

Optimization of Products Shelf Space Allocation Based on Product Price Using Multilevel Association Rules

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Abstract. Product allocation, product assortment, and product price have a significant influence on customer buying behavior. With limitation on shelf space, retailer must select, pricing, and allocate the products on shelf space optimally to maximize the profit for retailer. This study is focused on optimizing products shelf space allocation based on the relationship between product categories and product prices using data mining technique, that is, multilevel association rules. Takes advantage of data transactions, 9 associations between categories, 24 associations between subcategories, and 67 associations between products were obtained. Using zero-one integer programming, 61 products were selected along with their price, to be allocated in a minimarket outlet to maximize the retailer's profit. The results of this study shows the product allocation configuration based on the relationship between product categories and product price that maximize retailer's profit.

Keywords: Product allocation, data mining, association rules, integer programming

1. Introduction

The rapid growths of minimarket with outlet locations which are very close to one another create competition among them become very tight. In addition, the retailer's profit from this business is not that big, only about 7% to 15% of their sales turnover [1]. This makes the need for retail management. Retail Management is applied to develop retail mix that can satisfy consumer demand and influence consumer interest to buy the products [2]. Factors in the retail mix include: outlet locations, diversity of products, pricing, advertising and promotion, store design and display, service and personal selling [2]. Allocation and diversity of products in the stores will give a strong influence on consumer behavior to buy, so as to drive sales with stimulating interest in buying and cross selling [3].

Allocation of products on display space is a problem that should be further investigated as an efficient product allocation, because it can improve customer satisfaction which can simultaneously increase sales and profits [2]. In fact, today more and more retailers are turning to the model diversity of products and product allocation on shelf space display to maximize profits [3]. Given the limited shelf space display with the number of product items that tend to increase, this becomes a problem to be solved by the retailers. Therefore, retailers must perform product selection, pricing, and allocation of products on the available shelf space optimally [3].

Optimization study for the allocation of product on display racks have been carried out previously by Chen and Lin (2007), where they developed a model of the allocation of product on display racks by using data mining approach, which is based on the relationship between categories of products [2]. Hariga et al (2007) used diversity of products, method of inventory replenishment, and the display area as decision variables to optimize product allocation on display racks. This model is focused on the limited space on the display shelf and inventory space by assuming the demand of the product item to be fixed [4]. Hwang et al.

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(2009) developed a model of product allocation on display shelves to determine the distribution of rack space display, rack space area, and placement of products for each brand of each product category. In this model, the price of each product is assumed to be unchanged [5]. Nafari and Shahrabi (2010) developed a model of the allocation of product on shelf space display that was created by Chen and Lin (2007). Using data mining approach, this model was developed by adding a variable of price elasticity of the product. This model not only looks at the relationship between categories, subcategories, and items of the products, but also the price of the product [3]. Another optimization model was developed by Murray et al. (2010). This model incorporates variable of product prices, the area of facing display, and orientation of the allocation of the product on the shelf space display for each product category [6].

Based on previous studies, this study will model the product allocation on shelf space display by integrating a model developed by Nafari et al. (2010) and Chen et al. (2007). This study will look at the entire product category, considering the price and price elasticity of the product which may affect the demand of the product, and will also consider the relationship between the categories, subcategories, and items of the product. The objective of this study is to obtain the configuration of product allocation on shelf space display based on the relationships between categories, subcategories, and items of products and their prices, so as to maximize retailer's profits.

2. Methods

The study consisted of three stages: identifying the association between product categories and sub categories, selection of products and their prices, then product allocation on display racks. A multilevel association rules was used in the first stage to identify association. Association rules is a method used to obtain a general pattern and repetition in a set of transactions with a large amount of data. Association rules studied the frequency of occurrence of items simultaneously in a single transaction under two conditions, namely support and confidence [3]. A multilevel association rules is used to find associations of item combinations of products in a large amounts of data [7]. With multilevel association rules, the association will be acquired in stages, starting from the association between categories, then the association between subcategories, and finally the association between product items.

Based on the association between product items, then we will get a combination of product items that often appear simultaneously in a single transaction and their price. In the second stage, the chosen product items and their prices should remain on the display in the minimarket outlet so as to maximize retailer profits. The method used in this phase is zero-one integer programming. Optimization model used herein refers to a model developed by Nafari and Shahrabi (2010). With this model, profits are reckoned not only from one product alone, but also take into account if the product is associated with other products. In addition, this model also takes into account profit which is affected by the discount rate and not just from the normal price of the product. The optimization model can be written as follows:

Objective function:

$$Max Z = \sum_i M_i p_i - \sum_k \sum_j h_{jk} d_{jk} \quad (1)$$

Subject to:

$$d_{jk} \geq p_i \quad (2)$$

$$\sum_{j \in k} d_{jk} q_{jk} f_{jk} \leq S_k \quad (3)$$

$$p_i \in \{1,0\} ; d_{jk} \in \{1,0\} \quad (4)$$

The objective function of the model is to maximize total profits, namely the benefits of frequent item set minus the cost of inventory of product items in the item set. Equation (2) shows that if a frequent item set is selected, then the product items that are included in the frequent item set must also be selected. Equation (3) shows the constraints of shelf space availability for each product category. Equation (4) shows the decision variables; i.e., 1 means selected and 0 means not selected. A description of each parameter in the optimization model is shown in Table 1.

In phase three, product allocation on shelf space display was made based on the association, prices and profits generated by the product. Because each product will have different sales level when placed on

different shelves; therefore, the top, middle, and bottom shelves will have a different profit weights (i.e., medium, high and low).

Table 1. Description of model parameters

| Parameter | Description | Units |
|-----------|--|-------|
| M_i | Gross margin of i th frequent item set | IDR |
| p_i | Decision variables of i th frequent item set | |
| h_{jk} | Inventory cost of item j th in k th category | IDR |
| d_{jk} | Decision variables of item j th in k th category | |
| q_{jk} | Minimum facing of item j th in k th category | |
| f_{jk} | Facing length of item j th in k th category | Cm |
| S_k | Total shelf space allocated to category k . | |

On the product item, the allocation is based on the average profits generated from each product item. The average profit of each product item is calculated by formula as follows:

$$\text{Average profit} = \frac{p_j}{f_j} \quad (5)$$

where p_j is the profits generated by item j th, and f_j is the facing length of item j th. The average profit of each item of this product will determine the position of the item-level product on display shelf. Product items with an average high profit will be placed on a shelf level with high weight gain in order to deliver high sales results.

3. Results and Discussion

This study used data of 800 transactions from one of minimarket outlets in Jakarta, the capital city of Indonesia. To facilitate the data processing, a total of 793 items of products sold in the outlet are divided into 27 categories and 90 subcategories. With the help of Weka 3.6 software for identifying associations in the first phase, it was obtained 9 associations between categories, 24 associations between subcategories, and 67 associations between items and products. For all levels, the confidence value of 0.5 is used with support values ranging from 0.05 to 0.3.

In the second stage, with the help of solver of Microsoft Excel to solve the zero-one Integer Programming problem, 67 the results obtained from the selected frequent item sets, which means a total of 61 product items and their prices are selected. The selection of the 61 items of products showed that all the 61 product items must remain on display at the outlet according to the price level. Total profit generated by the optimization model is IDR 1,392,980.80.

In the third stage, allocation of categories based on the association between categories was performed, also allocation of items and products on the shelf level display based on the average profits generated by product item. In the category of products, change the position of a category that often appears causing a change in position on the categories that do not often arise. Allocation of items and products based on the association intended to create cross selling of a product item, so as to increase profits for the retailers.

4. Conclusions

A database transaction on minimarket outlets is a very useful source of information for retailers. From these data, retailers can determine the pattern of consumer spending. Associations that occur between the categories, subcategories, and product items can explain the pattern of consumer spending from the outlets. Not only is the association of the products, but retailers can also determine the level of prices of products which are often purchased together in a single transaction by the consumer. Based on the association and price level of the products, retailers can choose products that must be maintained to be displayed in stores that can provide profit for the retailers. The allocation of the product categories on display racks are based on the results obtained using the association rules, while the allocation of products on rack levels is based on the average profit earned from each product item. By doing the allocation and pricing of products based on the association of these products, it is expected to trigger a cross-selling of any product item, so that retailers can obtain the maximum profit.

5. References

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