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Incremental discount policy for taxi fare with price-sensitive demand

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Abstract

It takes some time for taxi driver to complete a requested service of passengers and the driver can attend to only one service at a time, and this distinguishes taxi service from ordinary goods. This paper deals with an incremental discount policy on the taxi fare. It is assumed that customers arrive following a Poisson process with price-sensitive arrival rates. With the objective of maximizing the average profit of taxi, a mathematical model is developed based on regenerative process. Through an analysis of the model, we show that the incremental discount policy is beneficial to the taxi company when the customer arrival rate is relatively small. Also, we propose a solution procedure to determine the optimal discount rate and price breakpoint. Finally, test problems are solved for sensitivity studies.

Keywords: Taxi fare; Incremental discount policy; Regenerative process; Price-sensitive demand

1. Introduction

Price discount encourages buyers to buy more than they used to and has been utilized as a strategy to improve the seller's profitability. Price discount policies can be classified into two categories, quantity discounts and volume discounts. Under volume discount policy, discounts are given if the volume of unit period demand of buyer is larger than a prescribed size (Sadrian and Yoon, 1994 ;Munson et al., 1999; Munson and Rosenblatt, 1998), while quantity discounts are based upon the quantity of an order.

Quantity discounts can be further divided into all-units discounts and incremental quantity discounts (Hadley and Whitin, 1963). Under the all-units model, a unit cost associated with the size of a particular order is applied to every unit in the order, while the incremental discount model applies a lower unit price only to those units purchased in excess of each successive breakpoint. Discount policies have been utilized in service transactions as well. For instance, some taxi companies in Japan are offering an incremental discount on the taxi fare. They give a 50% discount on the taxi fare in excess of ¥5000 (yen) expecting an increase in the number of long-distance customers.

There is a substantial body of literature about quantity discounts. A general literature review of quantity discount was provided by Dolan (1987).

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His paper also presented a systematic review of the different types of discount tariff structures and the motivation and rationale for order quantity-based pricing mechanisms. Kim and Hwang (1988) analyzed an incremental discount system with multiple customers. Rubin and Benton (2003) considered purchasing decisions in the presence of incremental discounts and constraints on budgets and space.

For all-units discounts, Monahan (1984) developed seller's optimal all-unit quantity discount pricing schedule with one price breakpoint. Lee and Rosenblatt (1986) generalized Monahan's model and solved the seller's joint ordering and price discount problem. Goyal (1987) provided further research based on Lee and Rosenblatt (1986) and improved the algorithm. Abad (1988) addressed the problem of finding an optimal retail price and lot size for a retailer when a suppler offers all-units quantity discounts. And Burwell et al. (1997) studied an economic lot size model under quantity and freight discounts. Wee (1999) developed a deterministic inventory model with quantity discount, pricing and partial backordering when the product in stock deteriorates with time. Viswanathan and Wang (2003) investigated the effectiveness of quantity discounts and volume discounts. Sarker and Kindi (2006) considered a temporary price discount, which is offered during a predetermined sales period.

Recognizing that customers tend to be sensitive to price, many researchers investigated price-sensitive demand. Polatoglu and Sahin (2000) studied a periodic-inventory model with stochastic demand, which is dependent on the unit price. And Abad and Jaggi (2003) considered the problem of setting unit price and length of the credit period with price-sensitive demand.

All the previous studies on discount policies dealt with commodity goods. Taxi service differs from ordinary commercial goods in the sense that at most one taxi service can be given at a time and also it takes time to satisfy service requests. In this paper, we deal with the pricing policy of a taxi company under an incremental discount policy. Passengers are assumed to arrive to get taxi service following a Poisson process with the arrival rate dependent on the amount of taxi fare. The rest of the paper is organized as follows.

In Section 2, we first describe the problem situation and introduce assumptions and notations. And then a mathematical model is developed with the objective of maximizing the profit of taxi driver based on regenerative process. The decision variables are the break point of taxi fare and discount rate. In Section 3, a solution procedure is proposed to obtain an optimal solution based on the analytical results of the model. For sensitivity test, example problems are generated by varying the system parameters and solved. Conclusions appear in the final section with the suggestions on further studies.

2. Mathematical model

The service processes of taxi under study are as follows. Taxi service is available in a given region R. The taxi driver drives his vehicle at a constant speed to a destination of passengers. At the end of the ride, the passengers pay the taxi fare and leave the vehicle. Then he waits in his vacant vehicle for the next passengers who arrive for service following a Poisson process. We assume that the taxi company plans to introduce an incremental discount policy with one price breakpoint in its fare system. The objective of this study is to determine both the optimal discount rate and price (taxi fare) breakpoint in a way to maximize the profit.

The following notations and assumptions are introduced for the development of the mathematical model.

Notations

- $\bar{P}$ a set of candidates for the breakpoint of taxi fare, $\bar{P} = \{p_0, p_1, \ldots, p_I\}$ with $p_0 = 0$
- $\bar{S}$ a set of the breakpoint for driving distances corresponding to $\bar{P}$, $\bar{S} = \{s_0, s_1, \ldots, s_I\}$ with $s_0 = 0$
- I_i ith distance interval, $I_i = (s_{i-1}, s_i)$
- λ_i^0 arrival rate of the passenger whose destination is in I_i under the full fare system
- λ_i arrival rate of the passenger whose destination is in I_i under the discount policy
- $\bar{\Lambda}^0$ a set of arrival rates under the full fare system, $\bar{\Lambda}^0 = \{\lambda_1^0, \lambda_2^0, \ldots, \lambda_{I+1}^0\}$ with $\lambda_i^0 \geqslant 0$
- $\bar{\Lambda}$ a set of arrival rates under the discount policy, $\bar{\Lambda} = \{\lambda_1, \lambda_2, \ldots, \lambda_{I+1}\}$
- d discount rate $(0 \leqslant d \leqslant 1)$
- β service time per unit fare under the full-fare system
- γ variable operating costs per unit fare under the full-fare system $(0 \leqslant \gamma < 1)$
- $p_{i,0}$ expected fare on I_i under the full-fare system