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Carbon Emission Cost Affects Location Decision: CO_2 Efficient Area Yields to the Less Efficient

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***Abstract*—Due to the global warming problem, it is more urgent than ever to take carbon emission problem seriously. It is needed to take carbon emission cost into consideration. Gravity method is used to do location selection. Three aspects of work have been done. First, the carbon emission cost of a certain kind of truck is calculated. Second, the comparison between considering and not considering carbon emission is done. Third, a distance parameter is added to transfer straight-line distance to real distance. The research gets the result in two cases: case 1 single mode transportation tools are used, the best site has no changes with total cost rising; case 2 multi-mode transportation tools are used, the best site coordination has changed with cost rising in general except extraordinary case. At the end, we show the application of the model. The carbon emission cost affects the location modeling, the cost like carbon dioxide tax will drive the location center to move a little bit in the direction of the CO2 efficient area towards less efficient area.**

***Index Terms*—logistics center, location decision, gravity method, transportation cost.**

I. Introduction

Many governments begin to handle carbon emission problem. The province of Quebec in Canada has begun to tax on oil, natural gas and coal. In some Nordic countries, the carbon tax has been widely accepted. Denmark, Finland, Netherlands, Norway, Poland and Sweden have launched different carbon tax policy. European plans to execute air transportation carbon tax. [1, 2]

Logistics center planning has a great influence on the cost of transportation. Gravity method is a good method to handle this kind of problems. But it not yet perfect. Gravity method can help us to plan the logistics center, but it does not include the carbon emission fees. [3, 4]

There are researches that permit customers to choose facility. [5] The carbon emission cost is a hot topic in e-commerce, some are research the carbon foot print in the delivery and conventional logistics [6]-[8]. We will also find an interest phenomenon that when considering the carbon cost the most suitable location for selecting as distribution center will move a little bit toward the less efficient area direction. Review Stage

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II. Hypothesis

The carbon emission cost drives the best location moves towards the direction which is less efficient in carbon emission reduction.

III. Parameter

A. *Exist Positioning Method*

1) Gravity positioning

Assumptions:

a) Transport fee is only related with the straight-line distance of distribution centers and customers, without regard to the urban traffic conditions;

b) The real estate prices of different geographical location are the same. The proposed distribution center coordinates is $p_0(x_0, y_0)$, the coordinates of its distribution customers is $p_i(x_i, y_i)$, for $i = 1,2,...,n$.

a_i -freight rates from distribution center to customer i

w_i - the traffic amount from the distribution center to customer i.

So we got coordination of $p_0(x_0, y_0)$, Refer to "(1)." As is shown in fig 1. [7]

$$x_0 = \frac{\sum_{i=1}^{n}(a_i w_i x_i)}{\sum_{i=1}^{n}(a_i w_i)}, \quad y_0 = \frac{\sum_{i=1}^{n}(a_i w_i y_i)}{\sum_{i=1}^{n}(a_i w_i)} \quad (1)$$

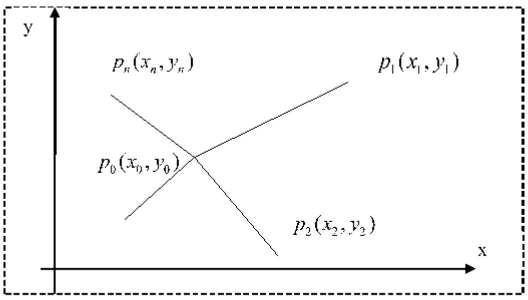

Fig. 1. Gravity method mode for location selection

FLAW: The center of gravity method considers the vertical and horizontal distance as independent factor. That does not match the actual, the obtained solution is rough and its practical significance is to provide a reference for site-positioning staff.

B. Exactly Positioning Method (Differentiation)

The exactly positioning method is proposed in order to overcome the shortcomings of the center of gravity method, the result of center of gravity method as the initial solution and exact solution obtained by iteration.

With n customers located in different coordinates (x_i, y_i) is assumed that the logistics center is set in place (x_0, y_0), shown in Fig 1.

Total cost fee C can be described as follows, refer to "(2)."

$$C = \sum_{i=1}^{n} a_i w_i d_i \qquad (2)$$

Among them,

a_i - Logistics center to customer i per unit weight per unit distance transportation costs required;

w_i - logistics center to customer i's traffic;

d_i - the straight-line distance between the logistics center and customer i.

$$d_i = \sqrt{(x_0 - x_i)^2 + (y_0 - y_i)^2}$$

$$d_i' = K_i \sqrt{(x_0 - x_i)^2 + (y_0 - y_i)^2}$$

l_i ——non-linear coefficient

b_i ——bypass coefficient

$$K_i = b_i + l_i$$

The logistics center site should ensure that the minimum transportation costs, i.e. C minimum. Order the gradient to 0, refer to "(3)."

$$\begin{cases} \dfrac{\partial C}{\partial x_0} = \sum a_i w_i (x_0 - x_i) / d_i = 0 \\ \dfrac{\partial C}{\partial y_0} = \sum a_i w_i (y_0 - y_i) / d_i = 0 \end{cases} \qquad (3)$$

In order to get the solution $p_0(x_0^*, y_0^*)$ of $p_0(x_0, y_0)$, the calculation is carried on, refer to "(4)."

$$\begin{cases} x_0^* = \dfrac{\sum_{i=1}^{n} a_i w_i x_i / d_i'}{\sum_{i=1}^{n} a_i w_i / d_i'} \\ y_0^* = \dfrac{\sum_{i=1}^{n} a_i w_i y_i / d_i'}{\sum_{i=1}^{n} a_i w_i / d_i'} \end{cases} \qquad (4)$$

Iterative center of gravity method for solving steps: target $p_0(x_0, y_0)$

a) Use the center of gravity formula to obtain the initial solution (x_0^0, y_0^0) ;b) Put the initial solution into the distance formula to obtain distances; Transfer the distances number into the formula of total freight costs, calculate the total freight; c) Take d_i into the target formula to obtain the first iteration solution (x_0^1, y_0^1); d) Repeat steps b) obtain a new value d_i; calculate the total freight C_1 compared with the size C_0, if $C_1 < C_0$,Continue iteration; if $C_1 = C_0$,end computing, (x_0^1, y_0^1) is the optimal solution;e) Repeat steps c) b), until the $C_n = C_{n-1}$ (n indicates the number of iterations).

FLAW: This method may have lots of iteration, the computing workload is relatively large, and the computational cost is also high.

Improvement is done to the differential method.

It is changed into the logistics center to the client i per unit weight, unit distance required to transport costs and the cost of carbon emissions combined, refer to "(5)."

$$a_i' = a_i + c_i \qquad (5)$$

Iterative center of gravity method needs to take the cost of carbon emissions into consideration, refer to "(6)."

Due to during actual situation of goods during transport, the transportation rates of different modes of transport and the cost of carbon emissions is different, refer to "(7)."

Therefore, we define:

c_i - Carbon emissions cost of mode i of per unit transportation weight, unit distance.

a_i - Transportation costs of mode i per unit weight, unit distance.

K_i-a parameter used to transfer straight-line distance to real distance.

K_i= bypass coefficient + non-linear coefficient

$$\begin{cases} x_0^* = \dfrac{\sum_{i=1}^{n} a_i' w_i x_i / d_i'}{\sum_{i=1}^{n} a_i' w_i / d_i'} \\ y_0^* = \dfrac{\sum_{i=1}^{n} a_i' w_i y_i / d_i'}{\sum_{i=1}^{n} a_i' w_i / d_i'} \end{cases} \qquad (6)$$

$$d_i' = K_i \sqrt{(x_0 - x_i)^2 + (y_0 - y_i)^2}_i \qquad (7)$$

When the logistic center transports goods to various locations, using single-mode of transportation, the transport rates are the same, rate of cost of carbon emissions is the same, either. When the logistics center use multi-ways of transportation to deliver goods to various locations at the same time, the transportation rates is the same, the rates of carbon emissions costs is different.

The study found that using the single mode of transport, the coordinates of the best positions does not change. Adding the

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cost of carbon emissions, the overall cost is raised. Using different modes of transportation, the coordinates of the best position in general is changed, unless the transportation rates before and after strict corresponding proportional. Adding the cost of carbon emissions, the total cost is on the rise.

IV. CASE STUDIES

A. *Based on a Single Transportation Mode*

Single Transportation Mode Carbon Emission Cost Location Allocation Problem(SCLAP problem)

A company intends to build a logistics center in a city to transport goods to G, H, L, M, N five urban cities. The coordinates and demand of five cities is known and is showed in the Table 1. Suppose all the materials have the same transport rate. gi, =5 / t • km, ti = 1 trial iterative center of gravity method to determine the best location of the plant. Company-owned heavy trucks use 40 liters loaded with 70 tons of diesel fuel per hundred kilometers, so the truck unit of fuel consumption is 0.57 L/ (t km). The bypass coefficients to the five cities are 0.34, 0.5, 0.6, 0.55 and 1.2. The non-linear coefficients to the five cities are 1.2, 1.1, 1.04, 1.15 and 1.2. The demand dots are shown in fig 2 and table 1.

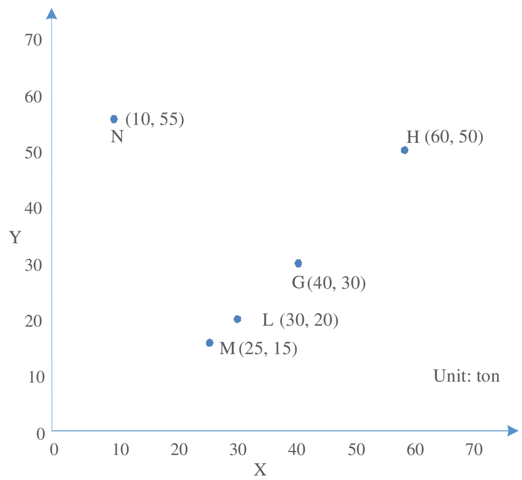

Fig. 2. Location selection

TABLE I. DEMAND COORDINATION OR TRANSPORTATION AMOUNT

Destiny	G	H	L	M	N
Coordination	**(40,30)**	**(60,50)**	**(30,20)**	**(25,15)**	**(10,55)**
Amount/t	**2000**	**3000**	**2500**	**1000**	**1500**

Solution

$$K_i = b_i + l_i \quad (8)$$

The distance coefficients to five cities are 1.54, 1.6, 1.64, 1.7 and 2.4, refer to "(8)." The parameters of single mode of transportation are shown in table 2.

TABLE II. SINGLE MODE OF TRANSPORT

	G(40,30)	H(60,50)	L(30,20)	M(25,15)	N(10,55)
FR	**5**	**5**	**5**	**5**	**5**
CECR	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
FRC	**6.2**	**6.2**	**6.2**	**6.2**	**6.2**
K_i	**1.54**	**1.6**	**1.64**	**1.7**	**2.4**

Freight rate shorts as FR, Carbon emission cost rate shorts as CECR, Freight rate with carbon cost shorts as FRC, K_i is Distance parameter.

The solution: The Company has heavy-duty trucks loaded with 70 tons of diesel with fuel consumption of 40 liters per hundred kilometers. So we get the truck unit fuel consumption of 0.57 liters/(t km).

However, carbon dioxide emission of per unit of fuel is not known, it is calculated by the amount of carbon dioxide that emitted in chemical reaction of fuel. Suppose road vehicle fuel density and carbon content is at a constant value, diesel fuel density of 0.830kg / L, the carbon content of 87%. According to the carbon content of vehicle fuel, carbon dioxide emissions per unit of fuel can be calculated. By calculating, the amount of carbon dioxide emissions from 1L diesel is 3.839kg.

CO2 emissions of unit weight unit transportation distance of the heavy-duty are 2.19kg / (t km). (It can be calculated by 3.839 × 0.57 = 2.19kg / (t km))

Per ton of CO2 emissions may cause economic cost of approximately $ 85.

U.S. dollar = 6.3661 Yuan (2012.6.16)

85 × 6.3661 = 541.1 Yuan

The economic cost of per ton of CO2 emissions is about 541.1 Yuan.

Each kg CO2 emission costs 0.54 Yuan.

The cost of carbon emissions from the company's heavy-duty trucks is 1.2/(t • km)

It can be calculated by0.54 × 2.19 = 1.2 / (t •km)

Use MATLAB or excel to do the calculation. Order $x_0 = 1$, $y_0 = 1$, trial iterative center of gravity method to determine the best location of the plant. Following results can be reached.

Under single mode of transport, the transport rates and the rate of carbon emissions are the same. The value of the location of the minima does not change. First, not considering the cost of carbon emissions, the coordination of the best point is (38.55314, 30.55259), the total transportation cost is 1849099.899 Yuan. Second, considering the cost of carbon emissions, the best site's coordination is (38.55314, 30.55259), the total transportation cost is 2,292,883.875 Yuan.

B. *Based on Multimode Transportation*

Multimode Transportation Mode Carbon Emission Cost Location Allocation Problem (MCLAP problem)

A company intends to build a logistics center in a city, the logistic center transports goods to G, H, L, M, N five urban cities. The coordinates and demand of five cities is known and is showed in the Table 1. Suppose all the materials have the same transport rate. a_i = 5 / (t • km). Company-owned heavy trucks use 40 liters loaded with 70 tons of diesel fuel per hundred kilometers, so the truck unit of fuel consumption is 0.57 L / (t km). Besides trucks, the company also uses trains and ships for transportation. The bypass coefficient to the five cities are 0.34, 0.5, 0.6 , 0.55 and 1.2. The non-linear coefficients to the five cities are 1.2, 1.1, 1.04, 1.15 and 1.2. The parameters are shown is table 3.

TABLE III. COORDINATION AND DEMAND OF FIVE CITIES

Demand site	G	H	L	M	N
Coordination	**(40,30)**	**(60,50)**	**(29,20)**	**(25,15)**	**(10,55)**
Demand/t	**2000**	**3000**	**2500**	**1000**	**1500**

Solution

The distance coefficients to five cities are 1.54, 1.6, 1.64, 1.7 and 2.4, refer to "(8)".

(1) Special case

Under multimodal transport conditions, transport rates are not the same, cost rate of carbon emissions is different. In special circumstances transport rates adding the cost of carbon emissions rate corresponding with the original transport rates proportional. The best site's coordination does not change. The parameters are shown in table 4.

TABLE IV. DATA UNDER USE MULTIWAY SHIPMENT CONDITION IN SPECIAL CASE

	G(40,30)	H(60,50)	L(30,20)	M(25,15)	N(10,55)
FR	**3.5**	**4**	**4.5**	**5**	**4.5**
CECR	**0.84**	**0.96**	**1.08**	**1.2**	**1.08**
FRC	**4.34**	**4.96**	**5.58**	**6.2**	**5.58**
K_i	**1.54**	**1.6**	**1.64**	**1.7**	**2.4**

Use MATLAB or excel to do the calculation. Not considering the cost of carbon emissions, the most advantage coordinates is (35.73378, 30.15857), the total transportation cost is 1,600,387.674 Yuan.

When considering the cost of carbon emissions, the most advantage coordinates is (35.73378, 30.15857), the total transportation cost is 1,984,480.716 Yuan.

(2) In ordinary condition

Multimodal transport conditions, transport rates are not the same, the cost rates of carbon emission differ. The total cost rise. In vast majority of cases, the most advantage location adding the cost of carbon emissions will change. Example, considering the cost of carbon emissions, we have the following two examples. The parameters are shown in table 5 and table 6.

TABLE V. DATA UNDER USE MULTIWAY SHIPMENT CONDITION IN GENERAL CASE (I.E. 1)

	G(40,30)	H(60,50)	L(30,20)	M(25,15)	N(10,55)
FR	**3.5**	**4**	**4.5**	**5**	**4.5**
CECR	**0.2**	**0.5**	**0.8**	**1.2**	**0.8**
FRC	**3.7**	**4.5**	**5.3**	**6.2**	**5.3**
K_i	**1.54**	**1.6**	**1.64**	**1.7**	**2.4**

When considering the cost of carbon emissions, the best site location's coordinates is (34.42188, 29.42786), the total transportation cost is for 1,855,495.394 Yuan.

TABLE VI. DATA UNDER USE RAILWAY AND SHIPMENT CONDITION IN GENERAL CASE (I.E.2)

	G(40,30)	H(60,50)	L(30,20)	M(25,15)	N(10,55)
FR	**3.5**	**4**	**4.5**	**5**	**4.5**
CECR	**0.2**	**0.5**	**0.8**	**1.2**	**1.2**
FRC	**3.7**	**4.5**	**5.3**	**6.2**	**5.7**
K_i	**1.54**	**1.6**	**1.64**	**1.7**	**2.4**

When considering the cost of carbon emissions, the best coordinates (34.16047, 29.65289), and total transportation cost is 1906169.191 Yuan.

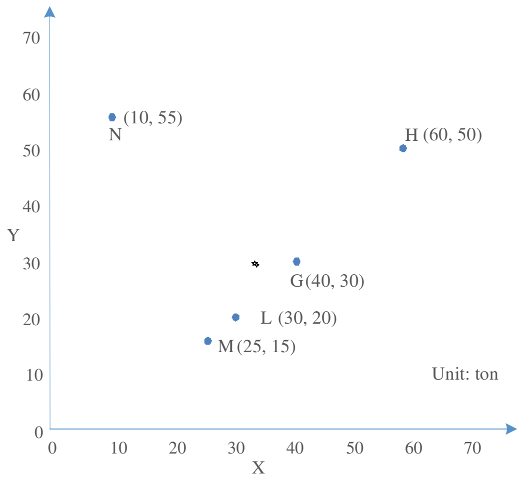

Fig. 3. Coordination of the five cities in the case

The case shows that the best location moves toward the point N direction which is less efficient in carbon emission.

V. APPLICATION

The carbon emission cost affecting location problem can also be found in E-commerce. We take the model from (Shang, 2009) as an example [9]. The optimized results could be like in figure 3.

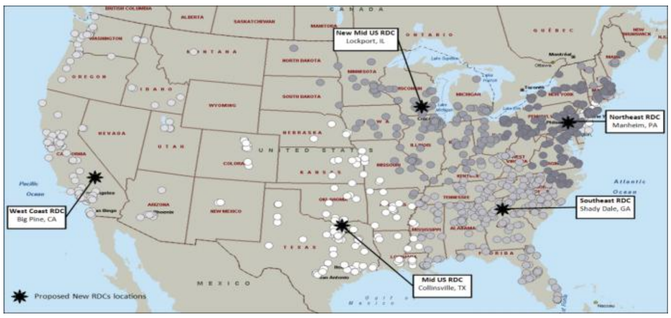

Fig. 4. The location of regional distribution center

Suppose we keep the allocation unchanged due to the consideration of maintaining the customer relationship. Suppose the CDC sets of each RDC serves as groups ordered by G_{CDC1}, G_{CDC2}, G_{CDC3}, G_{CDC4}, and G_{CDC5}. The set of plants is named as Gp. The set of G_{CDC1} and Gp is named as G'_{CDC1}, so as to other combined sets: G'_{CDC2} G'_{CDC3}, G'_{CDC4}, G'_{CDC5}. The carbon emission group gravity center of the $G'_{CDC1,}$ G'_{CDC2} G'_{CDC3}, G'_{CDC4}, G'_{CDC5} is marked in the fig4 in square dots named from dot_1 to dot_5. Theses dots will be closer to the G_{CDCi}, compared with ordinary gravity center. This has been illustrated by MCLAP model, since the transportation from the RDC to CDC uses LTL, the transportation from the plants to the RDC uses the TL.

Then each reginal distribution center should be changed a tiny bit towards dot_1, dot_2, dot_3, dot_4, dot_5, as the government begin to execute carbon tax.

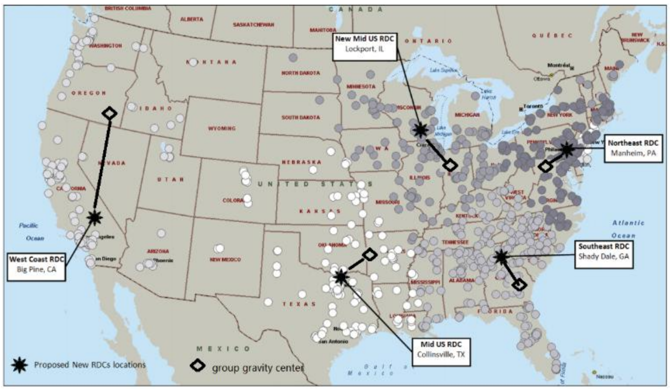

Fig. 5. The direction of regional distribution center location changes considering carbon emission

VI. Conclusions

We have two conclusions. When the company only uses trucks for transportation, the best position does not change no matter taking carbon emission cost into consideration or not. When the company uses multi-way for transportation, adding carbon emission cost will cause coordination change, unless in very special case which the cost considering carbon emission is proportional.

In this paper, the carbon emission cost of a certain kind of truck is also calculated and given out. The distance parameter is added in the function to make it fit to the actual condition better.

In the research, the building cost and real estate cost is not included and it is used to solve single logistics center position planning, so further research needs to be done in these areas.

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References

[1] Sgouris Sgouridis, Philippe A, Bonnefoy, R.John Hansman, “Air transportation in a carbon constrained world: Long-term dynamics of policies and strategies for mitigating the carbon footprint of commercial aviation,” Transportation Research Part A2011, 45 (10), pp. 1077-1091.

[2] Wu Xiaomin, Hu Shan, Mo Shaojia, “Carbon footprint model for evaluating the global warming impact of food transport refrigeration systems,” Journal of cleaner production. 2013, 54, pp. 115-124.

[3] Gérard P, Cachon, “Retail Store Density and the Cost of Greenhouse Gas Emissions,” 2014, 60(8), pp. 1907-1925.

[4] Brock William, Engström Gustav, Xepapadeas Anastasios, “Spatial climate-economic models in the design of optimal climate policies across locations,” European Economic Review. 2014, 69(0), pp.78-103.

[5] Drezner, T. and Z. Drezner, The gravity p-median model. “European Journal of Operational Research,” 2007, 179(3), pp. 1239-1251.

[6] Julia B. Edwards, Alan C. McKinnon, Sharon L. Cullinane. Comparative analysis of the carbon footprints of conventional and online retailing: A “last mile” perspective [J]. International Journal of Physical Distribution & Logistics Management, 2010,40: (1/2),pp. 103–123.

[7] Liu, Jiashi; Guan, Zhongliang; and Xie, Xiang, "B2C E-commerce Logistic channel structure in China" (2015). WHICEB 2015 Proceedings. Paper 5.

[8] Xie Xiang, Liu Jiashi, Guan Zhongliang, Ke Xinsheng. Fresh Food Online Supermarket Development Study[J]. Journal of Electronic Commerce in Organizations. 12(2), 2014,pp. 14-30.

[9] Shang, Jennifer and Yildirim, Pinar and Tadikamalla, Pandu R. and Mittal, Vikas and Brown, Lawrence H. Distribution Network Redesign for Marketing Competitiveness[J]. Journal of marketing.2009, 73(2), pp. 146-163.

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