RESEARCH PROSPECTS OF RAIL TRANSIT BASED URBAN DELIVERY NETWORK

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Abstract: *As the city distribution demand characteristics of many varieties, batch, small batch, more increasingly significant, and the construction of urban rail transit network, setting up a new type of urban distribution network based on rail transit has become possible. On the basis of studying the basic structure of urban distribution network, this paper explores the case of the vehicle-subway city distribution network. We also analyze its basic form and transportation modes. In the end, in the view of Location-Routing Problem and Profit distribution, exploring the key scientific issues. From the perspective of equipment, scheduling, safety and environmental protection, prospected the main technical problems. This study provides a clear research direction for constructing of rail transit based urban logistics and underground logistics system.*

Keywords: *Rail transit; Vehicle-subway; Urban distribution; Distribution mode*

I. INTRODUCTION

Nowadays, the growth of e-commerce, the accelerated pace of life, the rise of shared economy and the sustainable development trend constantly lead the development and change of urban logistics and distribution[1]. With the development of economic-technology and commerce circulation model of reformation, people have increasingly demands for goods. The city center has a large number of goods daily inflow and outflow. Multi-species, small batch, high frequency has become the main feature of urban distribution, C-terminal and B-terminal clients place a greater demand on the city distribution timeliness and response speed requirements. A large-scale daily necessities are highly concentrated in the limited urban space, bringing great pressure to the original fragile urban transport system, exacerbating the difficulty of distribution and complexity.

Urban distribution tends to have relatively shorter transport distance than trunk transport, and highway is the dominating transportation. Freight vehicles need to go deep into the city center of the business circle and residential community, driving in the center of the city might increase traffic flow and bring more serious impact to traffic. Due to the high density of population in urban center, the existing distribution network could not satisfy the passenger and freight needs. The government redistribution of traffic resources, giving passenger priority traffic rights, exacerbating the contradiction between supply and demand of distribution services. In order to control the environmental pollution, traffic congestion and other issues caused by the trucks entering the city. By putting freight car city road permits, many cities have managed freight vehicles engaged in urban distribution. This certificate is a specific restriction on the passage time and the passage area of different models and load trucks. This management mode greatly reduces the number of trucks traveling in the city during the day, which facilitates the traffic management. But it has seriously affected the material distribution in the city center, increased the logistics cost and reduced the distribution rate. Road delivery costs a lot of cost and time, and can not meet the urgent needs of fast response and on-demand delivery.

30-40% of the emissions from the transport process are caused by the transport of goods[2], in which the road transport accounts for two-thirds[3]. In the main process of transport, such as rail transport and subway, the transportation of the main road is more green and environmentally friendly than the direct route through the door to the door. Hoen et al.[3] suggested that producers could reduce their carbon emissions by changing the mode of transportation. To fulfill social responsibility, many companies voluntarily has reduced the impact of their transport activities on the environment. IKEA even established its own rail transport network, which adopts the railway transportation mode to achieve low-carbon operation[4]. Therefore, reducing unnecessary road transport is the fundamental of improving urban distribution efficiency and reducing traffic congestion.

Based on "Transportation development in China" White Paper (State Council Information Office), during the 13th Five-year plan period, China has accelerated the rail transit network of the city which has more than 3 million people, and increased the mileage of urban rail transit about 3,000 kilometers. At present, the construction of urban rail transit has entered a period of rapid development. By the end of 2016, 29 cities have 128 operation lines, with a total length of 3,832 kilometers. Besides, 57 cities are planning urban rail transit lines, in addition to the operation of the 29 cities, 11 cities are under construction, and another 17 cities have planned lines.

Rail traffic presents a trend in all directions, with punctuality, high efficiency, high frequency, low pollution and safety. The surrounding area of the site is the centralized residence of the passengers, the commercial office cluster and the centralized destination of urban logistics distribution, they have a high degree of unity. Rail transit network is taking shape in most Chinese cities. It has stronger service ability and the larger scope of services, which can realize the main commercial outlets and human settlement cover, has the development of urban distribution network and the site conditions.

Special planning for science and technology innovation in the 13th five-year plan presents the transportation needs and characteristics of the living material between the central region of the big cities, the central region and the suburbs. To develop intelligent and economical transport vehicles suitable for the urban rail passenger gap period, realizing the flexible dispatching management of material transport organizations in the above areas. With the rapid development of urban rail transit, using rail transit to carry out service can be an effective way to enter the urban centers.

Passenger transport public infrastructure is usually built and operated by the government, while the distribution of goods is completed by the private companies. The combination of passenger and freight transport as a whole is the future trend of the transport system[5]. Integration and coordination of passenger and freight flows as a single system, shared public transport infrastructure by using the public transport vehicles carry passengers at the same time delivery of goods, could ensure the efficient flow of passenger and freight[6]. If the free transportation capacity of the existing passenger transport infrastructure is used for urban distribution service, such as subway, light rail and bus, can maximize its utilization and share part of the road traffic, which is an effective solution. Diziain et al.[7] studied urban rail freight services in Japan and France, where the Kyoto city center carried out light rail freight services, delivering goods once a day before early peak and completing the final delivery with electric bikes. Liu et al.[8]analyzed the advantages such as stable, fast and high frequency service in the freight process of city subway freight. He et al.[9]elaborated the necessity and feasibility of Beijing rail transit for urban distribution from the perspective of advantages, estimated transport capacity, cost and social evaluation. Explored the technology required for the subway transport system, added a dedicated truck compartment, the use of conveyor goods will be transported to the compartment, and quickly fixed [10].

II. THE BASIS FORM OF URBAN DISTRIBUTION NETWORK

Urban distribution networks usually have two parts of trunk line transportation and city distribution, the main transport usually by air, rail and truck three kinds of modes of transportation, while urban distribution by trucks, vans, tricycles, electric bicycles and other vehicles. The basic structure of the existing urban distribution network is shown in figure 1. The basic configuration of the existing urban distribution network includes aviation-truck, railway-truck, truck-truck 3 species.

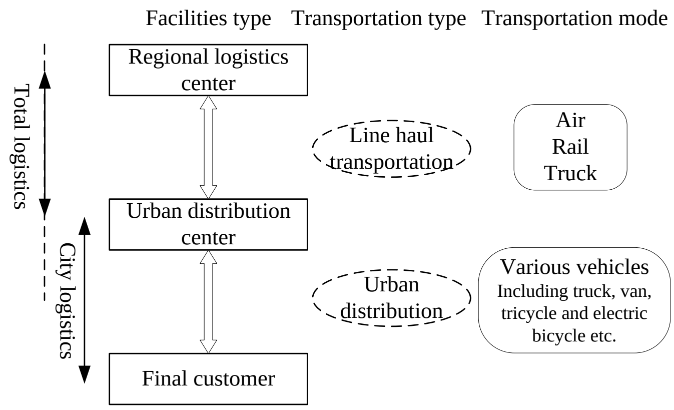

Figure 1. *The basic structure of existing urban distribution network*

III. THE CASE OF VEHICLE-SUBWAY URBAN DISTRIBUTION NETWORK

3.1. The pilot project

Case 1: In the northern Japanese city of Sapporo, the winter season has been covered by heavy snow, roads are shrinking and transport efficiency is reduced, causing traffic congestion. Based on the analysis of the current situation of urban distribution in the region and the advantages of integrating the subway distribution system, Yamato demonstrated a new urban distribution mode that integrated the Sapporo subway system with traditional truck transport in September 2010. A quarter of the truck transport was saved by running the service, so delivery of goods through the subway can effectively replace conventional truck transport. Through a questionnaire survey, 90% of the respondents supported the integration of the subway logistics project, thought that the project can reduce traffic congestion and carbon emissions. But some people worried about the congestion and safety management of subway stations caused by the mixing of passengers and freight, while others questioned the project's profitability. As a whole, the project had great social significance and economic significance, such as by way of alternative transport restrictions on vehicle unloading, mitigation of environmental problems, more efficient use of existing infrastructure, increase public transport bureau income and provide a new business services[11].

Case 2: In the northeastern UK city of Newcastle intended to use the subway to transport goods. Researchers had obtained the urban distribution based on subway transit as a viable plan to replace traditional urban distribution[12]. Take the Tyne and wear subway system as an example, according to the 329 businesses around Killingworth, it is estimated that if 50% of businesses make just one journey each week into Newcastle city center, the total road transport mileage including return journey is 4,485.48 km. If only 25% businesses made 1 trip weekly, it could reduce the flow of 4,732 vehicles and save ¥ 445,200 by reducing accident per year[13].

3.2. Vehicle-subway urban distribution stage

Generally speaking, vehicle-subway urban distribution stage includes two stages: rail transit network transport and terminal goods allocation.

Stage1: Rail transit network transport-city distribution center to rail transit site. The urban distribution center is the center of all distribution in the region, usually located in the suburbs of the city. In order to realize the urban distribution service based on rail transit, the distribution center should be as close as possible to the rail transit station, so that the goods can be conveniently in and out of the station. The goods are stacked in standard boxes according to the order group[14]. These boxes can be placed in wheeled carts, easily accessible from distribution centers to rail transit sites[11, 15], as shown in figure 2. The standard box is placed on the cart and is easily pushed onto the train. The use of a small area of each compartment set a set of snap, one minute you can finish the work push up and fix buckle work. The goods follow the subway to a site in the center of the city, with a minute you can unhook and push off.

Stage 2: Terminal goods allocation-rail transit site to customer. There are many ways, the most important is the electric trucks, electric bicycles, etc. The choice of vehicles depends on the number and weight of the goods. Electric trucks are mainly used for medium and short distance cargo transport, the effective load is between 2.8 metric tons and 7.4 tons, travel distance is between 65 km and 160 km. Cargo bicycles are used for short-distance transport in small batch of goods, there are quite a few cities in the city center using electric bicycles to transport goods, Paris[7, 15]and Berlin[14]cargo bicycles as shown in figure 3, figure 4.

Figure 2. *Example of placing standard box in cart*

Figure 3. *Examples of cargo bikes in Paris*

Figure 4. *Examples of cargo bikes in Berlin*

IV. THE CHARACTERISTICS OF CITY VEHICLE-SUBWAY DISTRIBUTION

This paper presents a new urban distribution network integrating rail transit, which is used for the transportation of small and medium sized parcels, low-density and high value-added goods. Use rail transit to transport directly from the urban distribution center in suburb to the city center, then allocate to customers through terminal delivery vehicles. The urban distribution system based on rail transit integrates rail transit network and road traffic network. A new network mode of urban distribution is realized by rail transportation and end delivery vehicle as shown in Figure 5.

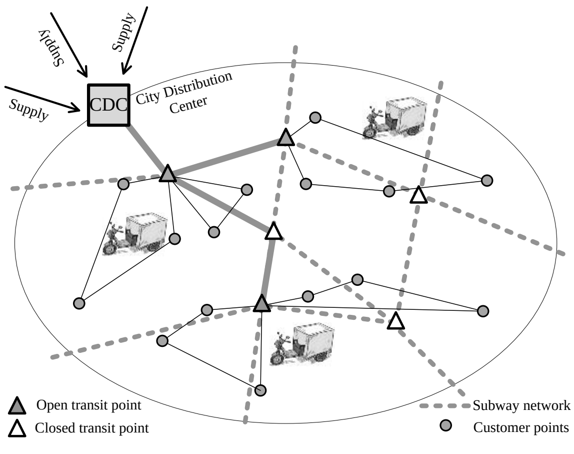

Figure 5. *Schematic diagram of urban distribution network system based on rail transit*

The urban distribution network based on rail transit has the main characteristics such as the many distribution link, high frequency of distribution, strong distribution reliability, alleviate the traffic congestion on the ground and reduce the air and noise pollution.

4.1. Basic composition of vehicle-subway urban distribution

The basic composition of the vehicle-subway city distribution network is shown in figure 6, which is composed by air-truck-subway-truck, rail-truck-subway-truck, truck-subway-truck 3 basic forms.

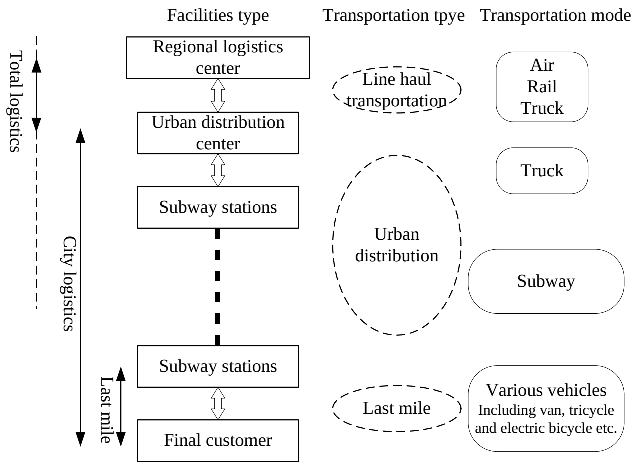

Figure 6. *Basic composition of vehicle-subway urban distribution*

4.2. Main delivery mode in rail transit

According to the technical characteristics of rail transit, as shown in Table 1, there are four possible modes of shipping in rail transit.

Table 1. *The main mode of freight transportation by rail*

Modes of freight transportation by rail	Specific description	Application
Freight train	During the period of free, freight trains are opened in the gap of passenger trains, and double tracks can be built in the future planning or rebuilding.	The Ministry of science and technology "13th Five-Year" traffic scientific and technological innovation in the field of special planning is put forward based on the development of urban rail network city supplies fast transfer vehicles.
Different compartments of passenger and freight	During the period of free, several freight carriages can be carried, and special freight truck can be added.	Japan Kyoto carries out light rail freight service before the peak period before the peak.
Special stock area	The carriage is provided with a special storage area and a special standard box is used to load the goods.	Japan Sapporo sets up a buckle in carriage for fixing the container.
Deliver goods incidentally	Passengers carry a small amount of cargo on the subway.	The Crowdsourcing delivery service using the goods to the customer from the subway.

V. KEY SCIENTIFIC PROBLEMS OF VEHICLE-SUBWAY URBAN DISTRIBUTION NETWORK

Urban rail transit is mainly based on passenger transport, while urban distribution is oriented towards freight. Research lacks the coordination of urban rail transit and urban distribution system network, capacity, technology, services and other aspects. The key technical problems of the vehicle-subway urban distribution network are location-routing problem and benefit distribution game.

5.1. Location-routing problem

First, the facility location problem, O (Origin) and D (Destination) points of urban distribution needs are not fixed, different from the traditional facility location, the whole problem is dynamic, goods can enter and leave rail transit network from any sites. The origin point, destination point, the adjacent rail transit stations and lines, and the path between origin and destination are shown in figure 7. The rail transit site near the origin point is d_1, d_2, d_3, the destination point is d_4, d_5, d_6. Therefore, if the goods are delivered by rail transit, there are 9 alternative paths.

The second is the path optimization of the network, when rail transit is networked, there are more than one optional path from one site to another, rail lines increased to five as shown in figure 8. Also form the origin point can go through one of d_1, d_2, d_3, then pass one of d_4, d_5, d_6 to the destination point. Three line intersection point are added, then the optional path is increased to 36.

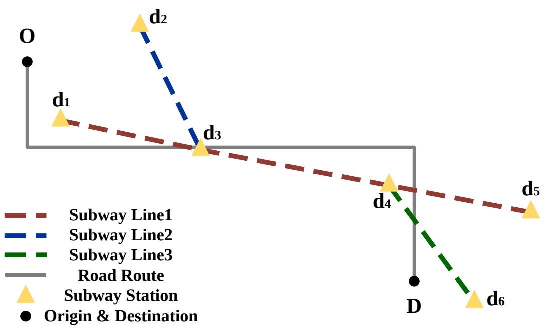

***Figure 7**. OD and rail transit stations and route distribution schematic*

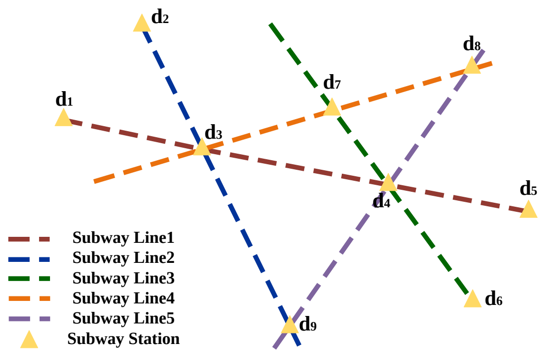

***Figure 8.** The network of rail transit lines increased to five*

In addition, it may be necessary for the convoys to bring the goods to the import site before entering the rail transit, and the vehicles will be sent to the end customers after they leave the rail transit. Therefore, the integration of the traditional vehicle routing problem is the multi-echelon location-routing problem. With the increase of the rail transit line, the distribution of the sites becomes more and more intensive, and the alternative path of using rail transportation to deliver goods will increase exponentially. It is very complicated to select the site of entry and exit rail transit, optimize the route between the import site and the exit site, optimize the frontend of the site and the vehicle path on the back end of the site. On the basis of the two-echelon location-routing problem[16], consider the route between the fixed import site and the export site, and build the vehicle-subway urban distribution network location-routing model.

5.1.1. Symbol description

To formulate the problem, the following notations are defined:

Indices

p	Represent supply nodes
q	Represent demand nodes
k, m	Represent transfer nodes, totally P transfer nodes, k is import sites, m is export sites
v	Represent road transportation
r	Represent subway transportation

Sets

V_P	Set of candidate supply nodes
V_S	Set of candidate transfer nodes
V_Q	Set of demand nodes
V_T	Set of vehicles of first echelon distribution system
V_R	Set of vehicles of second echelon distribution system
V_V	Set of vehicles of third echelon distribution system
$V_1 = V_P \cup V_S$	Set of nodes of first echelon distribution system
$V_3 = V_S \cup V_Q$	Set of nodes of third echelon distribution system

Parameters

d_q	Demand quantity at demand node q
c_{ij}^{t}	Travel cost per unit weight between node i and j by using vehicle t
c_{km}^{r}	Travel cost per unit weight between node k and m by using subway r
c_{ij}^{v}	Travel cost per unit weight between node i and j by using vehicle v
c_k	Transfer cost per unit weight at transfer node k
F_k	Fixed cost of transfer node k
F_P	Fixed cost of supply node p
F_t	Fixed cost of vehicle t in the first echelon system
F_v	Fixed cost of vehicle v in the third echelon system
Q_p	Capacity of supply node p
Q_t	Capacity of vehicle t
Q_r	Capacity of subway r
Q_v	Capacity of vehicle v

Variables

x_{ij}^{v}	1, if vehicle v traverses arc (i,j) from node i to node j; otherwise, 0
y_{km}^{r}	1, if subway r traverses arc (i,j) from import site k to export site m; otherwise, 0
z_{ij}^{t}	1, if vehicle t traverses arc (i, j) from node i to node j; otherwise, 0
m_{kp}	1, if freight at supply node p enter the subway at transfer node k; otherwise, 0
n_{mq}	1, if demand node q is supplied from transfer node m; otherwise, 0
o_k	1, if transfer node k is open; otherwise 0
s_p	1, if supply node p is open; otherwise 0
W_{it}	Avoid the sub circuit in the driving path of the vehicle t in the first echelon distribution system
U_{iv}	Avoid the sub circuit in the driving path of the vehicle v in the third echelon distribution system

5.1.2. Modeling

Considering the fixed path between import sites and export sites, vehicle-subway distribution network of multi-echelon location-routing model is established.

$$\mathrm{Min}Z = F_p \sum_{p\in V_P} s_p + F_k \sum_{k\in V_S} o_k + F_v \sum_{v\in V_V}\sum_{i\in V_S}\sum_{j\in V_Q} x_{ij}^{v} + F_t \sum_{t\in V_T}\sum_{i\in V_P}\sum_{j\in V_S} z_{ij}^{t} + \sum_{v\in V_V}\sum_{i\in V_3}\sum_{j\in V_3} c_{ij}^{v} x_{ij}^{v}$$

$$+\sum_{r\in V_R}\sum_{i\in V_S}\sum_{j\in V_S} c_{ij}^{r} y_{ij}^{r} + \sum_{t\in V_T}\sum_{i\in V_1}\sum_{j\in V_1} c_{ij}^{t} z_{ij}^{t} \quad (1)$$

s.t.

$$\sum_{j\in V_3} x_{ij}^{v} = \sum_{j\in V_3} x_{ji}^{v}, \forall i \in V_3, v \in V_V \quad (2)$$

$$\sum_{v\in V_V}\sum_{j\in V_3, i\neq j} x_{ij}^{v} = 1, \forall i \in V_Q \quad (3)$$

$$\sum_{m\in V_S} n_{mq} = 1, \forall q \in V_Q \quad (4)$$

$$\sum_{i\in V_Q}\sum_{j\in V_3} x_{ij}^{v} d_i \le Q_V, \forall v \in V_V \quad (5)$$

$$\sum_{m\in V_S}\sum_{q\in V_Q} x_{mq}^{v} = 1, \forall v \in V_V \quad (6)$$

$$\sum_{i\in V_Q} x_{mi}^{v} + \sum_{i\in V_3} x_{ij}^{v} \le 1 + n_{mq}, \forall j \in V_Q, m \in V_S, v \in V_V \quad (7)$$

$$\sum_{q\in V_Q} n_{mq} d_q \le M o_m, \forall m \in V_S \quad (8)$$

$$\sum_{q\in V_Q} x_{mq}^{v} \le o_m, \forall v \in V_V, \forall m \in V_S \quad (9)$$

$$\sum_{i\in V_S}\sum_{j\in V_S} x_{ij}^{v} = 0, \forall v \in V_V \quad (10)$$

$$U_{iv} - U_{jv} + |V_3| x_{ij}^{v} \le |V_3| - 1, \forall i \in V_3, \forall j \in V_Q, \forall v \in V_V, j \neq i \quad (11)$$

$$\sum_{k\in V_S} y_{km}^{r} \le o_m, \forall r \in V_R, \forall m \in V_S \quad (12)$$

$$\sum_{m\in V_S} y_{km}^r \le o_k, \forall r \in V_R, \forall k \in V_S \tag{13}$$

$$\sum_{m\in V_S} y_{km}^r \left(\sum_{q\in V_Q} n_{mq} d_q \right) \le Q_r, \forall r \in V_R, \forall k \in V_S \tag{14}$$

$$\sum_{j\in V_1} z_{ij}^t = \sum_{j\in V_1} z_{ji}^t, \forall i \in V_1, t \in V_T \tag{15}$$

$$\sum_{t\in V_T} \sum_{i\in V_1, i\ne j} z_{ij}^t = o_j, \forall j \in V_S \tag{16}$$

$$\sum_{p\in V_P} m_{pk} = o_k, \forall k \in V_S \tag{17}$$

$$\sum_{l\in V_1} \sum_{k\in V_S} \sum_{m\in V_S} z_{lk}^t y_{km} \left(\sum_{q\in V_Q} n_{mq} d_q \right) \le Q_T, \forall t \in V_T \tag{18}$$

$$\sum_{p\in V_P} \sum_{k\in V_S} z_{pk}^t = 1, \forall t \in V_T \tag{19}$$

$$\sum_{i\in V_S} z_{pi}^t + \sum_{i\in V_1} z_{ik}^t \le 1 + m_{kp}, \forall k \in V_S, p \in V_P, t \in V_T \tag{20}$$

$$\sum_{k\in V_S} \sum_{m\in V_S} m_{kp} y_{km} \left(\sum_{q\in V_Q} n_{mq} d_q \right) \le s_p Q_P, \forall p \in V_P \tag{21}$$

$$\sum_{k\in V_S} z_{kp}^t \le s_p, \forall t \in V_T, \forall p \in V_P \tag{22}$$

$$\sum_{i\in V_P} \sum_{j\in V_P} z_{ij}^t = 0, \forall t \in V_T \tag{23}$$

$$W_{it} - U_{jt} + |V_1| z_{ij}^t \le |V_1| - 1, \forall i \in V_1, \forall j \in V_S, \forall t \in V_T, j \ne i \tag{24}$$

$$x_{ij}^v \in \{0,1\}, \forall i, j \in V_3, v \in V_V \tag{25}$$

$$y_{ij}^r \in \{0,1\}, \forall i \in V_2, j \in V_S, r \in V_R \tag{26}$$

$$z_{ij}^t \in \{0,1\}, \forall i, j \in V_1, t \in V_T \tag{27}$$

$$m_{gj} \in \{0,1\}, \forall g \in V_S, j \in V_C \tag{28}$$

$$n_{dg} \in \{0,1\}, \forall d \in V_D, g \in V_S \tag{29}$$

$$o_g \in \{0,1\}, \forall g \in V_g \tag{30}$$

$$p_d \in \{0,1\}, \forall d \in V_D \tag{31}$$

The objective function (1) minimizes the total cost for the objective function, comprises seven parts: the first and second parts represent the open cost of the transfer point and the supply point. The third and fourth parts represent the fixed cost of vehicles in the first echelon and third echelon distribution systems. The fifth, sixth and seventh parts represent the driving cost of vehicles in the three-echelon distribution system.

Constraints (2-11) is the constraint condition of the third echelon distribution system. In particular, constraints (2) and (3) ensure the conservation of path flow, constraints (4) ensure that the goods of a customer can only come from a transport point, constraints (5) is the limit of vehicle capacity, constraints (6) ensure that each customer is assigned to a path, and each path starts from a transport point, constraints (7) ensure that if the demand point q is connected to the transfer point m, the customer is assigned to the transfer point $n_{mq} = 1$. Constraints (6) and (7) also indicate the relationship between the vehicle and the transfer point, determining the transfer points assigned to each vehicle. Constraints (8) ensure that if the demand point is assigned to a transit point, it shall be guaranteed that the transit point is open, constraints (9) ensure that each open transfer point is accessed by a vehicle at most once, and closed transfer point is not reachable by vehicle, constraints (10) ensure that the third echelon distribution system transfer points are not interoperable, and constraints (11) ensure sub circuit elimination of constraints. Constraints (12-14) are the constraint condition of the secondary distribution system. In particular, constraints (12) ensure that every open transfer point is only accessed once by the subway with the goods, and the unopened transfer point is not transferred to the subway, constraints (13) ensure that if the export site is assigned to a certain import site, it should be guaranteed that the site is an open transfer point, constraints (14) ensure subway capacity limitation. Constraints (15-24) are related to the first echelon distribution system, which corresponds to the constraints (2-11). Constraints (25-31) represent the scope and type of the variable.

In this model, we can also increase the time window constraint and continue to explore the traveling path of the subway network inside the network. In previous studies, Zhou F T etc.[17]presented the Point-Routing problem of Urban Distribution based on Subway. The model seeks to minimize the average delivery time. Without considering the problem of vehicle routing before entering the site, fixed the site of the goods entering the rail transit, thus simplifying the research problem to two levels.

5.2. Profit distribution

In the implementation of vehicle-subway urban distribution, there are facilities sharing, an enterprise cannot complete this task independently. Therefore, rail transit operation enterprises and logistics enterprises need to set up a cooperative alliance. With the emergence of new technologies such as e-commerce, collaboration among multiple participants in large-scale logistics distribution networks has become easier. Multiple participants reduced logistics cost through cooperation and increased overall revenue. And the benefit distribution is the process of dividing the cooperation benefit between enterprises that participate in subway distribution according to certain basis and principle. The cooperative alliance takes the benefit as the foundation, not only optimizes the allocation of resources from a global perspective, but also achieves maximum benefit and to take into account the interests of the partners in the alliance. Based on the cooperative game theory, the methods of benefit distribution such as Nash negotiation, core solution set, group weighted center and Shapley value method are used more.

The leading enterprise of the vehicle-subway urban distribution network enterprise alliance is rail transit operating company. It does not provide entity logistics operation, but it needs to invest in dedicated subway freight train, unloading platform, specialized freight operation team, supporting warehouse and handling equipment. Member enterprises are logistics companies, responsible for actual distribution and transshipment. In the distribution of interests, we should follow the principle of individual rationality and collective rationality, the corresponding principle of contribution and benefit distribution[18].

The enterprise alliance consists of a leading enterprise A and $n-1$ member enterprises. Enterprise contribution is determined by input cost and effort level. C_i is the total cost of member enterprises i in the vehicle-subway urban distribution, s_i is the proportion of the profits obtained by enterprise i, α is the effort level vector, and β is the contribution coefficient vector. The total profit function of the alliance is related to the completion level and contribution system of the alliance enterprise, the net income of the alliance is:

$$U = E(\beta,\alpha) - \sum_{i=1}^{n} C_i \tag{32}$$

The minimum income from traditional urban distribution is the lowest income of member enterprises $D = (\pi_1, \pi_2, \cdots, \pi_n)$. The aim of the distribution of the dominant enterprises is to maximize their expected earnings under certain constraints.

$$\max E(U_A, s_i) \tag{33}$$

$$X_i = s_i U \tag{34}$$

$$\sum_{i=2}^{n} X_i + U_A = U \tag{35}$$

$$X_i \ge \pi_i, i = 2,3,\cdots,n \tag{36}$$

$$U_A \ge 0 \tag{37}$$

Constraints (34) ensure that each ally can obtain part of revenue from the alliance. Constraints (35) ensure that the sum of the earnings of each member company is equal to the total revenue of the alliance. Constraints (36) ensure that the income allocated from the alliance by the enterprises in the alliance is not less than the income derived from the individual operation. Constraints (37) indicates that this union is only possible when the leading enterprise benefits are greater than 0. Therefore, the profit distribution is the value of the distribution coefficient s_i.

Set the utility function of enterprise i is u_i, d_i ($i = 1,2,\ldots,n$) represents the lower bound value of the distribution of benefits that each logistics enterprise is willing to accept. x_i ($i = 1,2,\ldots,n$) represents the benefits obtained by the enterprises.

$$\max \sum_{i=1}^{n} u_i(x_i) \tag{38}$$

s.t.

$$\sum_{i=1}^{n} x_i = U \tag{39}$$

$$x_i \ge d_i, i = 1,2,\ldots,n \tag{40}$$

The net income of alliance enterprises can be compared with traditional logistics distribution network by optimizing the vehicle-subway urban distribution network. In addition, it can also increase the participation index of enterprises in the logistics process, or increase the carbon tax and government subsidy, expanding and improving the model.

VI. MAIN TECHNOLOGY PROSPECT OF VEHICLE-SUBWAY URBAN DISTRIBUTION NETWORK

In addition, the research of vehicle-subway urban distribution network also involves serval technical aspects of equipment, scheduling and safety and environmental protection.

1. Equipment

(1) Unloading platform construction. In order to ensure the close connection of logistics, special unloading platform need be constructed and the station need be transformed, such as equipped with vertical elevator and other equipment.

(2) Special equipment configuration. Design special cargo pallets or flat car is to realize the unitized transport of goods. At the same time equipped with mechanical handling equipment, fulfilling automated operations and improving the efficiency of loading and unloading. Then ensure the operation time does not affect the normal operation of the subway.

(3) Improvement of freight compartment. Reforming or configuring the special freight car for the carriage.

2. Scheduling

(1) Dispatching system construction. Build professional freight dispatching and service command line, optimize operation organization and ensure the timeliness of operations.

(2) Time interval selection. Use night time and 9:30-11:00, 14:00-15:30 and other traffic trough interval.

(3) Formulate development plan. In order to make full use of the low period of passenger traffic flow in rail transit, on the basis of the plan of passenger transport, the freight train will be added to realize the overall dispatch organization of passenger freight. It is helpful for the rail transit operators to make decision on the train operation plan.

3. Safe and environmental protection

(1) Strict safety inspection. The goods must be tested by X-ray machines before the subway delivery it.

(2) Passenger and cargo separation and transportation. If passengers and goods are in the same train, it is necessary to separate goods from passengers. A compartment is used solely for freight transport to avoid the safety problems caused by passengers and carts.

(3) Environmental benefits. Compared with conventional truck transportation, this paper

studies carbon emissions of two ways, and quantified the social benefits of urban distribution services based on rail transit. So that the public will be more receptive to the new distribution way, and promote its formal implementation.

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