THE OPTIMIZATION OF ROAD NETWORK IN LOGISTICS HUB BASED ON LOW-CARBON ASPECT

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Abstract: Carbon emission is becoming a more and more popular issue recently. It is important to design a reasonable road network within logistics hub to reduce the whole carbon emissions. Previous studies have targeted as maximum economics benefits or least time consumed, which ignored the environmental effects. This paper uses the model of minimum cost maximum flow to optimize the road network, in the model, "cost" is defined as carbon emissions, so we can finally achieve the goal, then classify the type of road according to the capacity, the decreasing order is trunk road, secondary road and slip road. The above classification can help with arranging transportation and guiding the traffic flow. The paper lists the specific optimal plan to the logistics hub in Luan County. However the factors concluded in the model is not adequate, we should consider the factor of road length, and it is also a factor affected carbon emission.

1 INTRODUCTION

With the development of the logistics industry in China, the domestic Logistics Hus are expanded, the number is increasing to about 600 recently. According to related data, the CO_2 emission during transportation is accounted for 40% of the whole logistics process. Apparently the main reason which leads into carbon pollution in Logistics Hub is transportation. Some studies show that CO_2 emissions is related to traffic volume, road congestion, and therefore a reasonable layout of Logistics Hub are helpful to reduce carbon emissions, such as controlling the traffic volume in trunk road and improving the road condition.

The design of the Logistics Hub network include choosing the form of road network, planning red line(the direction and location of trunk road and secondary roads and the functional division of them),green belts and road node planning. Previous studies are aimed at the minimum of the total cost of the transportation or the shortest transit time, but environmental issues is not taking into consideration, for instance, total carbon emissions. This paper is to improve road network then increase the efficiency of trunk road and realize the low carbon transportation in the Logistics Hub, and finally reduce total carbon emissions.

The procedure of road network in Logistics Hub are as follows: 1, Forecasting the main logistics volume and the road capacity, then translate the logistic capacity into traffic volume. 2, Select the entrance of the Logistics Hub from the railway entrance, highway entrance, link entrance and other locations around the Logistics Hub which accumulate cargo flow. Then optimize road network within them. 3, Using EcoTransIT tool to calculate the volume of carbon emissions of each unit distance and weight, with the minimum cost maximum flow model to optimize the road network, the specific process are as follows:
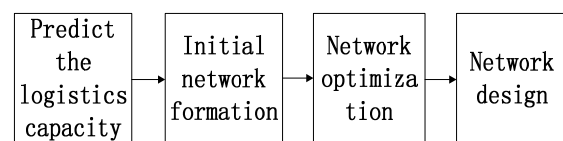

Figure 1: The steps of optimizing road network.

2 THE LOGISTICS HUB NETWORK OPTIMIZATION FACTOR ANALYSIS AND MODEL SELECTION

Logistics Hub road network is composed of different

levels of city roads and railways. The road network planning should determine the form of road network; then determine the nature of roads, width, the form of road cross section, the location of intersection and the parking lots and the receipt of road network maps. The current form of the existing road system can be summarized into four main types: grid-type, ring radial, freestyle, and hybrid. Then use model to plan direction and capacity of roads which make the overall road network release less emissions.

Optimization methods of road network are consisted of four-stage method, the total control method and graph theory method. They are mostly targeted as maximum economic benefits and least time consumed, they distributes the predicted traffic flow to the road after considering these factors, which are the layout of road network, traffic flow in the direction and distribution of goods. Further, according to the amount of traffic flow to determine technical level, the direction of the selected roads, extension angle and optimal points to the line. However, the above methodologies ignore the environmental effects. Carbon emissions are related to traffic volume and road resistance coefficient, while considering carbon emission, there are four-stage method and graph theory method can be selected.

Four-stage method is based on investigation, and then predicts the future distribution at the base of traffic condition. The basic steps are traffic generation, traffic distribution, traffic model selected, traffic assignment. We can gain some parameters about cargo flow through investigation. But it is difficult to implement, it will cost a lot of manpower, material and financial resources, so the minimum cost maximum flow is practical to optimize the road network. The so-called minimum cost maximum flow problem is to find a maximum flow f; simultaneously the total cost is minimum. Studying this problem is trying to find out: In order to achieve minimum cost, how to choose the path and assign traffic flow from A to B. The meaning of cost can be defined as carbon emissions in this model.

3 THE ESTABLISHMENT OF THE OPTIMIZE MODEL OF ROAD NETWORK IN LOGISTICS HUB

3.1 The Establishment Mind

While the initial road network planning is finished, then we can use EcoTransIT tool to obtain carbon emissions' weight, as we get the parameters about the minimum cost maximum flow, the road network can be optimized. Network planning is to reach the minimum carbon emissions based on meeting logistics requirements and rational distribution network. At the condition of knowing the total demand in a cycle, the permitted maximum capacity of each road, and carbon emissions of unit weight on different road type, we can determine which can be used as the trunk roads, secondary roads and slip roads for two random entrances of Logistics Hub.

3.2 Mathematical Model

If f whose flow is v(f) is the minimum cost flow of all feasible flow, and u is the smallest-cost augmented chain of all the augmented chain contained f, then adjust f along u, we will get f', which is the minimum cost flow of all the feasible flow. Thus, when f' is the maximum flow, it is what required minimum cost maximum flow.

As $b_{ij} \geq 0$, so $f = 0$ must be the minimum cost flow whose flow is 0. This always starts from $f = 0$. Generally, it also sets f is the minimum cost flow, and its flow is v (f), the remaining problem is how to find the augmented chain of minimum cost about f. So we can construct a weighted diagraph w(f), its vertices are vertices of the original network D, and change arc included in D into two arcs in opposite directions (vi, vj) and (vj, vi). We define the weights of arcs in the w (f) as:

$$W_{ij} = \begin{cases} b_{ij}, & f_{ij} < c_{ij} \\ +\infty, & fij = c_{ij} \end{cases} \quad (1)$$

$$W_{ji} = \begin{cases} -b_{ij}, & f_{ij} > 0 \\ +\infty, & f_{ij} = 0 \end{cases} \quad (2)$$

So seek the minimum cost flow in network D is equivalent to find the shortest paths in the weighted diagraph. Therefore, the following algorithm is:

Firstly, it can set$f(0) = 0$, if at the (k-1) step we get the minimum cost flow$f(k-1)$, then construct a

weighted diagraph $W(f(k-1))$, and seek the shortest paths in $W(f(k-1))$. If the shortest paths are not existed, and then $f(k-1)$ is the minimum cost maximum flow; if existed, we can get corresponding augmented chain u, and adjust $f(k-1)$ on u, the adjusted volume is:

$$\theta = \min\left\{\min\left(c_{ij} - f_{ij}^{(k-1)}\right)_{u^+} \Big\| \min\left(f_{ij}^{(k-1)}\right)_{u^-}\right\}$$

$$F_{ij}^{(k)} = \begin{cases} f_{ij}^{(k-1)} + \theta & \{v_i|v_j\} \in u^+ \\ f_{ij}^{(k-1)} - \theta & \{v_i|v_j\} \in u \\ f_{ij}^{(k-1)} & \{v_i|v_j\} \notin u \end{cases} \quad (3)$$

We get new feasible flow, and then repeat the above steps.

Then use EcoTransIT (Ecological Transport Information) tools to predict the relevant index, and calculate carbon emission of the unit mile and weight in different types of road. The tool is developed by Heidelberg's energy and environmental agencies and Cink Company, if we input related data in the software, we can obtain the amount of total energy consumption which include production and transportation, and gas emissions including CO_2, NO_X and SO_2 NMHC, and PM10 and so on.

The tool mentioned the road resistance coefficient of different road levels; it can be recognized as the carbon emissions standards.

Table 1: Related index about model.

	The trunk road	Secondary road	Slip road	Rail way
road resistance coefficient	3	4	5	2
Traffic volume per day	6000~10000	4500~8000	2500~5500	10000
Unit carbon emission index	3	4	5	2
Capacity index	11	5	2	25

Therefore, the specific model is as follows:

Object: making the maximum road network flow and minimum carbon emissions on transportation.

Constraints:

The capacity of each arc is greater than the total amount of logistics.

The traffic volume on each arc is less than the road capacity.

Related variables:

Total logistics cycle Q,

Capacity and flow of each road are C_{ij} and f_{ij}.

Carbon emissions of unit mile and weight are b_{ij}.

The functions are:

$$\text{Min} Z = \sum b_{ij} * f_{ij} \quad (4)$$

Constraints： (1) $\sum f_{ij} \geq Q$;

(2) $f_{ij} \leq C_{ij}$.

Figure 2: The model of minimum cost maximum flow.

2 CASE STUDY

We take example about Luan county's Logistics Hub planning, then show the procedure of optimizing road network. Luan County is 260 km west from Beijing, 84 km east from Qinhuangdao, adjacent to northeast old industrial base in the north, access to Cao Feidian National industrial Park. From the point of location, Luan city is in the development area of Beijing, Tianjin, it has close relationship with the main cities, and also inseparable from Tangshan industrial equipment manufacturing base, it is the only way which connected Northeast Economic Zone and North Economic Zone. It is Datong-Qinhuangdao railway that makes it through the western region, Luan county becomes an important transit node.

Luan county has a superior transportation, there are totally about 6 railways travel through it, and locates about 11 rail way stations .102 State Road, State Road 205, Provincial Road S 252 and Beijing-Shenyang Expressway runs through the county (Figure 3). Luan county connects with Tianjin port and Qinhuangdao port and Jing Tang port and other port by railway or highways, so shipping is very convenient. While choosing Luan County as a logistics transit point, it can display the advantage of transportation, reduce regional logistics costs and improve the efficiency of regional logistics and promote regional development of related industries.
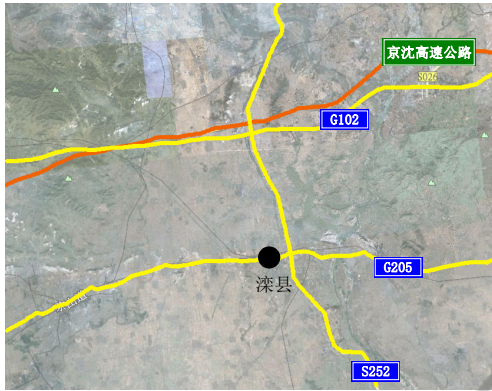
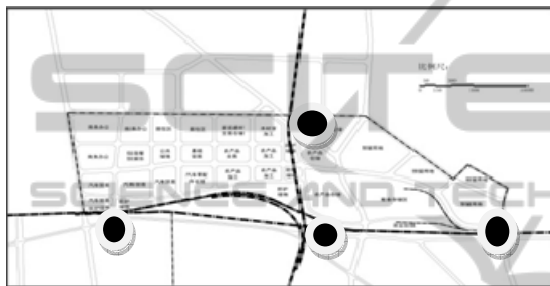Figure 3: Traffic map in Luan County.

Figure 4: Initial road network in Logistics Hub.

According to the traffic condition of Luan County, We set four logistics nodes. They are node 1, node 2, node 3 and 4 from top to bottom and left to right. Generally, the nodes locate in the point of large amount of traffic flow, so the nodes are in the junction of railway and state road or the junction of state road and provincial road.

Node 1 and Node 4 are regarded as the entrance; node 2 and node 3 are regarded as exports. We set node 1 and node 2 as OD points, there are following path, the weights and capacity index are given in table 1. The initial paths are:
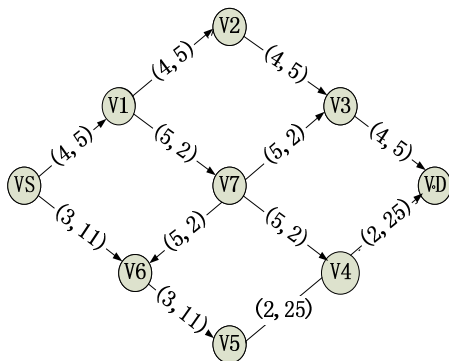

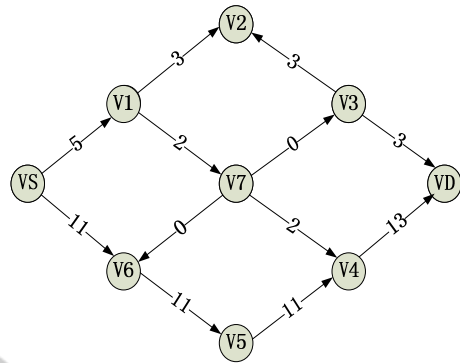Figure 5: The initial paths.

The flow after adjusted are:

Figure 6: The traffic flow in different kind of road after adjusted.

As the figure shows, the path V_S—>V_6—>V_5—>V_4—>V_D has the largest amount of traffic flow, so we set it as the trunk road.

The path V_S—>V_1—>V_2—>V_3—>V_D has the traffic volume. So it can be used as secondary roads.

The smallest traffic volume is V_S—>V_1—>V_7—>V_4—>V_D, so it is the slip road.

Then we can choose every two nodes in the Logistics Hub to plan the grade of road, finally optimize the whole network, the planning chart is:
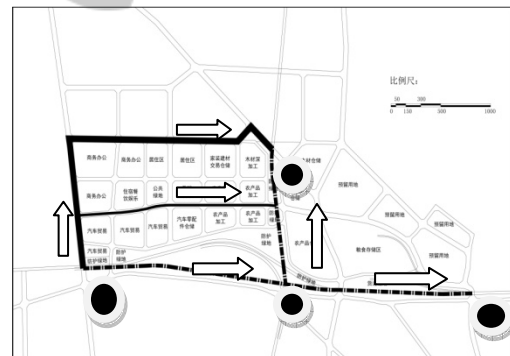

Figure 7: Schematic diagram of optimized network.

The two thickest arrows are represented the trunk road, the three dotted arrows are represented secondary road; the thin arrow in the middle are represented slip road. And the affiliated hollow arrows are the direction of them.

5 CONCLUSIONS

With the intensification of the greenhouse effect, carbon dioxide emissions reduction is increasingly

becoming the focus of activities related to warehouse, transportation, distribution, information process and other process of logistics. Each process will have carbon emissions, but transportation is main factor, so the most important thing is how to optimize the road network to achieve minimum carbon emissions, this paper use minimum cost maximum flow model to optimize the road network, then define road grade and guide traffic. This paper takes Luan County for example, using simulated data which is deduced by EcoTransIT tool to optimize the existing network, in order to make the Logistics Hub's carbon emissions reduced. But the model is just take the factor of carbon emissions and traffic volume into consideration, carbon emission is also related with the length of road, how to combine them is to be solved.

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