity of an airplane. A joint yield management system seeks a trade-off between the profitability of passengers and cargo in order to maximize the total airplane profitability subject to a given payload and belly volume. This may result in a higher overall airplane profitability than the combined profitability resulting from separate yield management systems for passengers and cargo.

The concept of joint yield management has not been addressed in the published literature. A few airlines have been practicing this on an ad hoc basis on a few selected segments. Ad hoc applications do not look at the impact of passenger load on cargo capacity on the entire airline network; thus it is only a quick fix for a significantly critical issue. The objectives of this paper are to introduce the concept of a joint-yield management system and to develop a framework for designing and implementing such a system.

A review of the literature is presented in the next section. Then an introduction to hierarchical yield management, a discussion on passenger yield management, and the important differences between passenger yield management and cargo yield management are presented. Alternative frameworks for the development of a joint-yield management system, suggested approaches for formulating and solving the forecasting and optimization models, and related research issues are presented in the following section. Finally, discussions and references are presented.

LITERATURE REVIEW

Some of the important articles in the area of yield management are listed in the references. The number of articles that have been published in this area is relatively small, considering the huge financial impact of a yield management system. This is partly due to the fact that yield management is a strategic tool to increase corporate profitability, and most airlines generally do not publish their yield management approaches, models, and implementation aspects for proprietary reasons.

The development and implementation of a passenger yield management system at American Airlines, and the system's impact on corporate revenue are presented in Smith, et al. [1992]. Belobaba [1987] presents some of the critical issues related to air travel demand and several theoretical approaches to airline seat inventory control. Overbooking, which is one of the critical problems in yield management, is addressed by Bodily and Pfeifer [1992] and Rothstein [1985]. Curry [1990] suggested certain seat allocation procedures based on origin-destination based fare class nesting.

Hendricks and Kasilingam [1992] present some of the challenging operations research problems encountered in the air cargo industry, which includes a high level discussion of cargo yield management. Kasilingam and Hendricks [1993] discuss the development and implementation of a cargo yield management system for American Airlines, which assumes that passenger profitability is higher than cargo profitability. Oakley et al. [1992] address the complexities involved in developing a cargo overbooking model. Kasilingam [1995] addresses the major differences between cargo and passenger yield management systems, and the complexities involved in developing a cargo yield management system. Kasilingam [1995] discussed a cost model for optimal overbooking of air cargo under stochastic capacity. Expressions are derived for overbooking levels under discrete and continuous distributions for capacity.

Cross [1993] presents the application of yield management techniques to other service industries, such as cruise lines and hotels. The generic yield management problem, also known as the perishable asset revenue management problem is addressed by Bodily and Weatherford [1993]. Weatherford and Bodily [1992] present a taxonomy and overview of research in perishable asset revenue management.

Most of the published literature in the area of yield management is focused on models and issues related to passenger yield management. A few articles discuss the operational issues and modeling complexities related to the development and implementation of cargo yield management systems. To date, there is no published literature available that addresses the concept or the practice of managing passenger and cargo inventory jointly.

HIERARCHICAL YIELD MANAGEMENT

An airplane can lift-off with a certain weight (payload) which is available for carrying passengers, passenger bags, and cargo. The main cabin has a fixed number of seats available for carrying passengers and some overhead cabin space for carry-on bags. The belly has space available for accommodating passenger bags and cargo. The number of seats available for sale is managed by a passenger yield management system.

The weight available for cargo sales is equal to payload less the weight of the expected number of passengers onboard, based on passenger yield management controls and passenger bookings, and their bags. The belly volume available for cargo sales is equal to total belly space less volume of passenger bags. The weight and volume available for cargo are managed by a cargo yield management system. In the case of a wide body airplane, the number of positions available for cargo sales is equal to the total number of positions (containers) in the belly less the number of containers required for passenger bags. From now on, the discussions will be in terms of weight and volume. However, all the discussions in this paper that are related to belly volume are applicable to belly positions in a similar manner for wide bodies.

A brief summary of the key features of passenger yield management and the important differences between passenger and cargo yield management systems are presented in the following subsections.

Passenger Yield Management

Passenger yield management is essentially a two-step process designed to maximize airline profitability from carrying passengers. The first step is to overbook the available capacity (number of seats) to compensate for passenger booking behavior in terms of cancellations and no-shows. This is known as overbooking. The second step is to allocate the overbooked capacity to different fare classes and markets in a way that maximizes the total passenger revenue or profitability. This is known as bucket allocation or discount allocation.

Overbooking is the practice of intentionally selling a greater number of tickets than the number of seats to compensate for no-shows and cancellations. The overbooking model considers the costs of oversale and spoilage along with the mean and variance of passenger no-shows and cancellations. Bucket allocation is the process of determining the number of seats to be allocated for each market and fare class on a given flight. This controls the number of passenger reservations by origin-destination and the type of fare a passenger is willing to pay. The objective of bucket allocation may be to maximize revenue or profit subject to certain constraints. These constraints are related to the number of seats that are available for sale and the demand for various markets and fare classes.

Several other support activities are required besides overbooking and bucket allocation, including forecasting passenger demand by market and fare class, forecasting no-shows and cancellations, determining other aspects of passenger behavior, and computing oversale and spoilage costs. Some of the support activities are related to the planning aspects of the yield management system. Others are related to the reservation control and booking aspects of the yield management system.

Passenger versus Cargo Yield Management

Cargo yield management differs from passenger yield management in a number of respects. Three important differences are discussed here.

- Passenger yield management controls a fixed and known number of seats. In cargo yield management, the weight and volume available for sale is not fixed. It depends on the payload, belly space, and the expected number of passengers on board and their bags. In addition to the variability of the expected number of passengers on board, payload is also a variable. It depends upon several factors, such as runways, weather, fuel weight, and ramp weight. Hence, the first step in cargo yield management is to forecast the capacity available for sale.

- Cargo capacity is three-dimensional, i.e., weight, volume, and number of container positions. For instance, when booking a low density shipment, capacity may be available in terms of weight but not in terms of volume.

- Passengers prefer to follow their planned itinerary without being bumped or rerouted. On the other hand, cargo may be shipped along any route as long as it is available at the destination within the specified or agreed upon delivery date and time. This provides flexibility in terms of operation but increases the complexity of bucket allocation models.

The above key differences warrant a special type of yield management system with models more complex than models for a traditional passenger yield management system. For instance, mathematically speaking, the overbooking model should be able to handle the stochastic nature of cargo capacity. Also, the relationship between weight and volume is another important issue to be addressed in all the yield management models. The understanding of the above mentioned key issues is essential to developing a joint yield management framework.

JOINT YIELD MANAGEMENT SYSTEM

A research methodology for developing and implementing a joint yield management system is presented in this section. The various components of the research methodology are grouped into three phases:

Phase I: Development of a Framework for a Joint Yield Management System

First, the various components of a passenger yield management system and those of a cargo yield management system must be identified. Also, the relationship between these components within a joint system must be analyzed. For instance, forecasting the capacity available for cargo for a flight may not be required in a joint yield management system. Instead, it may be required to forecast the payload for a flight. The sequence of yield management steps may be different. For instance, overbooking may be performed after bucket allocation. In other words, the structure of a joint yield management system may be different from that of a passenger yield management system and/or a cargo yield management system.

A detailed analysis of these components must be undertaken to clearly understand the objectives, data requirements, and the underlying complexities of each model. This is required to eliminate, combine, or add a new component for a joint yield management system. In essence, a complete auditing of the various models, tools, and reports used in a passenger yield management system and a cargo yield management system is required.

In this paper, two alternatives are presented for developing a framework for a joint yield management system. The alternatives must be analyzed in terms of ease of modeling, data requirements, and implementation constraints in order to determine the final framework. The first step in both alternatives is to forecast the total payload. Forecasting belly volume and the number of seats is not required since they are known and fixed for a given airplane type.

• For alternative 1, the second step is to overbook the forecasted payload and belly space using passenger and cargo no-show and cancellation behavior and to overbook the number of seats based on passenger cancellation and no-show behavior. The third step is to allocate the overbooked payload and the number of seats to different classes of passengers and different cargo products based on their demand and profitability.

• For alternative 2, the second step is to allocate the forecasted payload and the number of seats to different classes of passengers and different cargo products based on their demand and profitability. The third step is to overbook the allocated number of seats and the allocated cargo space separately, based on passenger cancellation and no-show behavior and cargo cancellation and no-show behavior, respectively.

For overbooking of payload and belly space, passenger no-show behavior is translated into weight and volume no-show and combined with cargo no-show in terms of weight and volume. This is done based on passenger and bag weight, and bag volume.

Phase II: Development of Forecasting and Optimization Models

This phase is concerned with the data requirements for each model, the exact formulations of the models, and the solution procedures to solve the formulations. This phase depends upon the framework, which is an outcome of phase I. The sequence of yield management steps will dictate the exact formulations of the models, and, hence, the data requirements and the solution procedures. For instance, if overbooking is performed before bucket allocation, then payload will be overbooked considering the combined weight no-show due to passengers, bags, and cargo. Otherwise, the space allocated for passengers and the space allocated for cargo by the bucket allocation model will be overbooked separately.

Forecasting Models: Accurate forecasting of payload, demand, and cancellation and no-show behavior is critical to an effective yield management system.

• Forecasting payload will be the first step in a joint yield management system. This may be accomplished using traditional exponential smoothing models with appropriate seasonality indices. Typically, most airlines have historical payload data. By analyzing the historical payload patterns, appropriate exponential smoothing models and model parameters may be selected. Payload can also be forecasted using causal models. Since payload depends on temperature, wind, ramp weight, fuel weight, and a few other factors, regression based causal modeling is another possibility. The selection of a suitable approach, or method, will be based on the performance of the forecasts in terms of bias and accuracy over a given period of time.

• Demand forecast for different passenger fare classes and cargo products at the market level (i.e., origin-destination level) is one of the key inputs for bucket allocation. Depending upon the alternative, the type of demand to be forecasted will be different. For alternative 1, gross demand forecasts are required. For alternative 2, net demand (gross demand less cancellations) forecasts are required. Forecasting demand for various passenger classes and cargo products for all markets will be undertaken using the methods currently being used by several airlines. These methods combine long-term and short-term forecasts using appropriate techniques. Long-term forecasts are obtained using exponen tial smoothing models based on historical data. Short-term forecasts are obtained using pre-departure booking information and historical booking profiles.

• Forecasting of no-shows and cancellations will be undertaken through the use of techniques that are very similar to demand forecasting using appropriate data.

Optimization Models: The formulation and solution procedures for the two important optimization models, the overbooking model and the bucket allocation model, are discussed here.

In alternative 1, overbooking precedes bucket allocation.

- Overbooking must be carried out in three parts. In part 1, payload is overbooked. The required model inputs are forecasted payload and its variance, mean and variance of the combined passenger and cargo booking behavior in terms of weight, and weight oversale and spoilage costs for cargo. In part 2, the belly space is overbooked. The required model inputs are belly volume, mean and variance of the combined passenger and cargo booking behavior in terms of volume , and volume oversale and spoilage costs for cargo. In part 3, the number of seats is overbooked. The required model inputs are the total number of seats, mean and variance of passenger booking behavior, and oversale and spoilage costs for passengers.

- The bucket allocation model is a network-based formulation. The objective is to maximize the combined profitability from all passenger fare classes and cargo products. The total allocated number of seats cannot exceed the 'overbooked' number of seats; the total weight of passengers, bags, and cargo cannot exceed the 'overbooked' payload; and the total volume of passenger bags and cargo cannot exceed the 'overbooked' belly space. The mean and variance of 'gross' demand forecasts for different passenger classes and cargo products for all markets are other required inputs.

In alternative 2, bucket allocation precedes overbooking.

- The bucket allocation model in this case is also a network based formulation. The objective is to maximize the combined profitability from all passenger fare classes and cargo products. The total allocated number of seats cannot exceed the 'actual' number of seats; the total weight of passengers, bags, and cargo cannot exceed the 'forecasted' payload; and the total volume of passenger bags and cargo cannot exceed the 'actual' belly space. The mean and variance of 'net' demand forecasts for different passenger classes and cargo products for all markets are other required inputs

- Overbooking must be carried out in three parts similar to those in alternative 1. In part 1, the weight allocated for passengers, bags, and cargo is overbooked. The required model inputs are payload allocated for passengers, bags, and cargo, the mean and variance of the combined passenger and cargo booking behavior in terms of weight, and weight oversale and spoilage costs for cargo. In part 2, the belly space allocated for bags and cargo is overbooked. The required model inputs are belly volume allocated for bags and cargo, mean and variance of the combined passenger and cargo booking behavior in terms of volume , and volume oversale and spoilage costs for cargo. In part 3, the allocated number of seats is overbooked. The required model inputs are the allocated number of seats, mean and variance of passenger booking behavior, and oversale and spoilage costs for passengers.

In both alternatives, the bucket allocation model must consider the availability of multiple routes between an origin and a destination. It should also address the issue of long-haul shipments displacing short-haul shipments on a leg.

Solution Procedures: The proposed overbooking model formulations may be solved by using the procedures currently available to solve passenger and cargo overbooking models. Modeling of the bucket allocation problem results in non-linear, stochastic programming formulations. These formulations may be solved by using lagrangian relaxation techniques (Fisher [1981]). A simple alternative approach will be to model the bucket allocation problem as a deterministic formulation and solve it using lagrangian relaxation based techniques.

Phase III: Performance Evaluation of a Joint Yield Management System - The performance of the proposed joint yield management system must be compared with that of a hierarchical yield management system. Performance comparison may be based on total revenue, total profit, airplane utilization, or revenue opportunity (Smith et al. [1992]). A simulation based model may be developed to compare the performance of a joint yield management system with the hierarchical system.

CONCLUSION

The concept of a joint yield management system was introduced in this paper. The importance and significance of a joint yield management system for combination air carriers was also discussed. The paper presented alternative methodologies for developing a joint yield management system, and identified approaches to model some of the important components of such a system.

Research efforts are needed to identify the various components of a joint yield management system from the point of view of development and implementation. Extensive studies have to be done to analyze the potential financial impact of a joint yield management system over a traditional hierarchical system, The interesting trade-off between passenger fares and cargo rates under various scenarios of market conditions have to be examined. Specifically, further research is needed to develop fairly sophisticated decision models and solution procedures for forecasting capacity, overbooking, and bucket allocation. It is anticipated that the results from further research in this area will generate a lot of interest from the airline industry, enabling them to take a new look at yield management procedures. Larger carriers may invest a lot of effort and money in designing and developing a commercial yield management system.

There are a large number of planning, operational, and political issues related to joint yield management that need to be identified and analyzed. These issues have to be analyzed with respect to the structure of passenger and cargo departments within various airlines. Airlines have been giving higher priority for passengers over cargo, both at the planning and operational level. The introduction of a joint yield management will force them to perform planning and operation in a non-traditional manner. For instance, load planning and real time aircraft loading processes will be different. The key factor will be profitability of cargo versus profitability of passengers as opposed to just passengers versus cargo. One major political issue may be related to the ownership of a joint system: who controls the system? who will make the decisions in real time under a crisis? Potential conflicts of interests and power politics must be identified and addressed, and efforts must be made for a smooth shift in paradigm

MANAGERIAL IMPLICATIONS

This paper introduces the concept of joint yield management for combination air carriers. With substantially low passenger yields and relatively saturated passenger traffic, the ability of cargo to provide additional revenue is becoming important these days. A joint yield management system seeks a trade-off between the profitability of passengers and cargo in order to maximize the total airplane profitability subject to a given payload and belly volume. This may result in a higher overall airplane profitability than the combined profitability resulting from separate yield management systems for passengers and cargo.

Most of the published literature in the area of yield management is focused on models and issues related to passenger yield management. A few articles discuss the operational issues and modeling complexities related to the development and implementation of cargo yield management systems. To date, there is no published literature available that addresses the concept or the practice of managing passenger and cargo inventory jointly. A few airlines have been practicing this on an ad hoc basis on a few selected segments. Ad hoc applications do not look at the impact of passenger load on cargo capacity on the entire airline network; thus it is only a quick fix for a significantly critical issue.

A research methodology for developing and implementing a joint yield management system is presented in this paper. The methodology includes two alternative frameworks for the development of a joint-yield management system and possible approaches for formulating and solving the forecasting and optimization models within each framework. The first step in both alternatives is to forecast the total payload. Forecasting belly volume and the number of seats is not required since they are known and fixed for a given airplane type. For alternative 1, the second step is to overbook the forecasted payload and belly space using passenger and cargo no-show and cancellation behavior and to overbook the number of seats based on passenger cancellation and no-show behavior. The third step is to allocate the overbooked payload and the number of seats to different classes of passengers and different cargo products based on their demand and profitability. For alternative 2, the second step is to allocate the forecasted payload and the number of seats to different classes of passengers and different cargo products based on their demand and profitability. The third step is to overbook the allocated number of seats and the allocated cargo space separately, based on passenger cancellation and no-show behavior and cargo cancellation and no-show behavior, respectively.

The performance of the proposed joint yield management system must be compared with that of a hierarchical yield management system. Performance comparison may be based on total revenue, total profit, airplane utilization, or revenue opportunity (Smith et al. [1992]). A simulation based model may be developed to compare the performance of a joint yield management system with the hierarchical system. There are a large number of planning, operational, and political issues related to joint yield management that need to be identified and analyzed. These-issues have to be analyzed with respect to the structure of passenger and cargo departments within various airlines. Airlines have been giving higher priority for passengers over cargo, both at the planning and operational level. The introduction of a joint yield management will force them to perform planning and operation in a non-traditional manner.

EXECUTIVE SUMMARY

Yield management, alternatively known as revenue management, can be defined as the integrated management of price and inventory to maximize the profitability of a company. For combination air carriers, yield management is concerned with managing passenger fares and seats together with cargo rates and belly space. In practice, the concepts of airline yield management are applied in a hierarchical manner. The hierarchical practice of yield management assumes that passenger profitability is higher than cargo profitability for the equivalent weight, which may not be true in certain segments of a carrier's route network.

A joint yield management system seeks a trade-off between the profitability of passengers and cargo in order to maximize the total airplane profitability subject to a given payload and belly volume. This may result in a higher overall airplane profitability than the combined profitability resulting from separate yield management systems for passengers and cargo. The concept of joint yield management has not been addressed in the published literature. A few airlines have been practicing this on an ad hoc basis on a few selected segments. Ad hoc applications do not look at the impact of passenger load on cargo capacity on the entire airline network; thus it is only a quick fix for a significantly critical issue.

The concept of joint yield management for combination carriers is introduced in this paper. An introduction to hierarchical yield management, a discussion on passenger yield management, and the important differences between passenger yield management and cargo yield management are presented first. Then, alternative frameworks for the development of a joint-yield management system, suggested approaches for formulating and solving the forecasting and optimization models, and related research issues are presented.

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