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A model for shelf space allocation and inventory control considering location and inventory level effects on demand

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Abstract

Shelf on which products are being displayed is one of the most important resources in retail environment. Retailers cannot only increase their profit but also decrease cost by proper management of shelf space allocation and products display. This paper addresses a problem of retailer who sells various brands of items through displaying on multi-level shelves. It is assumed that the level of shelf on which the product is displayed has a significant effect on sales. We develop an integrated mathematical model for the shelf space allocation problem and inventory-control problem with the objective of maximizing the retailer's profit. Then, a gradient search heuristic and a genetic algorithm are proposed for the solution to the model. The validity of the model is illustrated with example problems.

Keywords: Shelf space allocation; Location effects; Inventory control; Gradient search; Genetic algorithm

1. Introduction

Shelf on which products are being displayed is one of the major resources in retail environment. Accordingly, shelf management has been considered as an important decision to retailers. Retailers cannot only increase their profit but also decrease cost by managing shelf well. Increasing sales by attracting the consumer's attention and encouraging consumers to have additional purchase opportunities can be implemented by proper management of shelf space allocation and products display (location of the product within a display, product adjacencies, aesthetic elements, etc.).

There have been many empirical studies to estimate the space elasticity, which is defined as the ratio of relative change in unit sales to relative change in shelf space. Curhan (1972) took a large sample from store experiments, and found the

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average value of 0.212 for space elasticity. Also, Heinsbroek (1977) found the average value of 0.15 at the item level, referring to 20 experiments while Corstjens and Doyle (1981) found a low mean value of 0.086. On the other hand, Thurik (1988) found higher average space elasticity close to 0.6 at store level. Desmet and Renaudin (1998) found that space elasticities between categories are different substantially ranging from negative values to levels as high as 0.8. Larson and DeMarais (1990) called the displayed inventory which is carried to stimulate demand ‘‘psychic stock’’ and suggested ‘‘full-shelf merchandising’’ policy; that is, display area is always kept fully stocked, referring the experimental studies which concluded that substantially higher sales could be achieved merely by keeping shelves fully stocked. In addition, Dreze et al. (1994) made a series of field experiments and found that location of the product within a display, especially the level of shelf on which the product is displayed in case of multi-level shelf, has a significant effect on sales.

Motivated by those findings, many research articles appeared on the shelf space allocation problem to deal with how to optimally allocate shelf space to each brand of items so as to maximize the total sales volume. These models formulated the demand rate as a function of the shelf space allocated to products. Considering main demand effects, Anderson and Amato (1974) formulated an optimization model as a knapsack problem. Also, Hansen and Heinsbroek (1979) considered the main demand effects in their mathematical programming. Corstjens and Doyle (1981, 1983) developed a generalized geometric programming model with the main effects and cross effects of demand. Also, an optimization model of Bultez and Naert (1988) utilized marginal analysis. Zufryden (1986) solved the model of Corstjens and Doyle (1981) by dynamic programming approach. Borin et al. (1994) considered the main effects and cross effects of substitute items and suggested simulated annealing as a solution methodology. Observing that existing research papers on the shelf space allocation problem ignore the inventory-related decisions, Urban (1998) proposed integrated models of inventory-control and shelf space allocation problems. However, the above-mentioned models did not consider the location effects Dreze et al. (1994) emphasized. Recently, Yang and Chen (1999) and Yang (2001) proposed a space allocation model, a type of multi-constraint knapsack problem, incorporating the main and cross effects of demand as well as the location effects. Only for simplified versions of the original model, he found an optimal solution.

This paper is motivated by the operation of convenience stores in which much of the sales items are displayed on the multi-level shelves in refrigerated show cases. It is assumed that the manager is responsible for the shelf management in addition to the inventory control of the sales items. The reminder of this paper is organized as follows. In Section 2, we develop an integrated mathematical model for shelf space allocation problem and inventory control problem based on ‘full shelf merchandising policy’. Then two heuristic solution procedures, one with gradient search method and the other with genetic algorithm, are developed in Section 3. In Section 4, validity of the model is illustrated through solving example problems. Solutions obtained by the heuristics are compared with those from a total enumeration. Conclusions appear in Section 5.

2. Mathematical model

We deal with the problem of a retailer who displays various brands of items within a category to multi-level shelves that have limited space. Orders are initially received into backroom that is placed in the back of the multi-level shelves, and the items are restocked from the backroom into the shelves as the displayed items on shelves are depleted by consumer demand. The retailer’s total profit can be expressed as the gross margin subtracted by the holding cost of the items in the backroom and those on display, display expense, and ordering cost. We want to determine how many items to order for each brand, how much space to allocate to each brand and where each brand to be placed on shelves in order to maximize the retailer’s total profit.