Warehouse Allocation Problem

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ABSTRACT: This paper mainly focuses on constructing a model to reallocate warehouses in parts of China for maximum efficiency through minimizing the number of warehouses in China and minimizing the economic cost of the delivery. This research identifies that having a warehouse in every province could be a waste of resources. Therefore, we try to find a balance between smaller number of warehouses and cheaper transportation cost. We considered a few main factors and constructed models with formulas to get the optimal solutions. As for the goal of minimizing the number of warehouses in China, Zhejiang, Liaoning, Henan, Heilongjiang, Jiangxi, and Gansu are found to be the province set warehouses in addition to the independent and bidependent provinces. For minimizing the economic cost of the delivery, the transportation cost reaches its lowest point when there are only sixteen warehouses. These findings would enable transportation companies to take efficiency and the cost into consideration. The findings do consider that these companies need to achieve maximum satisfaction of the client. On the other hand, the efficiency of the delivery may save many unnecessary resources to enhance the world's sustainable development.

Keywords: Bidependent, independent, number, delivery, cost.

1. INTRODUCTION

Nowadays, people are mainly relying on online purchasing worldwide instead of going to traditional brick-and-mortar stores because the convenience that online stores bring to the consumers is a priority in a fast-paced life [1] Therefore, rearranging our warehouse distribution to make delivery much more efficient has become the main goal that people are focusing on, which can provide our consumers a positive shopping experience as well [2]. To achieve this idea, we started to investigate a mathematical model that can find the optimal locations for our warehouses, particularly in China, under various constraints. In our model, we contain a plan to minimize the number of warehouses in China and a plan to minimize the economic cost of the delivery while ensuring our delivery reaches every part of China by taking three key factors into our consideration: rent for different provincial capitals, delivery cost which varies between each city, and local average salary.

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2. SOLUTION FOR MINIMIZING THE NUMBER OF WAREHOUSES

2.1 Brief Introduction

Problem 1 is about how to minimize the number of warehouses in mainland China through linear programming with the help of statistics we collected before [3].

2.2 Variables

The variables that appeared in this solution are divided into 3 groups: 'Independent', 'Bidependent' and 'non' variables respectively. Independent variables stand for the cities that could cater with the demand individually as represented in figure 1 below; Bidependent variables stand for the cities that could tackle with the demands in several areas individually. Thus, Independent variables as well as the bidependent variables, are excluded in our solution since they have already reached the maximum efficiency with no need to rearrange. In a nutshell, the variables we considered are merely 'non' variables.

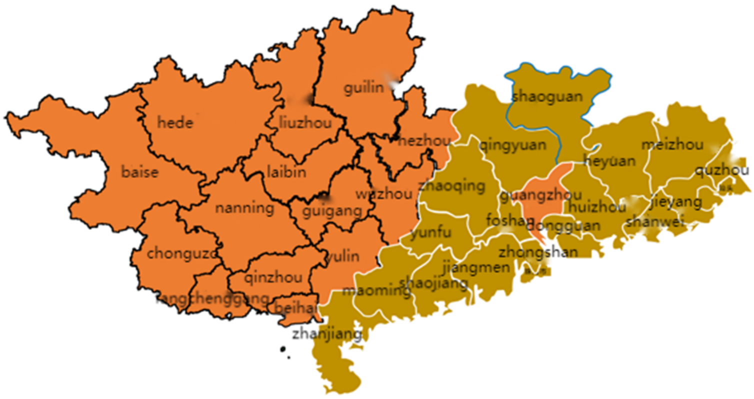

Figure 1: Orange areas are within one-day delivery with into a province.

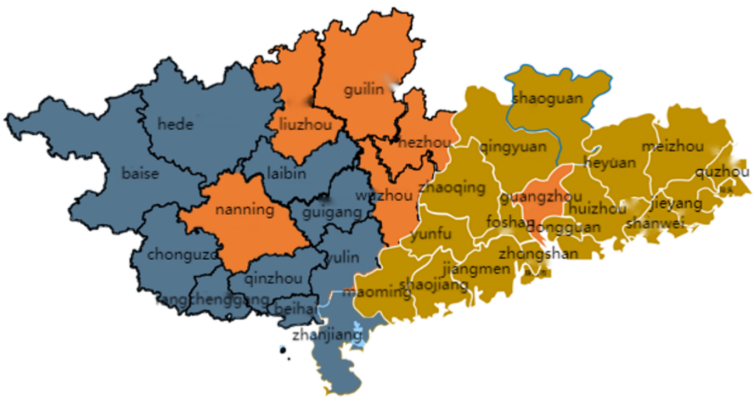

Figure 2: Dark blue areas are within Guangxi Province one-day delivery from Guangdong Province.

For example, Guangdong and Guangxi as illustrated in figure 2, are considered to be bidependent because setting two warehouses in their capital cities can completely meet their demands.

2.2.1 Independent Variables

Shanghai, Beijing, Fujian, Guizhou, Hunan, Hubei, Jilin, Shandong, Shanxi, Tianjin, Sichuan, Chongqing as illustrated indigo in figure 3 below.

2.2.2 Bidependent Variables

Anhui, Jiangsu, Guangdong, Guangxi as illustrated in blue in figure 3 below.

Figure 3: Blue and Indigo stand for bidependent and independent provinces respectively.

2.3 Statistic Used

The statistics we have utilized for part 1 question are the rents of the warehouses in different provinces, since we are attempting to minimize the number of the warehouses through setting constrains on economic factors.

2.4 Equation

$$minC^T X \tag{1}$$

$$C \in [0,1] \tag{2}$$

$$A * X \geq S \tag{3}$$

$$S = \sum_{i=1}^{n} a \tag{4}$$

$$a \in A \tag{5}$$

2.4.1 Explanation

Since our goal is to minimize the number of warehouses, X should be 1 and C which involves '1' and '0'will determine whether we will put a warehouse in that area. Meanwhile, the A appears in our equation is the rent of the warehouses in distinctive provinces. According to the boundary, the program would select the least number of warehouses for us. '1' means there is a warehouse, 0 means there is not any warehouses

2.5 Result

The result shows the need for warehouses in the following provinces, in addition to the bidependent and independent ones: Zhejiang, Liaoning, Henan, Heilongjiang, Jiangxi, and Gansu.

2.6 Code

2.6.1 Reason for Using Specific Code

Since the result we attempt to obtain should be an integer as well as the variables, we finally make use of integer linear program.

2.6.2 Code

```
f=ones (14,1)

intcon=[1,2,3,4,5,6,7,8,9,10,11,12,13,14];%every index is an integer

b=-386.9*ones (1,14);

A_row = [-31.66, -29.5, -31.99, -30.48, -23.95, -22.04, -22.77, -23.43, -17.93, -20.74, -19.63, -21.07, -19.2, -150];

A = [A_row; A_row; A_row; A_row; A_row; A_row; A_row; A_row; A_row; A_row; A_row; A_row; A_row; A_row; ];

Aeq  = [ ];

Beq = [ ];

lb = zeros (14, 1);

ub = ones (14, 1)

Intlinprog (f, intcon, A, b, Aeq, beq, lb, ub
```

3. SOLUTIONS FOR MINIMIZING THE ECONOMIC COST OF THE DELIVERY

3.1 Introduction

In this part, we assume that there is one warehouse in each provincial capital. Our goal is to come up with an allocation plan so that we can minimize the total delivery cost while meeting the basic demand of every province [4].

3.2 Setting Variables

Two factors, population, and economy are considered. Population index, p_i, is directly related to the provincial population. Economic index contains three parts: transportation expense (t_i), rent (r_i), and labor cost (w_i). Using the AHP method, we assign weights to these parts and then reach the economic index.

Both two indices range from 0 to 10. Their calculation processes are shown below.

$$p_i = \frac{Provincial\ Population}{National\ Population} * 10 \tag{6}$$

$$t_i = \frac{Local\ Motorway\ Fee}{Max\ Motorway\ Fee} * 10; \quad r_i = \frac{Local\ Rent}{Max\ Rent} * 10; \quad w_i = \frac{Local\ Average\ Wage}{Max\ Average\ Wage} * 10 \tag{7}$$

3.3 Model Solution

Then the question turns to the following linear programming problem:

$$min \sum_{i=1}^{31} \sum_{j=1}^{31} X_{i,j} * P_j * \frac{e_i + e_j}{2}$$

$$s.t. \qquad X * e \leq B,\ B_i = 10 * \frac{Provincial\ Freight}{Max\ Provincial\ Freight} \tag{8}$$

$$X^T * e \geq C,\ C_j = 10 * \frac{Provincial\ Total\ Consumption}{Max\ Provincial\ Total\ Consumption} \tag{9}$$

$$X \geq 0$$

Where $X_{i,j}$ denotes the weight of goods delivered from province i to province j; pj is the population density of the destiny, province j; $e_i + e_j$ covers the average economic cost for the delivery. In addition, B implies the maximum delivery capacity of each province, and C is related to minimum demand of each province. $X \in R^{31\times31}, B, C \in R^{31\times1}$

We reach the results with the formula $\frac{X*maxB_i}{10}$ and their units are in tons. The results are shown below, and each number in row m column n denotes the total weight of goods delivered from province m to province n. Table 1 below shows the maximum delivery capacity of each 2 province

Table 1. Maximum delivery capacity of each 2 province

	Beijing	Tianjin	Shanghai	Chongqing	Hohhot	Urumchi	Lhasa	Lhasa	Nanning	Harbin	Changchun	Shenyang	Shijiazhuang	Zhengzhou	Jinan	Taiyuan
Bcijing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tianjin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shanghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chongqing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Hohhot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urumchi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lhasa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lhasa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nanning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57558.15525
Harbin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Changchun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shenyang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	155660	0
Shijiazhuang	0	0	0	0	0	0	0	0	0	0	0	0	0	135485.0579	111837.9421	0
Zhengzhou	0	0	0	0	0	0	0	0	0	0	0	0	48107.39441	0	0	0
Jinan	0	0	0	0	0	0	0	0	0	0	0	0	59346.17729	0	0	0
Taiyuan	0	0	0	0	0	0	0	0	0	0	0	0	0	69458,60924	0	0
Lanzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chengdu	0	0	0	0	0	0	0	0	71821.02408	0	0	0	0	0	0	0
Wuhan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hefei	0	0	0	0	0	0	0	0	0	0	0	76942.69578	0	0	0	0
Nanjing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hangzhou	8000.599627	31999.63743	0	0	0	0	7005,326033	1123308354	0	0	0	0	0	0	0	0
Fuzhou	0	0	107748.3973	0	0	0	0	0	0	0	0	0	0	0	0	0
Nanchang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Changsha	0	0	0	120497.3158	0	30996.40556	0	0	0	41397.15258	0	0	0	0	0	4465.790643
Guiyang	86444	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kunming	21549.76179	0	23553.2069	0	39527.33593	0	0	0	0	0	36427.6951	0	0	0	0	0
Guangzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Haikou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2 below illustrates the minimum demand of each province

Table 2. Minimum demand of each province

	Taiyuan	Ianzhou	Xian	Xining	Chengdu	Wuhan	Hefei	Nanjing	Hangzhou	Fuzhou	Nanchang	Changsha	Guiyang	Kunming	Guangzhou	Haikou
Beijing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tianjin	0	0	0	0	48744.63189	3774.368111	0	0	0	0	0	0	0	0	0	0
Shanghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chongqin	0	0	0	0	121692	0	0	0	0	0	0	0	0	0	0	0
Hohhot	0	0	0	0	0	0	0	0	0	0	0	0	0	178071	0	0
Urumchi	0	0	0	0	0	0	0	0	0	0	0	0	0	57814	0	0
Lhasa	0	0	0	0	0	0	0	0	0	0	0	0	0	409	0	0
Lhasa	0	0	0	0	0	0	0	0	0	0	0	0	0	42850	0	0
Nanning	0	59451.35631	0	0	0	0	0	0	0	0	0	70434.48844	0	0	0	0
Harbin	0	0	0	0	0	0	48662	0	0	0	0	0	0	0	0	0
Changchun	0	0	0	0	0	0	0	0	0	0	0	0	0	44848	0	0
Shenyang	0	0	0	0	0	0	0	0	0	0	0	0	0	11681	0	0
Shijiazhuang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zhengzhou	0	0	0	171831.6056	0	0	0	0	0	0	0	0	0	0	0	0
Jinan	0	0	0	0	0	0	0	101497.1058	0	0	156180.7169	0	0	0	0	0
Taiyuan	0	0	0	0	0	0	120773.3908	0	0	0	0	0	0	0	0	0
Ianzhou	0	0	0	0	0	0	67239	0	0	0	0	0	0	0	0	0
Xian	0	0	0	0	0	165260	0	0	0	0	0	0	0	0	0	0
Xining	0	0	0	0	0	0	0	0	0	0	0	0	0	14478	0	0
Chengdu	0	0	0	0	219.5101962	0	0	0	0	10777.4696	0	0	89077.99612	0	0	0
Wuhan	0	0	0	0	0	16715.39755	0	143706.6024	0	0	0	0	0	0	0	0

Hefei	0	26853.39556	0	0	0	0	0	0	1818584414	89848.4173	0	0	0	0	0	0
Nanjing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hangzhou	0	0	6987.682989	0	0	0	0	0	0	0	0	0	0	0	19053.79492	0
Fuzhou	32949.6027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nunchang	0	0	0	31419.71313	0	0	125729.2869	0	0	0	0	0	0	0	0	0
Changsha	3521.335415	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guivang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kunming	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guangzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haikou	0	0	0	0	0	0	0	0	0	0	0	0	0	20670	0	0

The results are reasonable to a large extent. However, the distance factor is not considered in the model, which can greatly affect the delivery cost. Therefore, a distance index is introduced in the refined model.

$$d_{i,j} = 3 + 7 * \frac{Distance\ Between\ Provinces}{Max\ Distance\ Between\ Provinces} \tag{10}$$

And the LP turns to the following form:

$$\begin{gathered} min \sum_{i=1}^{31} \sum_{j=1}^{31} x_{i,j} * p_j * \frac{e_i + e_j}{2} * d_{i,j} \\ s.t. \quad x * e \leq b \\ x^T * e \geq c \\ x \geq 0 \end{gathered} \tag{11}$$

And the results are illustrated in table 3 below, which indicates the maximum delivery capacity of each 2 provinces with distance taken into account.

Table 3. Maximum delivery capacity of each 2 provinces with distance taken into account.

	Beijing	Tianjin	Shanghai	Chongqin	Hohhot	Urumchi	Lhasa	Lhasa	Nanning	Hurbin	Changchun	Shenyung	Shugzhuang	Zhengzhou	Jinan	Taiyuan
Bcijing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tianjin	20519.36257	31999.63743	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Shanghai	0	0	76220.31245	0	0	0	0	0	0	0	0	0	0	0	0	0
Chongqin	0	0	0	90336.68128	0	0	0	0	0	0	0	0	0	0	0	0
Hohhot	0	0	0	0	39527.33593	0	0	0	0	0	0	0	0	0	0	0
Urumchi	0	0	0	0	0	30996.40556	0	0	0	0	0	0	0	0	0	0
Lhasa	0	0	0	0	0	0	4091	0	0	0	0	0	0	0	0	0
Lhasa	0	0	0	0	0	0	2914.326033	1123308354	0	0	0	0	0	0	0	0
Nanning	0	0	0	0	0	0	0	0	71821.02408	0	0	0	0	0	0	0
Harbin	0	0	0	0	0	0	0	0	0	41397,15258	0	0	0	0	0	0
Changchun	0	0	0	0	0	0	0	0	0	0	36427.69537	0	0	0	0	0
Shenyang	0	0	0	0	0	0	0	0	0	0	0	76942.69578	0	0	0	0
Shiiiazhuang	95474.99885	0	0	0	0	0	0	0	0	0	0	0	107453.5717	0	0	0
Zhengzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	204943.6671	0	0
Jinan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	267497.9421	0
Taiyuan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62023.9459
Lanzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xian	0	0	0	8928.122964	0	0	0	0	0	0	0	0	0	0	0	0
Xining	0	0	0	14478	0	0	0	0	0	0	0	0	0	0	0	0
Chengdu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wuhan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hefei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nanjing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hangzhou	0	0	55072.29175	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nanchang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Changsha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Guiyang	0	0	0	6754.51156	0	0	0	0	0	0	0	0	0	0	0	0
Kunming	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guangzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hailkou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

On the other hands, table 4 below illustrates the minimum demand of each province with distance taken into account.

Table 4. Minimum demand of each province with distance taken into account.

	Lanzhou	Xian	**Xining**	**Chengdu**	**Wuhan**	**Hefei**	**Nanjing**	Hangzhou	Fuzhou	Nanchang	Changsha	Guiyang	Kunming	Guangzhou	Haikou
Beijing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tianjin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shanghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chongqin	0	0	0	31355.31872	0	0	0	0	0	0	0	0	0	0	0
Hohhot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urumchi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lhasa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lhasa	0	0	6987.682989	0	0	0	0	0	0	0	0	0	0	0	0
Nanning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19053.79492
Harbin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Changchun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shenyang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shijiazhuang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zhengzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jinan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taiyuan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lanzhou	36470.93812	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Xian	0	86304.75187	0	0	0	0	0	0	0	0	0	0	0	0	0
Xining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chengdu	0	0	0	171896	0	0	0	0	0	0	0	0	0	0	0
Wuhan	0	0	0	0	160422	0	0	0	0	0	0	0	0	0	0
Hefei	0	0	0	0	0	185749.7657	188753.2343	0	0	0	0	0	0	0	0
	Lanzhou	Xian	**Xining**	**Chengdu**	**Wuhan**	**Hefei**	**Nanjing**	Hangzhou	Fuzhou	Nanchang	Changsha	Guiyang	Kunming	Guangzhou	Haikou
Nanjing	0	0	0	0	0	0	173650.4433	0	0	0	0	0	0	0	0
Hangzhou	0	0	0	0	0	0	0	245203.7082	0	0	0	0	0	0	0
Fuzhou	0	0	0	0	0	0	0	0	140698	0	0	0	0	0	0
Nanchang	0	0	0	0	10234.14208	0	0	0	40160,49135	100625.8869	0	0	0	0	0
Changsha	0	0	0	0	0	0	0	0	0	0	156180.7169	0	0	0	0
Guiyang	0	0	0	0	0	0	0	0	0	0	0	70434.48844	0	9255	0
Kunming	0	0	0	0	0	0	0	0	0	0	0	0	89077.99612	0	0
Guangzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	344578	0
Haikou	0	0	0	0	0	0	0	0	0	0	0	0	0	20670	0

The problem with this set of results is that they follow a nearly diagonal form, which indicates the self-independence of each province and is not reasonable enough in reality. We attribute the unreasonable distribution to the ineffective distance index that ranges from three to ten, making distance overwhelmingly important in the LP.

Therefore, we alter the calculation process of the distance index.

$$d_{i,j} = 6 + 4 * \frac{Distance\ Between\ Provinces}{Max\ Distance\ Between\ Provinces} \tag{12}$$

which leads to the results indicated in table 5 below.

Table 5. After alternation of distance index

	Beijing	Tianjin	Shanghai	Chongqin	**Hohhot**	Urumchi	Lhasa	**Lhasa**	Nanning	**Harbin**	Changchun	Shenyang	Shijiazhuang	Zhengzhou	Jinan	Taiyuan
Beijing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tianjin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Shanghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chongqin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hohhot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urumchi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lhasa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lhasa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nanning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57558.15525
Harbin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Changchun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shenyang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	155660	0
Shijiazhuang	0	0	0	0	0	0	0	0	0	0	0	0	0	135485.0579	111837.9421	0
Zhengzhou	0	0	0	0	0	0	0	0	0	0	0	0	48107.39441	0	0	0
Jinan	0	0	0	0	0	0	0	0	0	0	0	0	59346.17729	0	0	0
Taiyuan	0	0	0	0	0	0	0	0	0	0	0	0	0	69458.60924	0	0
Lanzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chengdu	0	0	0	0	0	0	0	0	71821.02408	0	0	0	0	0	0	0
Wuhan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hefei	0	0	0	0	0	0	0	0	0	0	0	76942.69578	0	0	0	0
Nanjing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hangzhou	8000.599627	31999.63743	0	0	0	0	7005.326033	11233.08354	0	0	0	0	0	0	0	0
Fuzhou	0	0	131301.6042	0	0	0	0	0	0	0	0	0	0	0	0	0
Nanchang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Changsha	0	0	0	120497.3158	0	30996.40556	0	0	0	41397.15258	0	0	0	0	0	4465.790643
Guiyang	86444	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Kunming	21549.76179	0	0	0	39527.33593	0	0	0	0	0	36427.6954	0	0	0	0	0
Guangzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haikou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6 below also shows results after alternation of distance index

Table 6: Results after alternation of distance index

	Lanzhou	Xian	Xining	Chengdu	Wuhan	Hefei	Nanjing	Hangzhou	Fuzhou	Nanchang	Changsha	Guiyang	Kunming	Guangzhov	Haikou
Beijing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tianjin	0	0	0	0	0	52519	0	0	0	0	0	0	0	0	0
Shanghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chongqin	0	0	0	0	121692	0	0	0	0	0	0	0	0	0	0
Hohhot	0	0	0	0	0	0	0	0	0	0	0	0	0	178071	0
Urumchi	0	0	0	0	0	0	0	0	0	0	0	0	0	57814	0
Lhasa	0	0	0	0	0	0	0	0	0	0	0	0	0	4091	0
Lhasa	0	0	0	0	0	0	0	0	0	0	0	0	0	42850	0
Nanning	0	0	0	0	0	0	0	0	59451.35631	0	0	70434.48844	0	0	0
Harbin	0	0	0	0	0	0	48662	0	0	0	0	0	0	0	0
Changchun	0	0	0	0	0	0	0	0	0	0	0	0	0	44848	0
Shenyang	0	0	0	0	0	0	0	0	0	0	0	0	0	11681	0
Shijiazhuang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zhengzhou	0	0	0	1360123187	0	0	35819.28687	0	0	0	0	0	0	0	0
Jinan	0	0	0	0	0	0	0	101497.1058	0	0	156180,717	0	0	0	0
Taiyuan	0	0	0	0	0	0	120773.3908	0	0	0	0	0	0	0	0
Lanzhou	0	0	0	67239	0	0	0	0	0	0	0	0	0	0	0

Xian	0	0	0	0	48744.63189	116515.3681	0	0	0	0	0	0	0	0	0
Xining	0	0	0	0	0	0	0	0	0	0	0	0	0	14478	0
Chengdu	0	0	0	0	219.5101962	0	0	0	0	10777.4696	0	0	89077.99612	0	0
Wuhan	0	0	0	0	0	16715.39755	0	143706.6024	0	0	0	0	0	0	0
Hefei	0	86304.75187	0	0	0	0	0	0	121407.135	89848.4173	0	0	0	0	0
Nanjing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hangzhou	0	0	6987.682989	0	0	0	0	0	0	0	0	0	0	0	19053.79492
Fuzhou	9396.395799	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nanchang	0	0	0	0	0	0	157149	0	0	0	0	0	0	0	0
Changsha	3521.335415	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guiyang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kunming	23553.20691	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guangzhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haikou	0	0	0	0	0	0	0	0	0	0	0	0	0	20670	0

At this stage, we think that having a warehouse in every province could be a waste of resources [5]. Therefore, we try to find a balance between a smaller number of warehouses and cheaper transportation costs.

We set sixteen, which is the number of independent and bidependent provinces, to be the minimum number of warehouses. Each round we will reduce the number by one with the following method: set the supply capacity of the first province to be zero, and then equally distributes its capacity to the rest of the provinces, a new transportation cost will come out based on new sets of data; then we will reset the data, and conduct the same algorithm on the second province; the whole loop ends when all provinces have been covered; finally, the combination with minimum transportation cost is selected for next step, and such loop continues until only sixteen provinces remaining. Specifically, if not setting a warehouse in a province, i.e. setting its supply capacity to be zero, is the optimal solution for one stage, then the supply capacity from other province will not be distributed to it in the next stage, which means its supply capacity will always be zero until the end of the algorithm.

We find that the transportation cost keeps reducing as we cut down the warehouses [6]. The optimal solution reaches when there are only sixteen warehouses. The result is shown table 7 below, with independent and bidependent provinces in part 1 marked red.

Table 7. Supply capacity as 16 warehouses are set

Beijing	Tianjin	Shanha	Chongqing	Hohhot	Urumqi	Lhasa	Yinchuan	**Nanning**	Harbin	Changchun	Shenyang	Shijiazhuang	Zhengzhou	Jinan	Taiyuan
218500.4	248816	0	0	374368	254111	200388	239147.44	0	244959.44	241145.44	363638.4	443620.4375	0	0	386529
Lanzhou	Xian	Xining	Chendu	**Wuhan**	**Hefei**	**Nanjing**	Hangzhou	**Fuzhou**	Nanchang	Chana	Guiyang	Kunming	**Guangzhou**	Haikou	
263536.4	0	210775.4	0	0	0	0	0	0	353446.44	0	282741.4	317355.4375	0	0	

There are only a few warehouses set in bidependent and independent provinces in part 1, which to some extent implies the ineffectiveness of our model for part 2. This can be generated from distributions of supply capacity in the last step of this part or the insufficiency in setting up the variables, leaving us with a room for further exploration and improvement.

3.4 Code for Cutting Down Warehouses

```
load ( ‘part 2. mat’ )
b_old = b_;
b0 = [ ]
m0 = [ ]
for z = 1 : 15
total_cost = zeros (31, 1);
for        i = 1 : 31
           b = b_old;
           b_temp = b (i , 1) / (30-length(b0));
           sum_b = sum (b);
           b (i, 1) = 0;
           for j = 1 : 31
                      if b (j, 1) = 0
                                 b (j, 1) = b (j, 1) + b_temp;
                      end
           end
           disp ( ‘sum_of_b’)
           if abs (sum (b) – sum_b) > 1e-9
                      disp ( ‘wrong_supply’)
           end
           disp (sum (b))
           weight = linprog (P_i_E_i_D_i_new , A_, b, Aeq, beq, 1b);
           total_cost = P_i_E_i_D_i_new * weight;
           total_costs (i, 1) = total_cost;
end
disp ( ‘ sum_of _b_old’)
```

```
disp (sum (b_old))
[m, k] = min (total_costs);
b_temp = b_old (k, 1) / (30 – length (b0));
b_old (k, 1) = 0;
for j = 1 : 31
        if b_old (j, 1) = 0
                b_old (j, 1) = b_old (j, 1) + b_temp;
        end
end
disp ( 'sum_of_b_old_38')
disp (sum (b_old))
b0 = [b0, k]
m0 = [m0, m]
end
```

4. CONCLUSION

In this paper, we successfully rearrange the distribution of warehouse in China for different purposes.

In Part 1, for the purpose of minimizing the number of warehouses the need for warehouses in the following provinces, in addition to the bidependent and independent ones: Zhejiang, Liaoning, Henan, Heilongjiang, Jiangxi, and Gansu.

In part 2, the economic cost of the delivery is the lowest as there is only 16 warehouses set in certain provinces: Beijing, Tianjin, Shanghai, Chongqing, Nanning, Changchun, Jinan, Taiyuan, Chengdu, Wuhan, Hefei, Nanjing, Fuzhou, Changsha, Guangzhou.

The world is getting smaller as the internet brings people together [7]. People now can purchase products all over the world, however following the increase of demands of delivery. In that situation, transportation companies are supposed to take the efficiency and the cost into consideration [8]. On one hand, this behavior is to maximum the satisfaction of the client; on the other hand, the efficiency of the delivery may save much unnecessary resources to enhance the world's sustainable development.

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