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Dynamic pricing for passenger groups of high-speed rail transportation

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ABSTRACT

The widespread high-speed rail has become an important transportation mode for tourists in China, who travel primarily in groups. With more attractive price, railway operators may be able to expand ridership, improve customer satisfaction, and ultimately increase revenue. The traditional pricing method for passenger groups, however, is relatively simple, inflexible, which may lead to profit loss during off-seasons. In order to assist railway corporations in revenue improvement, a dynamic pricing model is provided to determine the optimal price for passenger groups. Numerical experiments show that the proposed method is able to suggest the optimal price for total revenue maximization, subject to the capacity constraint.

1. Introduction

High-speed rail (HSR) is gradually becoming the main thrust of railway passenger transportation for long distance travel with the advantage of comfort, speed and security. In China, there are 2673.5 pairs of general trains and 1556.5 pairs of electrical multiple units (EMU) trains (including the high-speed trains), which can be divided into one-stop HSR and multi-stop HSR. However, HSR is so costly that is difficult to make profit (Ryder, 2012). Recently, China's plans for HSR construction have slowed down; in the meantime, more attention is given to service improvement and pricing strategy in order to increase ridership and revenue.

Many people like to travel to the same destinations in groups for the same purpose, such as business or sightseeing (McGill and van Ryzin, 1999; Kuyumcu and Garcia-Diaz, 2000; Weatherford, 1997; Rui, 2014). As air passenger transportation, the rail passenger transportation includes individual passengers and group passengers. For the Chinese rail corporation, the railway regulation defines that for passengers with more than 20 persons may be used as group passengers and enjoy discount fare. For JR Group (Japan Rail Group), groups of eight or more adults enjoy 10–15 percent discount, and groups of eight or more students enjoy 30–50 percent discount. Rail operators set discount policies for groups to improve their revenue. The price of the group tickets is an important factor influencing the aggregate revenue from the sales of all tickets.

Dynamic pricing and seat inventory control are two main ingredients of revenue management. In particular, dynamic pricing includes setting up multiple fares in advance and then dynamically varying the availability of each according to

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demand forecasts and actual bookings to maximize revenue. On the other hand, seat inventory control is to accept or reject the request of customers at a time for a certain type of product or service in a predetermined period. Seat inventory control decides which class seats to keep open for purchase or to close as the remaining capacity of the fare class is depleted over time with the customer purchases.

In this paper, we propose a revenue management model that uses the dynamic pricing with seat inventory control to handle groups as well as individual travelers. Given an initial seat inventory of a HSR train and a finite time horizon over which sales are allowed, we formulate the tactical problem of dynamically pricing to maximize the aggregate revenue. Our approach consists of a two-stage dynamic program considering groups and individuals, separately. The demand for each fare class is uncertain and it depends on the set price. The booking horizon is finite and divided into multiple time periods. At the beginning of each period, the operator decides how many seats in each fare class are to be provided and at which price to charge in order to maximize the expected revenue.

Pricing is one of key transportation marketing activities. Price affects demand. If demand increases and supply remains unchanged, then it leads to higher ticket price. If demand decreases and supply remains unchanged, then it leads to lower ticket price. The total revenue is the price of the ticket multiplied by the quantity sold. So, comparing with full fare, the lower fare (discount ticket) may lead to higher demand and total revenue during off-season (lower demand season). For boom season (higher demand season), ***railway operators*** only provide full fare ticket for groups to maximize his revenue. Our results show that there is an optimal group discount for a specified demand. It is helpful for railway operator to adopt this discount for groups.

The remainder of this paper is structured as follows. Section 2 reviews the earlier literature, summarizing the relevant background to the present study. Section 3 specifies the proposed model. Properties are proofed in Appendix A. The empirical case study is presented in Section 4, with Section 5 concluding the paper by summarizing the present study, and a brief discussion of future research directions to extend this line of enquiry.

2. Literature review

Since little work on dynamic pricing for HSR has been reported due to limited operation experience in recent years, we studied the relevant literature in airline revenue management.

The primary method of airline revenue management is seat inventory control at a given set of prices, and on this subject McGill and van Ryzin made an extensive literature review (McGill and van Ryzin, 1999). Nevertheless, McGill and van Ryzin only reviewed the problems without considering different pricing for group and individual passengers. Kuyumcu and Garcia-Diaz further developed an analytical procedure for a joint pricing and seat allocation problem by considering the number of fare classes and aircraft capacities (Kuyumcu and Garcia-Diaz, 2000); similarly, Weatherford investigated the joint pricing and inventory control problem for a single-leg flight with prices of the different classes (Weatherford, 1997). Both of them solved the mathematical problem by using 0–1 integer programming model which neglected the dynamic booking process and the stochastic nature of the travel needs. In view of the stochastic travel demand, Gallego and van Ryzin looked into a dynamic pricing problem by treating ticket booking as a stochastic process to achieve the objective of maximizing the expected revenue (Gallego and van Ryzin, 1994), and they found the optimal pricing policy in a closed form for a family of demand functions; however, this work did not discuss the interactions between pricing and the demand in the booking process. To extend and refine the work of Gallego and van Ryzin, Zhao and Zheng used a dynamic pricing model for selling a given stock of a perishable product over a finite time horizon (Zhao and Zheng, 2000), where demand is modelled as a known and decreasing function of the price in a continuous-time stochastic process. In a separate effort, Chatwin allowed the operator to dynamically adjust the price between any of a finite set of allowable prices (Chatwin, 2000), and Feng and Gallego further extended the model by considering the demand intensity as a function of sales to date (Feng and Gallego, 2000). However, none of the above studies specifically treat group travelers separately from individual travelers.

A number of studies on railway passengers and revenue management have been reported, but only a few of them are discussing dynamic pricing. Martin and Nombela applied a gravity model to estimate trip demand for the year 2010 in Spain and then computed the parameters to fit a multinomial logit function (Martín and Nombela, 2007). Bharill used a premium segment of Indian Railways, the Rajdhani Express, to search for revenue management strategies in order to increase average revenue (Bharill and Rangaraj, 2008). In recent years, Sibdari developed a series of pricing policies for a multi-product revenue management problem for the Amtrak Auto Train (Sibdari et al., 2008; Lin and Sibdari, 2009), and You extended the single-fare, multi-leg model, presented by Ciancimino et al., to a two-fare, multi-leg model (You, 2008; Ciancimino et al., 1999). Overall, dynamic pricing on railway passenger operations has not been adequately studied and implemented as compared with the airline industry. In particular, the existing literature has little to report on the impact of group tickets discount to revenue management when dynamic pricing is incorporated, especially in the more price-sensitive HSR context. The motivation of this paper is to evaluate the effectiveness of dynamic pricing in HSR transportation, where the price of group tickets is treated separately and linked to demand function.