Proceedings of CONF-MLA 2025 Symposium: Intelligent Systems and Automation: AI Models, IoT, and Robotic Algorithms
DOI: 10.54254/2755-2721/2025.LD29857

Transportation Cost Optimization in Ice Cream Industry Based on Linear Programming

Mengyuan Ding[1†], Yixuan Chen[2*†], Zhibo Zhang[3]

[1]Beijing New Oriental Foreign Language School at Yangzhou, Yangzhou, China
[2]Shenzhen Senior High School, Shenzhen, China
[3]Changchun No. 11 High School, Changchun, China
**Corresponding Author. Email: chenyx1@cn-school.com*
[†]These authors contributed equally to this work and should be considered as co-first author.

Abstract. Optimizing ice cream distribution is critical for enterprises to reduce high logistics costs and improve operational efficiency. Addressing this need, this study develops a linear programming model that has the aim of minimizing the transportation cost. It is about the optimization of ice cream distribution from two factories to 18 retail stores in Shanghai Pudong New Area. The model incorporates real-world constraints, including factory capacity limits and store demand requirements. We use the Python package PuLP to help us build the model. The result successfully lowers the transportation cost to 3,321.1 RMB, demonstrating the model has high potential in practical application.

Keywords: Transportation network, Cost optimization, Linear programming, Simplex method

1. Introduction

In recent years, the developing economy and the rapid increase in the weight of moving have put a lot of pressure on the logistics systems. Logistics costs account for approximately 10% in developed countries and 18% in other developing nations. In which the transportation cost contributes largely to over 50% the total logistics cost. Transportation is an important activity in logistics systems. It helps connect regions, hinterland ports with ports, suppliers, and customers. The traditional transportation modes include truck, rail, water, and air.

The first formulation of transportation problems dates back to the late 1930s and early 1940s. Kantorovich (1960) contributed to this field in 1939. Later on, Hitchcock [1] discussed the problem of the distribution of a product from several warehouses (or sources) to numerous locations (or destinations). The problem of optimal routing messages in a communication network, the contract award problem, and the routing of aircraft and ships are important applications of transportation problems.

Traditional transportation problems involve topics such as supply and demand matching and route selection, but actual transportation systems face complex constraints such as dynamic demands and traffic restrictions. Therefore, using techniques like linear programming to construct

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2755-2721/2025.LD29857

transportation optimization models is crucial for enhancing the response speed and service quality of logistics systems.

2. Methodology

2.1. Variables

Table 1. Variables and notations

Description	Notation	Unit
Cost of cold chain transportation, including fuels	c_{ij}	Yuan/t/km
Demand of stores	x_{ij}	t
Capacity of factories	p_i	t

2.2. Data collection

2 factories and 18 stores selling Häagen-Dazs are found in Shanghai Pudong New Area on Google map. Distances of each route from factories to stores are recorded given the same date and time. Stores' demand for ice cream are chosen according to an average number of demand per month and their locations. While stores at centre of city like L(2.8 tons) has higher demand, stores at relatively remote areas like A(1.0 tons) have lower demand. The total demand from stores is 30.0 tons per month. The typical capacity of an ice cream factory can reach several hundred tons, but one factory may cover many areas. So we assume that amount of ice cream that factories can provide is 15.5t and 20.0t respectively. Transportation cost is 5¥ per kilometer.

Table 2. Distance and demand data

stores	Distance from factory 1/km	Distance from factory 2/km	demand/t
a	19.7	11.4	1
b	9.1	21.6	2.2
c	15.9	25.7	1.5
d	17.5	30.4	1.1
e	16.7	26.4	1
f	16.8	24.1	2
g	14.8	33.4	2
h	17.3	30	2.6
i	16.5	33.5	1.9
j	16.6	33.5	1.7
k	14.2	31.1	2
l	13.8	30.7	2.8
m	24.8	41.9	1.6
n	23.4	43	1.5
o	18.1	39.3	1.4

DOI: 10.54254/2755-2721/2025.LD29857

Table 2. (continued)

p	22.4	39.2	1.4
q	18.8	35.6	1.3
r	17.1	33.3	1

2.3. Model formulation

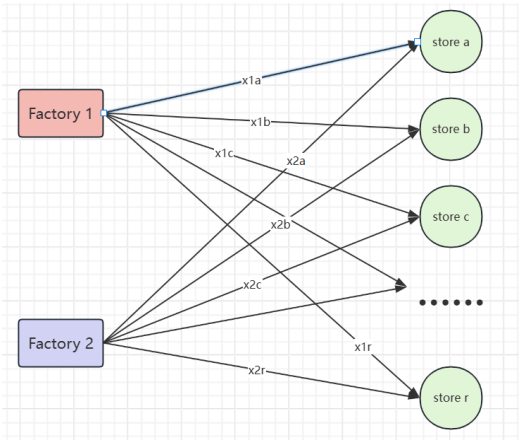

Figure 1. The transportation problem

The routes are shown in figure 1. Linear programming is used to solve this problem. Total cost must be minimized while the amount of ice cream transported to each store meets its demand, and ice cream transported from each factory should not exceed its yield. Both cost and amount of ice cream transported should not be negative.

Minimize

$$\sum c_{ij} * x_{ij},$$

Subject to

$$\sum_{i=1}^{2} x_{ij} = x_j, j = a, b, c...r,$$

$$\sum x_{ij} = p_i, i = 1, 2; j = a, b, c...r,$$

$$c_{ij} \geq 0,$$

$$x_{ij} \geq 0,$$

3. Computational experiment

The solution of equations is obtained using python and puLP [2], a package specializing linear programming. Coin-or Branch-and-Cut Solver, which utilizes simplex method, solves the inequalities. Simplex method is introduced in 1947 by George Bernard Dantzig. Simplex method is

DOI: 10.54254/2755-2721/2025.LD29857

a classic and highly efficient algorithm for solving linear programming problems [3]. This method is effective and fast in solving linear programming problems. Linear inequalities are plotted in a x-y coordinate system to from a convex polyhedron X. The simplex method runs in two phases. In phase 1, a feasible vertex x_0 of X is determined and calculated. In phase 2, Starting from vertex x_0 , a sequence of vertices of X is constructed such that consecutive vertices are adjacent and that $v_{x+1} > v_x$. The algorithm stops if either none of the edges adjacent to x_s is increasing or if one finds an unbounded edge adjacent to x_s improving the objective [4]. So when the algorithm stops, the optimum solution is found.

Table 3. Transportation amount

Store\Factory	1/t	2/t
a	0.0	1.0
b	0.0	2.2
c	0.0	1.5
d	0.0	1.1
e	0.0	1.0
f	0.0	2.0
g	2.0	0.0
h	0.0	2.6
i	1.9	0.0
j	1.7	0.0
k	2.0	0.0
l	2.8	0.0
m	1.6	0.0
n	1.5	0.0
o	1.4	0.0
p	0.0	1.4
q	0.6	0.7
r	0.0	1.0

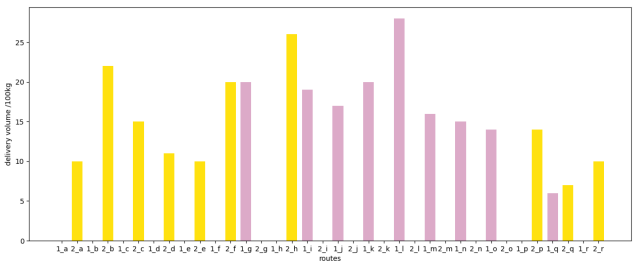

Figure 2. Result of optimization

Table 3 and figure 2 shows the solution of the problem, amount of ice cream transported through each route. The minimum cost is reached. All stores except q receive ice cream only from one factory, as from the map, two factories are distant and most of stores are closer to factory 1.

DOI: 10.54254/2755-2721/2025.LD29857

4. Sensitivity analysis

4.1. Minimum limitation

To test the model's robustness, lower bound of amount of ice cream on each route is added, ranging from 0.1t to 0.7t. Sometimes certain roads are blocked and another factory must transport some ice cream to the stores.

Table 4. Result of lower bound test

Lower bound/t	Total cost/yuan	Percentage change in cost/%
0.1	3359.2	1.15
0.2	3397.4	2.3
0.3	3435.6	3.45
0.4	3473.8	4.6
0.5	3512.1	5.75
0.6	3636.6	9.5
0.7	3794.2	14.2

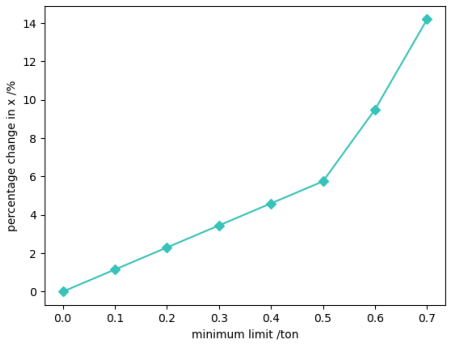

Figure 3. Line graph of lower bound test

As shown in Figure 3, lower bounds from 0.1t to 0.5t cause a linear change in total cost. After 0.5t, the total cost rises at a higher rate. The maximum value of bound is 0.7t, as beyond this value, restrictions in the equations--demand of some stores--can not be satisfied.

This result shows that, with a small change in the lower bound, an increase in total cost is relatively small and acceptable.

4.2. Change in capacity of factories

To figure out how the amount of ice cream transported in each route responds to a change in capacity, capacity of each factory is increased by 0.5t each time with no change in other variables.

DOI: 10.54254/2755-2721/2025.LD29857

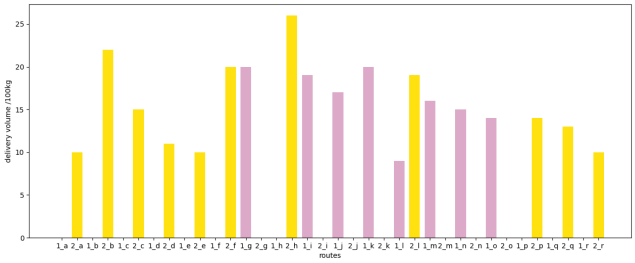

Figure 4. Optimization result at total capacity -5t

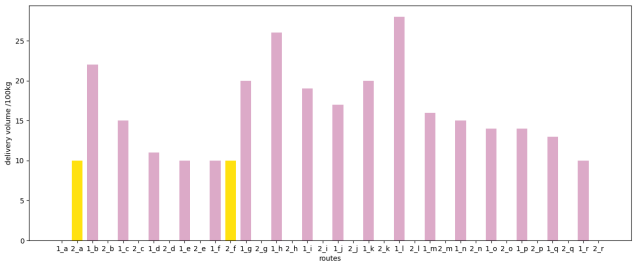

Figure 5. Optimization result at total capacity +25t

From figure 4 and 5, a clear trend can be seen. As factory 1 is closer to most of the stores, when total capacity increases, more stores are supplied by factory 1. So in the previous solution, stores supplied by factory 2 are likely to be a compromise when factory 1's capacity is not enough.

5. Conclusion

After gaining basic understanding of this problem, we conducted research and found a package called puLP to construct the model. Finally, we developed a model and obtained results about the optimal allocation of the supply from two factories to various stores. The model calculated the total cost of transporting ice cream. By using the real-world map data and the controlled-variable method, our model can be adapted for real-world applications with further refinement. The project also has limitations, including assumptions regarding factory supply levels. However, this limitation stem from our inaccessibility to trade secrets. The model remains valid and functional. For further work, we plan to consider the waypoint optimization, a strategy commonly employed by major companies in the reality. Also, we will add the cost factor in the model. After improvement, a model for optimizing ice cream transportation in Shanghai Pudong can be developed. This highly specific and novel approach offers significant practical value, which might become a possible approaches for real-world companies to consider [5].

References

[1] Hitchcock, F. L. (1941). The distribution of a product from several sources to numerous localities. Journal of Mathematics and Physics, 20(1), 224-230.
[2] Mitchell, S., O'Sullivan, M., & Dunning, I. (2011). PuLP: A Linear Programming Toolkit for Python. The University of Auckland, Auckland, New Zealand.
[3] Dantzig, G. B., & Thapa, M. N. (1997). Linear Programming 1: Introduction. Springer-Verlag.
[4] Karl Heinz Borgwardt. The Simplex Method: A Probabilistic Analysis [M].University of Augsburg, 1987

DOI: 10.54254/2755-2721/2025.LD29857

[5] Cordeau, J. F., Laporte, G., Savelsbergh, M. W., & Vigo, D. (2007). Vehicle routing. In Transportation (pp. 195-224). North-Holland.