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Pricing System for Seeking Optimal Prices in the Diet Foods Market

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Abstract— The purpose of this study is to introduce a case study on the application of data mining technology to the matter of pricing in business, and to clarify the latent risks contained in that process. In this paper, we have used data mining technology to analyze the purchase history data of customers for the purpose of discovering the price pattern that maximizes store profits. We describe the processes from data analysis to implementing a business plan, and we consider the risks involved in the business application of data mining.

Keywords— business application, data mining, pricing, diet food market.

I. INTRODUCTION

In recent years, data mining has been applied to a wide range of fields, including distribution, production management and marketing. Many businesses have used data mining technology to build their own efficient operational processes [6]. However, the business application of new information technology will not necessarily always lead to success [1]. A variety of problems can arise in the application process, and the members of the organization have to respond competently. The purpose of this study is to examine a case study in which data mining technology has been applied to business, and to clarify the latent risks involved in this process.

In this study, we introduce a case study on the business application of a system for supporting pricing strategy designed to maximize store profits. In Japan's market for diet foods, there is a high-value customer group that prefers to purchase high value-added products. In this case study, we conduct a detailed analysis of their purchasing behavior, and by building models for predicting purchase probabilities [4] [5], we have discovered the optimal price pattern for various product groups. In this case study, the project encountered a number of problems. We extracted rules from the data analysis, and we recognized that significant risks exist in the process of applying the rules to the field. In this study, we examined two types of risk in the business application of data mining: the risks resulting from a lack of understanding of the analysis results, and the risks resulting from a lack of field knowledge.

II. PRICING SYSTEM FOR SEEKING OPTIMAL PRICES

In this paper, we have used PRISM [10] [11], which uses the purchase history data of customers to find the price pattern that maximizes store profits. In the past, most conventional research on pricing has used either the prices of individual products or the pricing of small product groups that belong to the same category [2] [3]. The system in this study is able to handle the pricing of multiple products across different categories. The system uses the following procedure [10] to calculate the optimal pricing.

First, data cleaning and preprocessing is conducted. In this process, basic analysis is conducted, and characteristic tendencies are found for target categories. Next, a target category is established based on the advice of experts. An understanding of direct rival products is gained, and is reflected in the construction of the purchase probability models. Following this, other categories related to the target category are discovered. In the case study mentioned later, with regard to these steps, we analyzed the data together with experts, and established the respective categories.

After this, purchase probability models are built to calculate the probabilities that certain products will be purchased in various price patterns. Price patterns related to the abovementioned target category and related categories, and various attributes related to the customers are extracted based on the purchase history data, and then using this information as explanatory attributes, purchase probabilities for certain products are predicted. Models are built for all products that belong to the target category and related categories. Finally, these models are combined to discover the optimal price pattern that will maximize store profits. Since determining optimal prices from the combinations of all prices for all products is difficult, we have used approximate solution methods.

III. THE CASE STUDY

In this case study, we used customer purchase data from supermarkets in Japan to tackle the pricing dilemma for diet foods designed to maximize store profits. We have used customer purchase data from January to December, 2005, from

seven supermarket stores in the Tokyo region. On average, each store has approximately 5,000 customers and accumulates approximately 300MB of data each month.

A. The Diet Foods Market

In Japan, there is a notable health consciousness among consumers, and in particular, diet foods have attracted the interest of many consumers, both male and female. In recent years, the market has continued to grow in size, and has become one of the most important product categories for manufacturers and retailers [9]. Our case study covers the two products that have the greatest volume of sales in the diet foods market in Japan, namely cooking oil and mayonnaise.

Both cooking oil and mayonnaise have top brands in the diet-oriented market. The top brand of cooking oil is Product A. Compared to other cooking oils, Product A entered the market claiming such positive effects as lowering blood cholesterol and being difficult for the body to convert it into fat. It now commands an overwhelming share of this market. In the mayonnaise market, Product B has the top share. It is an existing top brand that expanded into the diet market, and it has half the calories of other products. In both markets, sales have demonstrated year-on-year increases of 10-15 percent.

TABLE I. COOKING OIL PRODUCT COMPARISON

Item	Volume	Regular Price ^a
Product A: Diet-oriented cooking oil	600 g	628 yen
Product C: Regular cooking oil	1500 g	398 yen

TABLE II. MAYONNAISE PRODUCT COMPARISON

Item	VOLUME	Regular Price ^a
Product B: Diet-oriented mayonnaise	400 g	398 yen
Product D: Regular mayonnaise	500 g	398 yen

Table 1 and Table 2 show a list of volumes and prices for typical cooking oil and mayonnaise products. As can be clearly seen in Table 1, Product A is considerably more expensive compared to a typical regular cooking oil (Product C). Also, the volume of Product A is significantly smaller than Product C. Product A has pushed such dietetic effects as those mentioned above, and has succeeded in differentiating itself from other products. For this reason, it has been attracting the attention of retailers as the product with the greatest profit margin. Meanwhile, for mayonnaise, as shown in Table 2, Product B has the same price as the regular mayonnaise Product D, but its volume is slightly less. Since it is a top brand product group, it is very readily recognized by consumers, but from looking at its price, it is far from being fully differentiated. This shows us that, even in the same market for diet products, there are various product strategies.

Figure 1. Sales of Product A when sold at discounted prices.

At present, the price competition in the Japanese food market is fierce. These high-priced diet foods are also frequently sold at discounted prices. Figure 1 shows the sales of Product A when sold at discounted prices. The horizontal axis shows the discounted prices, and the vertical axis shows the amount of sales per 1,000 customers to the store (PI index). As is shown in the graph, there are a number of different actual discounted selling prices for Product A, and it is clear that customers' reactions to prices are also not fixed. Looking at previous cases of discounting, it cannot be simply inferred that lowering prices will result in increased sales. In view of these facts, it is conceivable that the current pricing strategies for these product groups contain inefficient parts.

Figure 2. Market shares in the mayonnaise market by different customer groups.

The reason why traditional pricing plans for these products may not have been successful is because there are a number of customer groups within the market. Figure 2 shows the market shares of regular products and diet products in the mayonnaise market. In the overall market, regular products account for 75 percent of the market share and diet products for 25 percent. If we then calculate the market shares for customers who purchase diet-oriented cooking oil, diet-oriented mayonnaise accounts for 63 percent. These customers had a strong interest

in health awareness and in diet-oriented products across multiple categories.

Figure 3. Response by customer groups to discounted prices.

It is claimed that regular customers are acutely sensitive to the price of mayonnaise. Consequently, the price of mayonnaise is discounted very frequently. However, it would appear that the sensitivity toward diet-oriented products is different. Figure 3 shows the responses by current users of Product B and by general users when the diet mayonnaise Product B (discount price 158 yen, 238 yen) is sold at the discounted price. As the graph shows, general users respond hardly at all to discounted prices. Possible reasons for general users not switching to Product B are that the volume of Product B is less, and also that, when Product B is sold at a discounted price, usually, regular products of the same brand are also being sold at the same price.

Retailers hope to sell these kinds of value-added products at a high price wherever possible. We also know that customers with a strong health conscious have a strong interest in both of these products, and they have a high frequency of purchasing them both at the same time. Furthermore, the current pricing for these products contains inefficient parts. The purpose of this study is to maximize the profits of stores derived from these two product groups, by controlling their prices.

B. Discovering the Optimal Prices for Maximizing Store profits

In this section, PRISM [10] [11] was used to discover the optimal prices for maximizing store profits. Analysis was conducted on each of the four products having the largest shares in the diet-oriented cooking oil and mayonnaise markets. Their total market shares exceeded 95 percent in both of their respective markets.

PRISM uses past purchase history data to build models for finding the probabilities of customers purchasing certain products, and it then predicts the amount of store sales and profits according to various price patterns by using the models in simulations. The information used in the construction of the models is primarily the price information for each of the products and the information related to the past purchasing behavior of customers. The latter includes their past sales, their purchase frequency of health-oriented products, and their brand

loyalty for Product A and Product B. Based on the abovementioned analysis, this also includes a flag showing whether a customer is a user who prefers diet-oriented products.

Figure 4. Price simulations in the mayonnaise market.

Figure 4 a) shows a simulation of the total sales for a store using various price patterns for the four products. As the graph shows, the total amount of sales for a store is maximized when the top brand Product B is discounted only slightly to 312 yen, and Product D is sold at 298 yen, Product E at 148 yen, and Product F at 358 yen. In other words, rather than discounting all products, it was discovered that overall sales could be maximized by significantly reducing the price for only the product with the lowest market share, namely Product E.

Figure 4 b) shows a simulation of the total profit for a store using various price patterns for the four products. According to this chart, a store's total profit would be maximized when Product B is sold at 312 yen, Product D at 318 yen, Product E at 218 yen, and Product F at 358 yen. In other words, a store's total profit is maximized when Product B is discounted slightly and the other products are sold at their regular prices.

What is evident from these results is that a store's total sales and profit cannot be maximized using a pricing plan that pays attention to one product. Although the explanation has been omitted from this paper, in the actual analysis, we also

conducted a price pattern simulation for both mayonnaise and cooking oil categories. From the results, we identified that, in order to maximize store profits, rather than just a single category, consideration needs to be given to the price patterns of multiple related categories. Based on the results of this detailed simulation, we formulated an actual sales promotion plan, and held preliminary discussions together with the managers of stores that intend to implement the plan. We then made careful revisions to the plan based on the opinions of the store managers.

C. Store Properties and prices

As a result of the comments made by the store managers, it became clear that the ratios of sales attributable to different products vary from store to store. Figure 5 shows the market shares for mayonnaise at an average store (Store M) and a smaller store with fewer sales (Store S). As the graph shows, the top brand Product B had only a 43 percent market share at Store S. In these kinds of instances where the market shares differ greatly, we can predict that the percentages of customer groups making up these shares are also different. Furthermore, if the ratios of the customer groups were to change, then the results of the simulation would also change.

Figure 5. Market shares for mayonnaise at Store S and Store M.

Figure 6 shows the results of the profit simulation at Store S. As can be seen from the graph, the total profit of the store is maximized when Product B is sold at 268 yen, Product D at 348 yen, Product E at 218 yen, and Product F at 358 yen. In other words, for Store S, at which Product B has a small market share, the total store profit is maximized when the top product is sold at a discount and the other products are set at regular prices. The results of this simulation were clearly different to the results for other stores.

Figure 6. Simulation for profit maximization at Store S.

IV. LATENT RISK IN THE ANALYSIS PROCESS

In the above description of the case study, you can probably imagine that we steadily proceeded with the pricing project. Unfortunately, the project came up against various problems. This was because there were two significant risks hidden in the analysis process of the project.

A. Risk Resulting from a Lack of Understanding of Preprocessing and Basic Analysis

The first risk is that the members of the project would lose an understanding of the analysis results in the preprocessing of data and basic analysis. During the process, we promote a common understanding of various kinds of basic aggregate data, we share several doubts on the detailed results of analysis, and we must resolve those problems by way of further analysis. However, in many cases, partway through the analysis, members fail to understand the results, and they stop communicating with others. In dealing with this kind of risk, we must bear in mind data representation that is easy for the members to understand. It is believed that technology related to data visualization will contribute greatly to this problem.

B. Risk Resulting from a Lack of Field Knowledge

The second risk is one that arises from there being insufficient field knowledge when the new business plan based on the discovered information is applied to the field. Even if careful analysis has been conducted using data, it is rare that the perfect result will be obtained. When the information is applied to the actual supermarket shelves, only an expert with specialized domain knowledge [7] [8] will be able to pick up on any flaws in the analysis results. If this risk is not detected, the new measure will not be able to achieve satisfactory results, or it will fail. Preventing these risks with systems or technology is difficult. Rather, prevention is possible by means of the project or organization members and the communication systems employed in applying the information to the field.

V. CONCLUSION

In this paper, we introduced the case study on the business application of a system for supporting pricing designed to maximize store profits. In this case study, we discovered the

optimal prices for diet-oriented mayonnaise and cooking oil products. During this process, we were able to discover significant factors such as customer groups and store properties, and we were able to provide important information to actual price plans. During the discovery process, we recognized the need for ways and means for members to understand the results of analysis. Furthermore, we identified that participation and advice by experts with specialized field knowledge reduces risks when applying the information to reality.

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