Research on automatic pricing and replenishment decision of vegetable commodities based on optimization model

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Abstract. In fresh food superstores, because vegetable commodities are characterized by perishability and high value loss, superstores usually replenish daily commodities based on the historical sales and demand of various commodities. In order to make the optimal replenishment decision, this paper firstly firstly uses Matlab fitting toolbox to get the functional relationship between the total sales volume and the cost-plus pricing, so as to analyze the relationship between the total sales volume and the cost-plus pricing of each vegetable category, and then takes the category as a unit, and then constructs the optimization model, and solves the optimal replenishment volume and pricing strategy. The replenishment decision is obtained by filtering out the most profitable single product among the factors of unit price, sales volume, and total replenishment volume through objective planning under the constraints of considering the single product category and minimum display volume.

Keywords: Cost-plus pricing; LSTM model; Backpack model; Optimization model.

1. Introduction

Fresh produce is an indispensable necessity in people's daily lives, it is different from other consumer goods, the general freshness period of vegetables is relatively short and the quality of the sales time inversely proportional to its perishable properties, most of the fresh agricultural commodities are not sold on the day, the next day will not be able to sell, the super sales pricing and replenishment of sales through the history of sales and demand. Due to the super sales of many varieties of vegetables, different places of origin, and vegetables, usually in the early hours of 3:00 - 4:00, this business must not know exactly the specific single product and the price of goods in the case of replenishment decisions made on the day of the various categories of vegetables. Effective pricing and replenishment decisions have the potential to lead to significant increases in revenue. In many cases, consumer sensitivities may vary [1].Vegetables are generally priced using a "cost-plus pricing" approach, and supermarkets often discount for shipping losses and poor quality items. Reliable market demand analysis is important for replenishment and pricing decisions.

For the study of optimal replenishment decisions, Ventura, José A.[2] et al. developed a multi-product dynamic supply chain inventory model that takes into account supplier selection, joint replenishment, and transportation costs; Goedhart Joost [3]et al. modeled the rationing and ordering decisions as a Markov decision-making problem that maximizes the expected profit; Adeinat Hamza [4]et al. used a mixed-integer nonlinear programming model with the objective of maximizing total profit per unit time to confirm that pricing and inventory replenishment decisions are more sensitive to the parameters of the demand function; Zhao Nenggui [5]et al. drew relevant conclusions by investigating the single and joint effects of the reference effect (RE) and the quick replenishment (QR) strategies on customers' purchasing behaviors, retailer's optimal decisions, and total profit in both periods; Wan Guangyu [6]et al. investigated a novel joint replenishment strategy controlled by a sales threshold; Castellano Davide [7]et al. solved a stochastic joint replenishment problem by assuming stochastic demand with a controllable lead time and imposing a fill-rate constraint on each item in the context of a joint replenishment problem under a class of recurring strategies; Carlos Otero- Palencia [8]et al. proposed the stochastic collaborative joint replenishment problem (S-CJRP) approach to solve the stochastic joint replenishment problem with transportation and warehouse constraints; Ji Seong Noh [9]et al. developed a mathematical model describing the replenishment activities of a single type of item from the buyer's point of view, and proposed an algorithm to find a low-cost base period, order interval multiplier, and a safety factor; Jing Lu [10] The first-order linear partial differential equations about time and product freshness are used to portray the inventory dynamic system of fresh agricultural products, construct a system optimization model, and solve the optimal pricing strategy of the enterprise by using the theory of optimal control of distribution parameters.

In solving this problem, the data are first pre-processed and the problem is analyzed to be subdivided into two sub-questions: (1) The Matlab fitting toolbox is used to obtain the functional relationship between the total sales volume and the cost-plus pricing, so as to analyze the relationship between the total sales volume and the cost-plus pricing of each vegetable category. (2) Daily replenishment totals and pricing strategies for the coming week from July 1-7, 2023 for each vegetable category. The ratio of cost-plus pricing can be obtained if the sales price and cost can be calculated in terms of categories, and then the optimization model is constructed to solve the optimal replenishment total and pricing strategy. Consider the following four conditions that need to be achieved under the constraints of total sales and display volume: 1. Consider the case of damage. 2. Order quantity is greater than 2.5 and the total number of saleable items is 27-33. 3. Meet the market demand. 4. Maximize the revenue of the superstore. Through the objective planning, this paper is optimally estimated and the problem is viewed as a backpack problem, in which the factors of unit price, sales volume, and total replenishment are filtered out to the most profitable single product, and the total replenishment and pricing strategy are analyzed for the purpose of seeking the optimal solution.

2. LSTM modeling

2.1. Problem Solving Ideas

Firstly, the Matlab fitting toolbox is used to process the preprocessed data to get the functional relationship between the total sales volume and the cost-plus pricing, after which the relationship between the total sales volume and the cost-plus pricing for each vegetable category can be analyzed. Then for the total daily replenishment and pricing strategy for the vegetable category in the coming week from July 1-7, 2023, in terms of category, there are a vegetable category, where the replenishment type of the bth vegetable category is X_b(X is a positive integer), and the total category of pricing is Y_b (Y is a real number), and the sales price and cost of each type of goods are calculated, so as to get the proportion of the cost-plus pricing, and then construct an optimization model to solve the optimal replenishment total and pricing strategy.

2.2. Modeling

First, the data were integrated and processed (the data came from https://cumcm.cnki.net) to ensure that each order in the data presented the name of the commodity traded, the sales volume n, the sales unit price P_{sale} and the wholesale price $P_{\text{wholesale}}$, and the sales data were categorized into different material categories based on the commodity information through formulas in Excel, and the total revenue and total profit were found:

$$S_{revenue} = n * P_{\text{sale}} \tag{1}$$

$$S_{\text{total revenue}} = \sum n * P_{\text{sales volume}} \tag{2}$$

$$S_{profit} = n * (P_{\text{sale}} - P_{\text{wholesale}}) \tag{3}$$

$$S_{\text{total revenue}} = \sum n * (P_{\text{sale}} - P_{\text{wholesalers}}) \tag{4}$$

The cost markup percentage and markup rate are calculated from the resulting total revenue and total profit:

$$\text{Cost-plus ratio}\quad \alpha = \frac{S_{\text{total revenue}}}{S_{\text{total revenue}} - S_{\text{total profit}}} - 1 \tag{5}$$

$$\text{Additive rate}\quad \beta = \frac{\text{price} - \text{purchase price}}{\text{purchase price}} * 100\% \tag{6}$$

The data was analyzed to produce line graphs of cost and profit for each category over time, as shown in Figures 1 and 2.

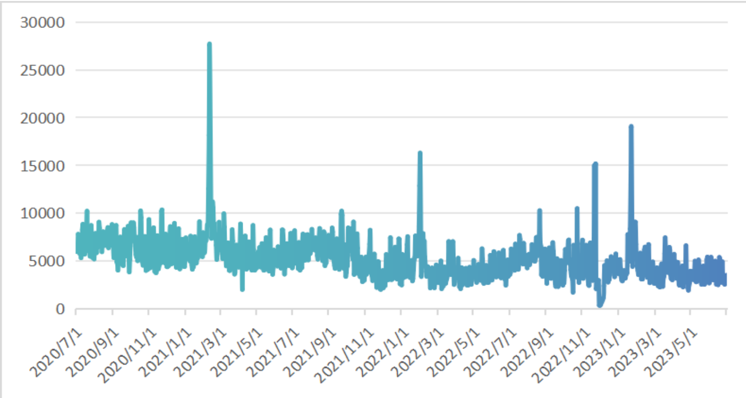

Figure 1. Line graph of cost changes over time by category.

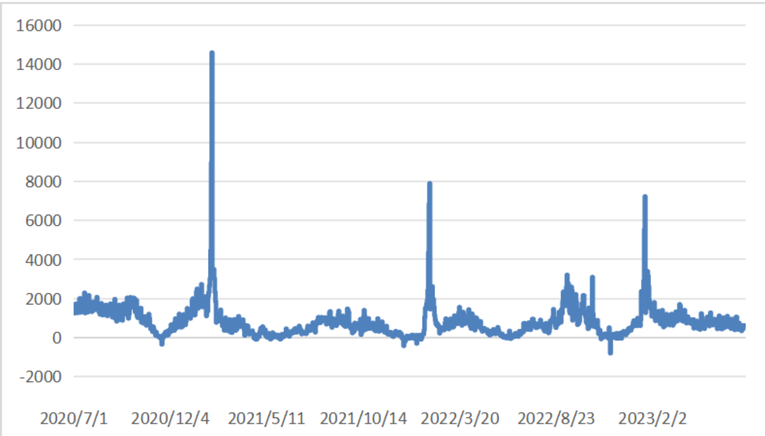

Figure 2. Line graph of profit over time by category.

According to the distribution pattern and interrelationship between the total sales volume and time of various categories of vegetables, so then solved the relevant data, analyzed the cost-plus ratio of all categories, calculated the mean value of 0.583, and all the missing values in the data table were filled with 0.583. After the missing values were filled in, then diversified linear regression analysis was performed to obtain the functional relationship between total sales and cost-plus pricing. From the data obtained it can be concluded that there is a low linear correlation between total sales and cost-plus pricing. According to the data analysis 2023.06.01-2023.06.30 the total sales of each category within the 30 days is relatively stable, July 1-7, 2023 and no statutory holidays, weekdays and weekends will affect the sales of goods, in order to get the maximum revenue, the superstore needs to meet the sales demand for each vegetable category and $\text{replenishment}_i = \text{total sales volume}_i + \text{consumption}_i$ (referring to the attrition rates provided in the relevant data) and so on, we will nearly 30 days of sales data of each category through the LSTM model to predict the future week (7.1-7), to get the cost-plus pricing of each individual item is relatively low linear correlation. We fit the sales data of each category in the last 30 days by LSTM model to predict the data of the coming week (7.1-7), and get the daily replenishment and pricing strategy of each item to maximize the revenue of the superstore.

3. Modeling of the backpack

3.1. Problem Solving Ideas

These four conditions need to be met in the available varieties from June 24-30, 1. Consider the case of damage 2. Order quantity is greater than 2.5 and the total number of available items is 27-33 3. Meet the market demand 4. Maximize the profitability of the superstore. Through goal planning, optimal estimation can be made from this, and the problem is viewed as a backpack problem to filter out the most profitable individual items among the factors of unit price, sales volume, and total replenishment.

3.2. Analysis of model data

The problem has multiple constraints:

Inventory constraints: Vegetable items have limited space to sell, and fresh produce superstores need to ensure that the quantity in stock does not fall below the inventory threshold;

Total number of saleable individual items controlled: $27 \le \sum \text{replenishment} \le 33$

Minimum display volume control: $\text{order quantity} \ge 2.5 * \text{replenishment quantity}$

Commodity demand requirements: $\text{total sales volume} \ge \text{sales demand}$

According to the above constraints for screening data, and then the screening data for multi-objective planning, and optimal processing. The problem is a typical knapsack problem, in the "knapsack" constantly stuffing things, we generally give priority to the high profit contribution rate of the goods, the data will be merged for processing and analysis, calculated the average daily revenue of each single product, the average daily unit price and the average daily sales volume, through the screening of the data, you can filter out the no-transaction information of the commodities. From the previous model, the daily replenishment and pricing strategy on July 1, 2023 can be obtained, and the problem data need to be further analyzed and cleaned according to the constraints before building the model. Due to the perishable and perishable characteristics of vegetable commodities, resulting in a short shelf life of vegetable commodities, and the quality of the product deteriorates with the growth of the sales time, most of the varieties in the day if they cannot be sold, the next day cannot be sold again, so the data will be introduced into the data of the loss rate of each vegetable commodity, to establish a correlation between the shelf life and the loss rate, and to further filter the problem data. Through the analysis, it is found that the lower the wastage rate of fresh commodities, the longer their shelf life; the higher the wastage rate of fresh commodities, the shorter the shelf life.

First, we processed the data first and calculated the mean value of wastage rate as 9.4% and its standard deviation as 0.05. After analyzing the problem data and filtering out 198 vegetable items, finally only 49 categories of goods are left to be selected. From the data, a total of 61 categories of items available for sale from 24-30, 2020-2023 were derived, and a total of 36 categories of items meeting the two conditions were filtered out.

4. Conclusions

In fresh food superstores, due to the perishable and high value loss characteristics of vegetable commodities, superstores usually replenish daily commodities based on the historical sales and demand of various commodities. Therefore, in this study, based on relevant information and data, the LSTM model and the backpack model are constructed for the automatic pricing and replenishment decision problem of vegetable products, and the optimal replenishment quantity and pricing analytical solutions are obtained. The following conclusions are obtained by combining the examples: (1) the selling price and cost can be calculated in terms of categories to get the proportion of cost-plus pricing, and then the optimisation model is constructed, from which the optimal replenishment quantity and pricing strategy are solved. (2) In the case of the total number of single products and the minimum display quantity are restricted, the replenishment quantity and pricing strategy for the coming week can be predicted on the premise of meeting the market demand for various types of vegetable commodities. (3)Pricing strategy. This also provides a good solution for fresh food superstores to make corresponding replenishment decisions and pricing strategies.

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