

Application of Linear Programming on the Maximum-Profit of Milk Tea Store

Yuewei Wang*

Department of Math, University of North Carolina at Chapel Hill, NC, US.

*Corresponding author: ywang2@unc.edu

Abstract. The aim of this article is the application of the industrial profit optimization on milk tea store. The linear programming model is used to determine the optimal production structure of amount of raw material purchased. The first part optimizes only the single profit from the sales which are put into the objective function. The second section of the article extends the model by the considering factors of employee. This model will have more constraints. The model aims to meet the maximum cost of raw materials, and meet the situation that the staff will have different abilities on making tea and each tea for each person takes different time to complete. The model will be built based on real data, and then will compare the real data results with the calculated results. Conclusions of the paper demonstrate the applicability of the model and possibilities of its extensions.

Keywords: Optimization; Linear programming; Industrial cost management; Production cost.

1. Introduction

Milk tea stores are now a hot business all over the world. More and more people are choosing to join the milk tea industry to start their own business. A variety of milk tea spots have come into existence and the control of milk tea cost and sales and inventory is a very important part. In this paper, a milk tea store will be analyzed that once opened but closed down in the United States in the direction of ingredient purchasing and profit rationing, combined with the linear programming model learned in the course [1].

Linear programming is an important model for optimization class problems. It has a mature theory and is widely used by the class in practical applications. It has a unique advantage in studying the optimal allocation of limited resources. It is convenient for users to make decision analysis in order to make the best use of resources to obtain the best economic benefits [2]. There are also genetic algorithms, neural networks, ant colony algorithms and other methods to find optimal solutions in optimization class problems [3]. Linear programming is a common contemporary mathematical model, which is very suitable for dealing with multi-species problems. There are a large number of papers that use linear programming for industrial warehouse cost management as well as human resource management [4,5]. Therefore, this paper will do multi-objective linear programming model on the basis of milk tea cost control. All the data came from a milk tea store that has gone bankrupt and has been made public with the owner's permission. This article will also examine why this milk tea store went bankrupt by comparing the calculated results with the actual operating costs [6].

2. Model building and solving

2.1 Cost organization

We obtained through the Internet means that a brand of milk tea store has three hot commodities which are whitening and skin care milk tea, skin clearing milk tea, fitness milk tea. The brand focuses on nutrition, health, safe milk tea, which is popular with girls. The series of milk tea mainly consists of five kinds of ingredients. They are milk, mung bean powder, pearl powder, honey, and lotus seed powder. Each milk tea needs to consume different proportions of raw materials, and the profit margin varies between each raw material. The relevant data is shown in the following Table 1.

Table 1. Milk Tea Recipe and Profit Table

Name	Milk	Mung bean powder	Pearl powder	honey	Lotus seed powder	profit
Whightening tea	250	8	0.5	10	0	10
Skin-refreshing tea	250	10	0.5	10	10	8
Fitness tea	500	12	0	20	0	12

According to the feedback from the industry, the shelf life of each raw material is limited, and for food safety. If too much raw material is supplied, it will cause the problem of raw material wastage, which will cause additional burden to the enterprise. Therefore, this paper will focus on solving this internal problem. At the same time, in order to take care of various tastes, the enterprise needs to ensure enough at least 5 copies of whitening and skin care milk tea, 20 copies of skin clearing milk tea and 30 copies of fitness milk tea every day. The maximum supply of milk is 30,000, the supply of mung bean powder maximum is 5,000, the supply of pearl powder maximum is 160, honey 3,000, lotus seed powder 3,000.

By analyzing the survey data and content of this paper, this paper will use linear programming as the solution model of this paper. Here we set X_1 copies of whitening milk tea, X_2 copies of skin-clearing milk tea and X_3 copies of healthy milk tea are sold every day. The objective function is

$$\text{Max} = X_1 + X_2 + X_3, \tag{1}$$

and it is subject to

$$250X_1 + 250X_2 + 500X_3 \leq 30000 \tag{2}$$

$$8X_1 + 10X_2 + 12X_3 \leq 5000 \tag{3}$$

$$0.5X_1 + 0.5X_2 + 0X_3 \leq 160 \tag{4}$$

$$10X_1 + 10X_2 + 20X_3 \leq 3000 \tag{5}$$

$$0X_1 + 10X_2 + 0X_3 \leq 3000. \tag{6}$$

Here we use Python's PuPl library to solve the problem (see the attachment for the code). The final result is as follows

$$\text{Max value } z = 920.0, X_1: 40.0, X_2: 20.0, X_3: 30.0. \tag{7}$$

Ultimately, we get that selling 40 servings of whitening and skin-clearing milk tea, 20 servings of skin-clearing milk tea, and 30 servings of fitness milk tea will achieve the greatest profit given a specific supply of ingredients.

2.2 Considering manual cost and other cost

At first the owner of the milk tea store was not very willing to disclose, but only gave a part of the data. After the calculation was completed, the data was compared with the data of the owner of the milk tea store and found to be similar to the actual situation [7]. However, the owner only disclosed the subsequent data. So there is a more complicated model. Table 2 is available based on the data.

Table 2. Components and Profits

Name	Milk	Sugar	Milk essence	tea	Mung Bean powder	Pearl Powder	Honey	Lotus Sed Powder	Profit
Whitening Tea	250	18	30	120	8	0.5	10	0	10
Skin-Refreshing Tea	250	18	30	120	10	0.5	10	10	8
Fitness Tea	500	18	30	120	12	0	20	0	12
Signature Tea	10	18	30	120	0	0	0	0	10
Bubble Tea	10	18	30	120	0	0	0	0	10
Lychee Jelly Tea	10	18	30	120	1	1	0	0	12
Pudding Tea	10	18	30	120	1	1	0	0	12
Red Bean Tea	10	18	30	120	1	1	0	0	12
Brown Sugar Tea	10	18	30	120	1	1	0	0	12
Sencha tea	10	18	30	120	1	1	0	0	11
Jasmine Tea	10	18	30	120	2	1	0	0	12
Caramel Macchiato	10	18	30	120	3	1	0	0	11
Chocolate Tea	10	18	30	120	1	0	0	0	14
Yuan Yang Tea	10	18	30	120	2	1	1	0	12
Cake Tea	10	18	30	120	3	2	1	0	9

The store has three employees, each of whom processes different types of milk tea at different times, which has an impact on sales. Customers who came to the store to check the queue were too many and would give up buying the relevant products [8]. Therefore, a reasonable arrangement of staff scheduling and production of related raw materials is crucial to the output of the store. The staff's production time for each type of milk tea is as follows in Table 3.

Table 3. Time for Making Each Milk Tea

Name	A	B	C
Whitening Tea	1	2	1
Skin-Refreshing Tea	1.5	1.5	1
Fitness Tea	2	1.5	1
Signature Tea	1	2	1
Bubble Tea	1.5	1.5	1
Coconut Jelly Tea	2	1.5	1
Pudding Tea	1	2	1
Red Bean Tea	1.5	1.5	2
Brown sugar Tea	2	1.5	2
Sencha tea	1	2	2
Jasmine Tea	1.5	1.5	2
Caramel Macchiato	2	1.5	2
Chocolate Tea	1	2	2
Yuan Yang Tea	1.5	1.5	2
Cake Tea	2	1.5	2
Salary per hour	65	70	80

To simplify the model, the hourly rate is set to p here, and the corresponding labor cost per unit of no-minute milk tea is represented by the following equation: to make the model more general, all ingredients are represented here by $x_i \in [1, N]$ in Table 4. Employees are denoted by $e_i \in [1, N]$.

The employee list each employee makes $N_{(ci)} \in [0, N]$ kinds of milk tea for sale every day. The types of milk tea are denoted by $C_{(i)} \in [1, N]$. The following objective function is obtained.

Table 4. Symbols and meanings

Symbol	Explanation
$e_i \in [1, n]$	Number of employees
$x_i \in [1, n]$	Number of raw materials needed for each milk tea
$C_j \in [1, n]$	Number of milk tea
$N_j \in [0, n]$	Number of sold out milk tea
$P_j \in [1, n]$	Profit for each milk tea
$R_i \in [1, n]$	Single day storage for raw materials
T_{ec}	Time for employee making each tea
t	Work time

Objective function is

$$\text{Max} = \sum_{i=0}^n \sum_{j=0}^n P_j N_i \tag{8}$$

and it is subject to several restrictions as shown below.

Number of all milk tea sold

$$N = N_1 + N_2 \dots + N_j. \tag{9}$$

Number of raw materials used

$$x_i \times N_j \leq R_i. \tag{10}$$

Time constraint

$$\sum_{i=0}^n \sum_{j=0}^n T_j N_i \leq e \times t. \tag{11}$$

The model is

$$\begin{aligned} &\max 10x_1 + 11x_{10} + 12x_{11} + 11x_{12} + 14x_{13} + 12x_{14} + 9x_{15} \\ &+ 8x_2 + 12x_3 + 10x_4 + 10x_5 + 12x_6 + 12x_7 + 12x_8 + 12x_9 + 0 \end{aligned} \tag{12}$$

subject to

$$\begin{aligned} C_1: &10x_1 + 10x_{10} + 10x_{11} + 10x_{12} + 10x_{13} + 10x_{14} + 10x_{15} + 8x_2 + 12x_3 + 10x_4 + 10x_5 \\ &+ 10x_6 + 10x_7 + 10x_8 + 10x_9 \leq 30000 \\ C_2: &18x_1 + 18x_{10} + 18x_{11} + 18x_{12} + 18x_{13} + 18x_{14} + 18x_{15} + 18x_2 + 18x_3 + 18x_4 + 18x_5 \\ &+ 18x_6 + 18x_7 + 18x_8 + 18x_9 \leq 30000 \\ C_3: &30x_1 + 30x_{10} + 30x_{11} + 30x_{12} + 30x_{13} + 30x_{14} + 30x_{15} + 30x_2 + 30x_3 + 30x_4 + 30x_5 \\ &+ 30x_6 + 30x_7 + 30x_8 + 30x_9 \leq 30000 \\ C_4: &10x_1 + 120x_{10} + 120x_{11} + 120x_{12} + 120x_{13} + 120x_{14} + 120x_{15} + 8x_2 + 12x_3 + 120x_4 \\ &+ 120x_5 + 120x_6 + 120x_7 + 120x_8 + 120x_9 \leq 300000 \\ C_5: &x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 \leq 3000000. \\ C_6: &x_1 \geq 30, x_2 \geq 20, x_3 \geq 30, x_4 \geq 30, x_5 \geq 30, x_6 \geq 30, x_7 \geq 30, x_8 \geq 30, x_9 \geq 30, x_{10} \\ &\geq 30, x_{11} \geq 30, x_{12} \geq 30, x_{13} \geq 30, x_{14} \geq 30, x_{15} \geq 30. \end{aligned}$$

In addition, the variables x_i ($1 \leq i \leq 15$) are all integers.

The maximize output is $z = 12830.0$, while for each variable: $\{x_1:30.0, x_{10}:30.0, x_{11}:30.0, x_{12}:30.0, x_{13}:620.0, x_{14}:0.0, x_{15}:30.0, x_2:20.0, x_3:30.0, x_4:30.0, x_5:30.0, x_6:30.0, x_7:30.0, x_8:30.0, x_9:30.0\}$. From this, the number of individual raw materials that should be purchased can be derived, which is the maximum profit when maximizing both employee efficiency and output. This calculation was compared with the actual operating profit, and after deducting some fixed costs, the operating profit was actually lower than the calculated result, so it is likely that this led to the bankruptcy of the store.

3. Conclusion

The aim of the paper is to create proposal of an economic model, which would optimize production of a milk tea company with respect to a maximization of the profit from selling its production. Through the application of the model on the real data to get the final result, the maximized profit is smaller than cost in real life, which leads to the bankruptcy of the milk tea store [9]. If the owner of the store can buy the similar quantity of each type raw material as calculated, he can earn economic profit. Because the store itself is owned by the owner, the effect of rent is not considered in this calculation, and only the cost of goods and labor is included in the calculation [10].

The model could be further extended. It is possible to alter it for conditions of specific milk tea store with different types of products or extend the model structure, so the scope would be wider. One of proposal is that the model could be enriched by analysis of different elasticities such as price elasticity, especially prices of different rental among different places and number of substitutes among consumer choices.

References

- [1] Gary D, Ferrier C, Knox-Lovell A. Measuring cost efficiency in banking: Econometric and linear programming evidence, *Journal of Econometrics*, 1990, 46: 229-245.
- [2] Frederick V. The Minimum-Cost Dairy Feed (An Application of "Linear Programming"), *Journal of Farm Economics*, 1951, 33(3), 299-310.
- [3] Amjady N. Short-term hourly load forecasting using time-series modeling with peak load estimation capability. *IEEE Transactions on Power Systems*, 2001, 16(3): 498-505.
- [4] Fred H, Sidney W. Hess A Linear Programming Approach to Production and Employment Scheduling. *Management Technology*, 1960, 1: 46-51.
- [5] Vishwa N. M., Ram B. M., Peter K. A. et al. Profit Optimization Using Linear Programming Model: A Case Study of Ethiopian Chemical Company. *American Jour. of Biological and Environmental Stats.*, 2015, 1(2): 51-57.
- [6] Charnes A. Cooper Management Models and Industrial Applications of Linear Programming. *Management Science* 1957, 4(1):38-91.
- [7] Aigner D. J., Chu S.-F. On Estimating the Industry Production Function. *American Economic Review* 1968, 58(4): 826–839.
- [8] Lovell C.A.K., Grosskopf S., Ley E. et al. Linear programming approaches to the measurement and analysis of productive efficiency. *Top*, 1994, 2: 175–248.
- [9] Assessing competition in the banking industry: A multi-product approach. *Journal of Banking and Finance*, 2015, 50: 340-362.
- [10] Baki S M, Cheng J K. A Linear Programming Model for Product Mix Profit Maximization in A Small Medium Enterprise Company. *International Journal of Industrial Management*, 2021, 9(1): 64-73.