UNIVERSITI PUTRA MALAYSIA

MODELLING PASSENGERS' SHOW-UP PREDICTION FOR INVENTORY MANAGEMENT OF AIRLINE INDUSTRY IN MALAYSIA

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By

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

MODELLING PASSENGERS' SHOW-UP PREDICTION FOR INVENTORY MANAGEMENT OF AIRLINE INDUSTRY IN MALAYSIA

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July 2015

Chair: Lee Lai Soon, Ph.D.
Faculty: Institute for Mathematical Research

This research studies the inventory management of an airline industry in Malaysia. In airline industry, no shows are inevitable when handling the passengers on the departure day. Therefore, the overbooking process has been introduced to cope with this issue and aimed to improve the flight optimization. However, the performance of the flights' load factor reflects a moderate seats' utilization and this allows for further improvement. Further analysis needs to be done by the inventory analysts to improve the flights' load factor. Due to high volume of daily ad hoc requests that need to be answered, inventory analysts have a limited time to focus on the analysis. In addition, it is found that there are very limited previous studies found on predicting passenger's show up rate in the airline industry and none of the papers found was conducted in Malaysia. Thus, the main objective for this study is to advocate operational methods that could assists the analysts on the show up analysis and their daily inventory decisions. Specifically, the study aims to formulate a logit model to predict the passengers' show up probability on the departure day. Extending the usage of the model, this study aims to generate a scorecard and a decision tree as tools to assist the analysts on their daily operation tasks.

Using SPSS 22, the show up prediction is modelled by using the logistic regression approach and linear discriminant analysis. The logit model is found to correctly predict 78.5% out of the validation set. Result from the Receiver Operating Characteristic (ROC) curve shows an area under the curve of 0.708 and depicts a satisfactory model. The discriminant function obtained from the linear discriminant analysis resulted in 97.5% correct prediction. A scorecard is developed in extension to the logit's results using Microsoft® Office Excel 2010. The Weights of Evidence are calculated using the formula defined and tailed by the calculation of scores for each significant attributes. The sample scorecard is shown in Chapter 4. A decision tree is also developed to support the task, but focusing more on the analysts' daily inventory decisions i.e. handling ad hoc requests by phone bookings and emails. From the result, the tree generated a correct prediction of 81.5% in the validation process. The scorecard and the decision tree developed are believed to be helpful to the inventory analysts in strategizing the flight seats in pursue to a better flight optimization. Based on the previous studies done, using scorecard to predict the passengers' attendance on flight departure, as demonstrated in this thesis, is a new approach to the industry. Hence, this research aims to advocate the scorecard method and also utilize the decision tree method to help the flight analyst strategies efficiently in their daily inventory management.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

PERMODELAN KADAR KEHADIRAN PENUMPANG UNTUK PENGURUSAN INVENTORI BAGI SUATU INDUSTRI PENERBANGAN DI MALAYSIA

Oleh

SITI NUR'AZHIIMAH BINTI ABD HALIM

Julai 2015

Pengerusi: Lee Lai Soon, Ph.D.
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Kajian ini mengkaji mengenai pengurusan inventori dalam industri penerbangan di Malaysia. Dalam industri ini, ketidakhadiran penumpang di hari berlepas adalah suatu situasi yang tidak dapat dielakkan. Oleh itu, proses pengambilan lebih tempahan (*overbooking*) telah diperkenalkan untuk mengawal isu ini dan bertujuan untuk meningkatkan optimaliti dalam setiap penerbangan. Walaubagaimanapun, prestasi faktor beban menunjukkan bahawa masih terdapat ruang penambahbaikan dalam pengurusan inventori. Dalam bahagian operasi, analisa lanjut perlu dilakukan oleh penganalisa inventori demi membaikpulih prestasi faktor beban setiap penerbangan. Oleh kerana jumlah permintaan ad hoc inventori yang tinggi setiap hari, penganalisa inventori mempunyai masa yang terhad untuk memberi tumpuan kepada analisa kehadiran penumpang. Selain itu, jumlah kajian yang terhadulu terhadap ramalan kehadiran penumpang dalam industri penerbangan didapati sangat sedikit dan tiada diantara kajian tersebut yang dilakukan di Malaysia. Sehubungan itu, objektif utama kajian ini adalah untuk mengketengahkan kaedah operasi untuk membantu pernganalisa inventori dalam analisis kadar kehadiran penumpang. Secara spesifik, kajian ini bertujuan untuk menghasilkan satu model logit bagi meramal kebarangkalian kehadiran penumpang untuk hadir pada hari berlepas. Susulan penggunaan model logit, kajian ini juga bertujuan untuk menghasilkan kad skor dan pokok keputusan sebagai alat untuk membantu penganalisa dalam melaksanakan tugas operasi harian mereka.

Dengan penggunaan SPSS 22, ramalan kehadiran penumpang dimodelkan dengan menggunakan pendekatan regresi logistik dan analisis diskriminan linear. Model logit didapati meramal 78.5% daripada set pengesahan dengan betul. Keputusan daripada graf Penerima Ciri Operasi (ROC) menunjukkan luas di bawah lengkung sebanyak 0.708 dan ini menandakan model logit berada dalam tahap memuaskan. Fungsi diskriminan yang diperoleh daripada analisis diskriminan linear menghasilkan ramalan yang betul sebanyak 97.5%. Kad skor dihasilkan dengan menggunakan keputusan model logit dan mengambil Microsoft® Office Excel 2010 sebagai medium kiraan. Berat Bukti dikira menggunakan formula yang ditentukan dan daripada situ, markah bagi setiap ciri dikira. Sampel kad skor ditunjukkan di dalam Bab 4. Pokok keputusan juga dihasilkan untuk menyokong tugas kad skor, tetapi memberi tumpuan lebih pada keputusan inventori harian penganalisa iaitu pengendalian ad hoc dari tempahan telefon dan e-mel. Dalam proses pengesahan, pokok keputusan meramal 81.5% data dengan betul. Sepanjang analisa terhadap kaedah kajian yang terdahulu, penggunaan kad skor untuk meramal kadar kehadiran penumpang adalah satu kaedah baharu dan tidak

pernah digunakan sebelum ini. Oleh itu, tesis ini bermatlamat untuk mengetengahkan kaedah tersebut bagi membantu penganalisa mengawal inventori harian secara lebih efisyen.

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Finally, to the readers, it is a great pleasure to share my findings through this thesis and hopefully, it would be beneficial in your future works.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Masters of Science. The members of Supervisory Committee were as follows:

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I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BKDAYS	Book Days
BKDAYS_TYP	Type of Book Days
BKG_CLS	Booking Class
CART	Classification and Regression Tree
FLTDAY	Flight Day
FLTDAY_TYP	Type of Flight Day
LDA	Linear Discriminant Analysis
LEG_NBR	Leg Number
LR	Logistic Regression
OB	Overbooking
RM	Revenue Management
RPM	Revenue Passenger Miles
ROC	Receiver Operating Characteristic
STATUS	Passengers' Show-up Status
PAXNUM	Passenger Number
PNR	Passenger Name Record

CHAPTER 1

INTRODUCTION

1.1 General Background

Have you ever encountered a scenario with "fully booked" answers when making a flight booking, managed to secure the seats after several attempts, and finding out that there were many vacant seats when the flight departed? You must be wondering where are all the passengers that made the flight "fully booked" in the first place. Another puzzling scenario is seats are all secured and the booking is ticketed. However on the departure day, the flight is found to be overbooked and a number of passengers need to be offloaded and rerouted to the next flight. These situations are common to the airline industry. Even so, they are obviously unpleasant experiences to the customers or the air travellers.

How do airline companies manage their bookings to maximize their revenue and minimize their cost? Are there glitches in managing the customers' booking throughout the booking period? What are the measures taken by the airline companies to reduce such cases mentioned above and improve customers' satisfaction? These are some, out of many queries, that fall under the optimization category in the airline revenue management. Revenue Management (RM) is a method that is introduced in late 1970s to the industry to maximize the revenue and operation effectiveness by allotting the right inventory to the right customer with the right fare (Kimes, 1989). Specifically, RM in the airline field comprises of three main aspects which are inventory, pricing and demand. Here, rather than price or demand optimization, the focus of this study is on the inventory control. Specifically, our focus is on the elements with the red arrows, as displayed in Figure 1.1. The connectivity of the two will be explained shortly.

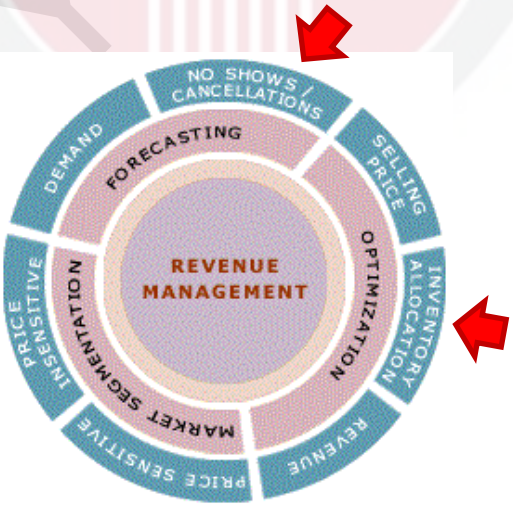

Figure 1.1 General Concept of Airline Revenue Management, (Source: Revenue Management, n.d.)

Inventory control is generally known to be one of the operations research (OR) problem (Panneerselvam, 2011) as its basic rule in the decision making procedure agreed with the OR main principal of maximizing profit and minimizing cost. In the application of this industry, the seats inventory control aims to maximize the number of occupied seats in the plane and minimizing the spoilage cost. Spoilage cost is the cost borne by the company when the flight flies with empty seats, despite having sufficient demand to fill it beforehand. The fact that the analysis involves human factor and hence develops uncertainty models, Panneerselvam (2011) stated that engaging in certain statistical tools and probability concept would help the OR procedures to be more realistic and adaptable to the real case. Understanding the needs, the statistical tests used in the analysis will be discussed in detail in the later chapters.

The practice of flight optimization in the airline industry is beyond important in today's world. The emerging competitiveness in the field has urged the analysts and researchers to conduct methods to improve the flight performance day by day. In addition, flight optimization has become more critical nowadays as the demand for air transport is intensely amplified. No show behaviour of the passengers now become more frequent due to handling a higher number of demand and therefore causing the company to bear a higher spoilage cost. Cederholm (2014) reported the increase of Revenue Passenger Miles (RPM) globally, based on the statistics gathered by the International Air Transport Association (IATA). RPM is one of the demand measures where an increment to its value shows a higher number of passengers that use the service (Cederholm, 2014). An increment of 5.5% in RPM internationally on July 2014 supported the fact that air transportation is indeed becoming a more popular preference among travellers.

Overbooking (OB) is one of the procedures undertaken in the inventory management aiming to improve the flight optimization. Absence of the passengers in a flight on the departure day is a normal occurrence to the airline industry. OB process was introduced to minimize empty seats caused by the no shows and thereby increasing flight optimization. By putting virtual extra seats in the system at the early stage of the booking period, it is found to be one of the best ways to utilize the capacity in the aircraft, thus promoting a better revenue performance.

Though OB practice has its benefits, there is also a downside to it. This is due to the fact that no show behaviour of the passengers on future flights is unpredictable and hence there is an element of risk involved in accepting more reservations than can be possibly accommodated on the flight (Belobaba et al., 2009). However, the benefits of applying OB outweigh that of not applying it. Siddappa (2007) shared a view on the controversial strategy of OB where the author stated that even if a company encountered negative book-load cases (having more passengers than the actual seats on the departure day) caused by overbooking, the loss from compensating the denied-board passengers is still relatively less compared to the loss borne by the company if it did not apply OB and faced the spoilage cost instead. Aydin et al. (2012) agreed that despite the uncertainties, OB is still a profitable strategy for optimizing the seats.

On flights operated by Lufthansa, more than 5.5 million passengers did not show up in 2004 (Klophaus, 2006). In the paper, the author emphasized that OB is one of the most powerful techniques to be applied by the company when the air carrier successfully grabbed additional 640,000 passengers, promoting an increase in revenue of €126 million after OB took place in their inventory management strategy.

One of the measures that can be taken to evaluate the performance of OB is load factor. Load factor is the number of filled capacity in a flight by percentage. Obviously, load factor near to 100% is favoured. Looking back to many years before, from the establishment of the OB process in the airline reservation system, through the development and emergence of the industry worldwide, to this date of advance airline operations, rarely do we find any companies to actually capture near to 100% of demand in the system at the departure day. Figure 1.2 shows the load factor of some of the selected western airlines.

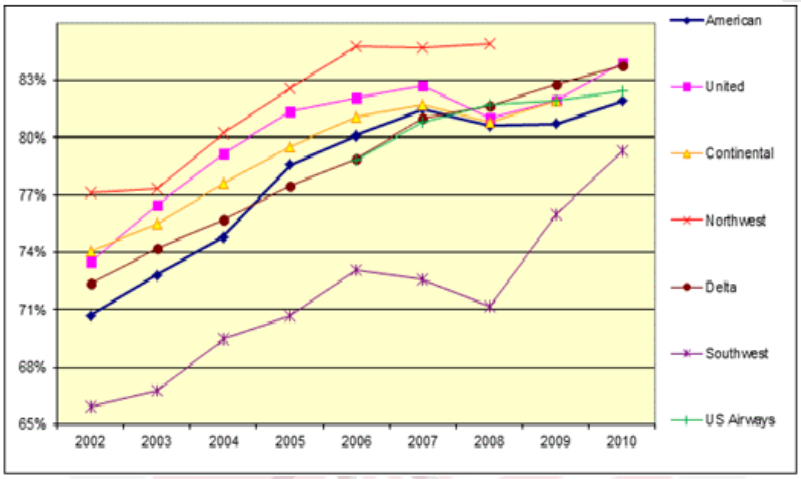

Figure 1.2 Load Factor from Selected US Airline Companies, (Source: Load Factor, 2013)

Some of the largest companies in the western have yet to even reach 86% of the load factor as according to the line chart above. Although the chart only covers the data up to 2010, Maxon (2012) has reported a compilation of data from the airline companies in Dallasnews.com that the airlines mentioned in the chart were still having a load factor of below 90% from the total capacity for 2011 and 2012.

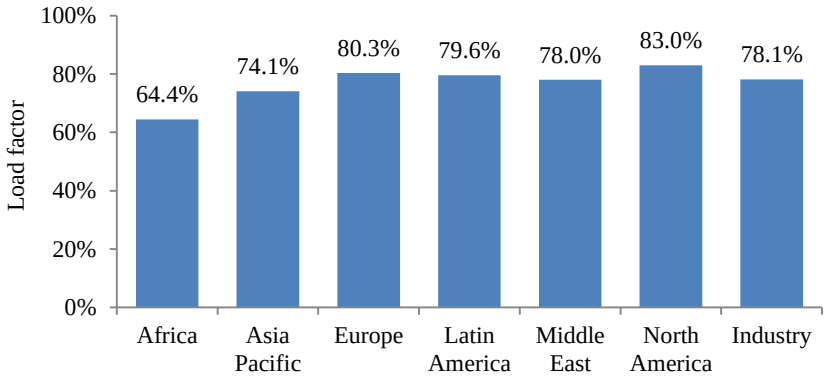

Figure 1.3 Load Factors of International Flights in May 2014, By Region, (Source: Passenger Load Factor, 2014)

Recent statistics, displayed in Figure 1.3, conveys somewhat the same depiction where in May 2014, the load factor was globally calculated up to a maximum of only 83% from the total plane capacity. For the Asia Pacific, the load factor is generally up to 74.1%, ranked second last among the rest. While OB is recognized to be a good enhancer for the inventory control, this information implies that there are still room for improvements.

To allot the right number of seats to overbook in the system, it is crucial for the inventory management to study on the previous no show cases and estimate the number of seats that might be empty on the departure day. If we could predict, for example, five passengers are going to be absent on the flight departure beforehand, we could overbook five extra seats in the system to utilize the no show's seats later and reduce the spoilage cost.

This study is motivated by the working environment undertaken as flight analysts, also known as inventory analysts of an airline company in Malaysia. Besides the analysis to optimize the inventory, there are many seat requests coming in daily from the agents and sales unit to answer and a prompt reply of approval or denial is a necessity. In this kind of work environment, this research aims to assist the analysts on the analysis part, as highlighted in a red box in Figure 1.4. A scorecard that could predict the showup status of a booking could, not only help analysts to further understand about the flight and determine the right number of OB seats, but also eases them to make decisions when handling each of the ad hoc seat request, be it an approval or in need of turning down the demand. Alternatively, a decision tree could also be an aide in determining the show up rate of the passengers. These proposed methodologies will be further explained in Chapter 3.

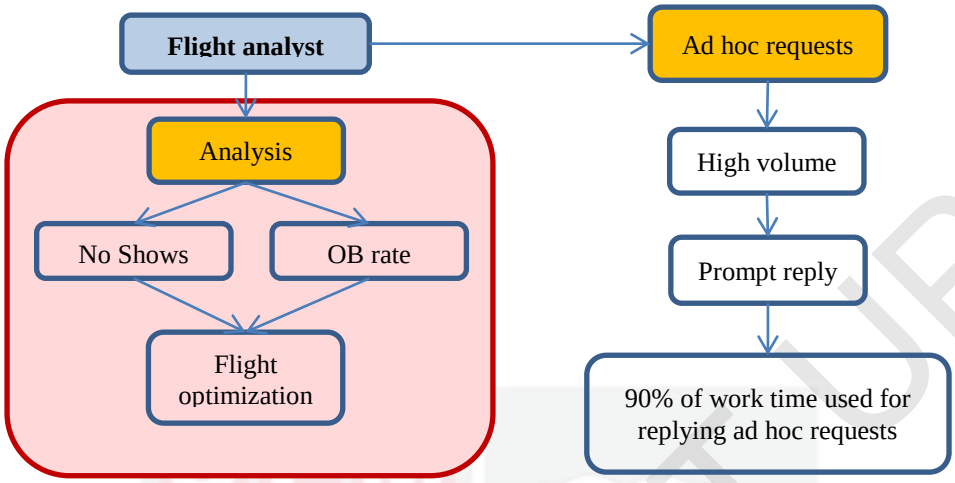

Figure 1.4 Main Tasks of a Flight Analyst

Knowing the passengers' show up rate could also give a positive impact towards a process called firming, another procedure taken within the booking period. It is undergone by the operation team, to contact passengers and to confirm their itineraries on the travelling date. If the prediction of the passengers' attendance on the departure day could be obtained, the team can target a specific group e.g. passengers that have less than, say, 30% show up rate, and confirm their presence for the flight rather to contact all. This promotes efficiency and productivity improvement.

The diminution of seat optimization in the airline industry as deliberated earlier, clearly questions the performance of the current working procedures. With this study, it is also targeted to understand better on the collected passengers' attributes obtained from the Passenger Name Records (PNRs) and see their significance in determining the passengers' show up rate.

There are limited papers found related to this topic. As to our awareness from the literature reviews, building a scorecard to predict the passengers' show up status on the departure day is a new approach to the airline industry as no previous studies has conducted the analysis using the method. For that, this thesis opts to advocate the scorecard and also the decision tree as tools to help the flight analysts in strategizing their inventory efficiently.

1.2 Problem Statement

The study on no shows is crucial in managing the OB process in this industry. In fact, not only in the airline field, but to any other industries that offers a product or service that is perishable. OB process is introduced to address the issue and aimed at optimizing the flights. However, the change in economy and surrounding has caused the optimality in the inventory management to deteriorate. Also, the application of OB procedure today in coping with the empty seats seems to affect the optimization with

minor impact. The declining of effectiveness of OB might be due to the inaccurate prediction of number of no shows and therefore inaccurately set the overbooking rate. Two outcomes may result from this; 1) if the overbooking seats are lesser than the number of no shows, the seats will be poorly optimized as the remaining no shows are not filled with other demands and the flight will depart with empty seats, and 2) if the OB seats are higher than the no shows, this will result in offloading some passengers due to insufficient seats. Further investigations, particularly, on determining the right number could help to boost the effectiveness and ultimately promote a better flight optimization.

In the operation side, a flight analyst handles, not only on the optimization analysis i.e. determining the right number to allocate the seats accordingly, but also on making the right decisions for daily ad hoc seat requests. To simultaneously perform the two tasks is not easy, as the seat request coming in daily is high in volume. A prompt decision is a must to cope with the seat requests and also to allot time for analysing the inventory and OB rate.

1.3 Objectives of Research

The overall objective for this study is to advocate operational methods that could assist the analysts on the show up analysis and their daily inventory decisions.

Specifically, the study aims:

- to formulate a model to predict the show rate of passengers using logistic regression and linear discriminant analysis,
- to develop a scorecard for the available attributes to predict the passengers' probability of show,
- to utilise the decision tree methodology to predict the show up probability of a passenger; as a tool for decision support for interactive channels e.g. phone bookings and emails.

1.4 Scope and Limitation

The data for this study are collected from one of the airline companies in Malaysia. The data set comprises of booking attributes extracted from the PNR and the bookings are only focuses on the economy cabin.

Our limitations, however, are recognized where the data access for this study has a limited contact to the available attributes in the PNRs. It is undeniable that the study in this field of airline revenue management can be difficult due to most of the historical records are censored (Zeni, 2001). Due to the policy held by the industry in Malaysia, we are only able to acquire five passengers' attributes to be analysed in this study. With this limitation, it is expected that the result and the model fit might get affected.

1.5 Organization of the Thesis

In Chapter 1, we have shared a brief introduction on the research background. Revenue management is clarified in the beginning and its divisions that related to this thesis are explained. The OB process in the airline industry is then elucidated. The importance of applying OB in the seat inventory control is further explained where its relation towards the passengers' show up rate has been briefly discussed.

Chapter 2 consists of literature reviews, categorized in three sections. First, it gives the readers a more detailed explanation on the OB process itself. OB is taken as quite a controversial strategy and the issue is brought up in Section 2.2. Secondly, it discusses entirely on the show up rate and related previous studies in Section 2.3. Finally, the literature reviews found on the logistic regression analysis are presented. Some previous studies that used logistic regression in the airline industry are mentioned in Section 2.4 to familiarize the readers to its application. More studies on the method in other industries are shared in the following section. General reviews are made on linear discriminant analysis approach in Section 2.6. Credit scoring method is rather new to the aviation field. Since no papers are found related to the credit scoring analysis on the passengers' show up rate, the method is reviewed generally in Section 2.7. Similarly, CART is explained is Section 2.8.

In Chapter 3, an overview on the theory is explained. The data structure is first deliberated in Section 3.2, followed by a discussions on the statistical tests related to this study. The theory of logistic regression analysis and the development of logit model are discussed in the following subsection. Next, the formulae in calculating the scores to develop the scorecard are further explained, followed by the discussion on the CART approach.

In Chapter 4, results obtained through the analysis are showed and discussed. In the beginning, data frequency and the cross tabulation analysis are explained. Results on the logistic regression analysis are discussed in Section 4.3. LDA's result is showed in the following subsection as an alternative approach to the logistic regression. The scorecard result is discussed in Section 4.5 while the decision tree in Section 4.6.

In the final chapter, the logit model is summarized and the results of the two decision tools developed in this study are recapped. Some recommendations on future works are also suggested to improve the study area.

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