



# Capacity and pricing policies with consumer overflow behavior

Juan Li <sup>a,\*</sup>, Ou Tang <sup>b,c</sup>

<sup>a</sup> School of Management and Engineering, Nanjing University, Nanjing 210093, China

<sup>b</sup> Division of Production Economics, Department of Management and Engineering, Linköping University, SE-581 83 Linköping, Sweden

<sup>c</sup> School of Economics & Management, Tongji University, Shanghai 200092, China

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## ABSTRACT

We analyze consumers' choice and overflow behavior between two potential market segments with different fares, capacity allocated, and then develop the optimal capacity and pricing policies assuming that such consumers' strategic behavior can be observed. Every consumer prefers to choose a fare to obtain their utmost value surplus, and select the second if the first-best choice cannot be satisfied. Our study indicates that the effort of fencing the segments should be considered to cope properly with pricing and capacity decisions in order to direct the overflows. Disregarding overflows could create differences in decisions as well as economic consequences. The study results can be implemented, but not limited, to understand the flight seat allocation problem with strategic consumers.

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## 1. Introduction

### 1.1. Research background

Revenue management started to gain significant research attention after the airline's deregulation on price control in USA in 1978 (Talluri and Van Ryzin, 2004, pp. 6–7). The seat allocation problem in a flight leg is an important issue in the revenue management literature. The so called “see-so-move” is a major problem during the early time of revenue management studies. Market segmentation is then introduced as a technique which is followed by various models with an aim to price independently to different consumer groups and consequently maximize revenues. Later, the revenue management techniques were introduced to other industrial sectors such as restaurants, hotels and manufacturing to deal with problems, for example, booking limits, over-booking, pricing policy, auction, reselling and others.

Understanding and describing consumers' demand behavior are important issues in revenue management. In the literature, models often assume that consumers are already segmented and follow certain types of distributions. With regards to the economy and business class consumers, the assumptions of pre-defined and independent distributions are very appropriate in dealing with classic pricing and seat allocation problems. However, with the appearance of many low-fare airlines such as Ryanair and EasyJet, the above assumptions need to be reinvestigated due to two reasons. First, such airlines often aim at economy consumers who also likely have the same or similar value preferences.

Second, consumers also have strategic behavior, i.e. actively determining which product to buy and when to buy etc, based on the conditions and restrictions added by flight seat reservations and purchasing. Thus there are questions whether such airlines should enforce clear market segments for the distinguished products (services), and what the response of consumers will be? Such strategic consumers have been less investigated in the revenue management literature (Shen and Su, 2007). Further investigating consumers' choice behavior is thus important as it will definitely influence the revenue management decisions.

In this paper we therefore investigate the flight seat allocation problem in a single leg with “potentially” two market segments, in which consumers are willing to pay high and low fare tickets. Instead of assuming the demand of two classes are independent and exogenously defined (such as in Netessine and Shumsky, 2005), we let the consumers come from the same pool with a known distribution indicating their values. In addition, consumers have the opportunity to select seat classes based on ticket fares, perceived seat value and seat availability. The consumers' overflow pattern is analyzed with consideration of an airline's market segmentation policy. Furthermore, pricing and seat allocation policies are developed to understand the decisions in a flight leg including consumers' strategic behavior.

### 1.2. Related literature

There are extensive studies focusing on how airlines can apply pricing and rationing policies to extract maximum revenue. Even before deregulation, Littlewood (1972) first describes revenue management principle in the airline industry, and afterwards numerous authors have expanded on Littlewood's work. For an overview on revenue management up to 1999 we refer to McGill

\* Corresponding author. Tel.: +86 1599 6228 055.

E-mail address: [juanli@njnu.edu.cn](mailto:juanli@njnu.edu.cn) (J. Li).

and Van Ryzin (1999) whereas developments occurring afterwards are discussed in Hu et al. (2010); Board and Skrzypacz (2011). For a comprehensive instruction of the methodology in revenue management, we refer to the book by Talluri and Van Ryzin (2004).

The flight seat allocation problem in legs can be divided into static and dynamic models. In a static model, the booking period is regarded as a single interval. The tasks are setting a booking limit for every booking class at the start of the booking process and then making price decisions. Furthermore, the static models can be categorized into two types. The first type assumes that the distribution of the demand for different fare classes is known in advance. With an aim to maximize the expected revenue, this type of problem is often formulated as mathematical programming models (Haerian et al., 2006), or competitive game theoretic models (Netessine and Shumsky, 2005). The second type assumes that the decision maker knows part of consumer behavior and demand information, and then it is solved by the dynamic programming approach, where the stages correspond to fare classes (Wright et al., 2010).

In this paper, we carefully focus on consumers' overflow behavior and an airline's pricing and booking policies in a static model. This paper connects three important streams of literature in revenue management, namely, consumers' valuation modeling, consumers' overflowing behavior and an airline's pricing and capacity decisions. The literature review below will focus on these streams.

Some authors study revenue management with consideration of consumers' valuation. Shen and Su (2007) review existing models, which consider customer behavior in revenue management. Dana et al. (2011) present a model of revenue management with strategic behavior, i.e. forward looking consumers. The consumers are heterogeneous in their valuations or willingness to pay. Using a mechanism design approach, the authors show that the optimal is a menu of expiring refund contracts. The authors also identify the conditions under which the manager can achieve the first-best solution, thereby extracting the entire consumer surplus. With this optimal mechanism, contracting takes place after the consumers learn their types but before they learn their true valuations. Levin et al. (2009) present a pricing model for oligopolistic firms selling differentiated perishable goods to multiple finite segments of strategic consumers. They encompass the strategic behavior of both firms and consumers into a unified stochastic dynamic game. The model provides insights about equilibrium price dynamics at different levels of competition, and multiple market segments with different properties. Ahmed and Abdelghany (2007) adopt a micro-simulation approach that replicates how prospective travelers select their travel itineraries that are provided through ticket distribution channels, and examine the trade-offs between two common types of ticket distribution channels: (i) one with high market penetration and high competition among subscribed flight legs and (ii) one with low market penetration and low flight legs competition. In the above literatures, the market segments are often clearly predefined. Consumer demand in the segments follows independent, externally defined distributions. Such assumptions are not true when we study low cost flight-legs (Ryanair and EasyJet), in which, consumers are likely coming from the same pool with similar valuation preference.

In the research domain of consumers' overflow behavior, Dumas and Soumis (2008) provide consumers flow estimation with given forecast data concerning: (i) the demand distribution for each itinerary; (ii) the time distribution of booking requests for each itinerary; and (iii) the proportion of spill (from an itinerary) that is attracted to a given alternative itinerary. Zhang and Bell (2010) present an approach to model demand leakage

among different market segments and propose cost functions representing the effort devoted to fences. After establishing the connection between costs/revenue gains with market segmentation, they show how the optimal cost should be devoted to customer migration across segments. Little attention, however, has been given to show how consumers overflow behavior affects an airline's pricing and capacity decisions.

Another group of authors study revenue management considering airlines' pricing and capacity decisions. Jean (2009) discusses two nesting methods: net nesting and threshold nesting, and investigates the underlying assumptions. The findings indicate whether or not having a stationary demand process is a key issue in such a problem, and an event study methodology has been suggested to reach the appropriate assumptions in practice. You (1999) considers a seat inventory control problem with multiple booking classes in both single- and multi-flight leg cases. Before the flight departure, the airline may face typical problems such as: (i) what are the suitable prices for the opened booking classes, and (ii) when to close those opened booking classes. Chew et al. (2008) jointly determine the price and the inventory allocation for a perishable product with a predetermined lifetime and they develop a discrete time dynamic programming model to obtain the optimal prices. Dai et al. (2005) consider the pricing strategies of multiple firms providing the same service in competition for a common pool of customers in a revenue management context, each of which satisfies demand up to a given capacity limit.

As mentioned before, in this paper we aim at investigating consumers' overflow behavior. Instead of assuming consumers have already been segmented, we consider the case that consumers have similar demand pattern, however their tickets' selection depends on the airline's effort of fencing the segments. This investigation should bring some insights about the interaction of consumers' choice behavior and an airline's seat allocation policies, such as pricing, capacity reservation and segment effort.

## 2. Problem setting

In this section, we describe the background of problem settings. We describe the passenger types, present the decision of consumer's choice and then develop the expressions for demand function (volume).

### 2.1. Passenger types

In the early studies, market segments are often assumed to be pre-defined and having independent distributions. These assumptions are true when we consider economy and business classes in commercial airlines, in particular with long distance flights. However, the low-fare airlines such as Ryanair and EasyJet, are becoming popular in practice. Among these airlines, consumers are more likely having the same or similar value preferences. In this study, thus we assume that consumers have different values when buying the flight tickets. However this heterogeneity of consumers' value is uniformly distributed within a unit-length line  $v \in U[0,1]$ . We also normalize the number of consumers as one. Thus the maximum demand volume (market size) is one. We have to note this normalization does not change the conclusion of this paper, it only brings convenience in model development.

The above mentioned consumers' value refers to a normal booking condition of a flight leg. It can be interpreted as the consumers' utility of transferring the locations. If a consumer is offered a flight ticket with restrictive booking conditions or service limits, its value is discounted and then becomes  $\theta v$ . Hence we define the tickets with the normal booking condition as high

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