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A new approach of supply chain cost modeling for integrated rail-post package distribution system in China

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Abstract: This paper analysis the current situation of Chinese Railways (CR), the progress of reforms in future, and possible future developments, the purpose to give a new integrate rail-post package distribution system in China. Based on it, this paper proposed a new approach of supply chain time-cost modeling. The first section describes the current research and problems. Integrated rail-post package distribution system is defined in second section. The third section some notations are given for understanding the formulation. Next section, the paper analysis the component of the cost construction which is divided four parts including local cost, access cost, long-haul cost and reposition cost. Furthermore, each part is considered for obtaining the cost function respectively. The fifth section gives integrated rail-post package distribution cost functions. Finally, conclusion is given in this paper.

Keywords: Supply Chain, Cost Modeling, Integrated Rail-Post Package Distribution

1. Introduction

Chinese railway is one of the largest and busiest railways in the world. It has already been affected by the pressure from reforming of economic institutions in China, although the changes so far are less radical than those affecting many railway companies around the world. The package market is facing the challenge in modern management system. With the rapid movement of customers and logistics, the current package transportation system cannot meet the demand of the modern logistics. Because of having much larger market in logistics transportation, the problem of package distribution is concerned by manager more than before.

The Council of Logistics Management (1993) defines logistics as "the process of planning, implementing, and controlling the efficient, effective flow and storage of good, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements". The components of a logistics system may include some or all of the following: suppliers, production facilities, transshipment points, and demand points (Figure 1). Distribution of freight from one or more origins to one or more destinations is the core of logistics. A supply chain may be defined as an integrated process that a number of various business entities (i.e.& suppliers, manufacturers, warehouse, distributors, and retailers) work together in an effort to: (1) acquire raw materials, (2) convert these raw materials into specified final products, and (3) deliver these final products to retailers (Figure 2). This chain is traditionally characterized by a forward flow of materials and a backward flow of information. For years, researchers and practitioners have primarily investigated the various processes of the supply chain individually. Recently, however, there has been an increasing attention on the performance, design, and analysis of the supply chain as a whole. From a practical standpoint, the supply chain concept arose from a number of changes in the manufacturing environment, including the rising costs of manufacturing, the shrinking resources of manufacturing bases, shortened product life cycles, the leveling of the playing field within manufacturing, and the globalization of market economies. With the development of the freight movement rapidly between cities and areas, designing and modeling based on the integrated logistics theory are becoming more and more important.

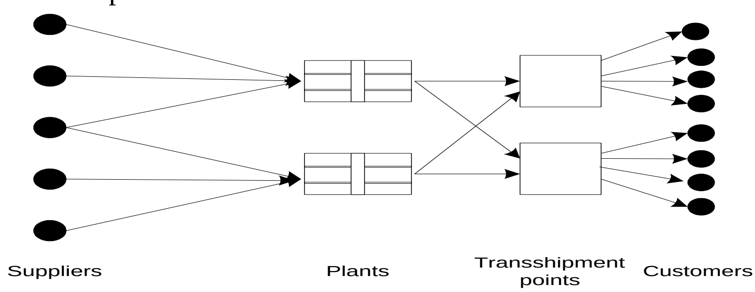

Figure 1: Logistics system.

As an important component of the logistics, railway is playing a key role in the transportation, especially for the transportation of the lot-size package. However the traditional operation is dominant in railway service. Now, the service production of rail package transportation is mainly for the popular service which offers the station-to-station appendix service to the customer. But it is short of the benefit service coming from small package transportation market which effects the market competition directly. In general, station-to-station is a basic model in station management and operation. It is to say, customers send the package to the location station, then the package is stored in the warehouse waiting to be consolidated and delivered. When the distribution schedule is determined, the packages are distributed destination station, and the customers must go to station receiving the packages. Because it cannot accomplish the door-to-door service, it must get the help of other types of transportation, such as port, truck and so on. Recently, government has carried out many effective measures to integrate the logistics resources for increasing the profit. But the design and operation of large-scale transportation networks is difficult due to the large number of decision variables and constraints. This is particularly true of the complex hierarchical networks adopted in the package delivery industry. In order to adapt the modern logistics ideas, railway need many principal approaches have been employed in the literature to address components of this problem, however this principal approaches is more suit for the traffic logistics network. Because the railway has its own special, this paper propose a new idea for building an integrate rail-post package distribution system. And general package distribution systems are designed using idealizations of network geometries, operating costs, demand and customers, and routing patters, the new rail-post is also not an exception.

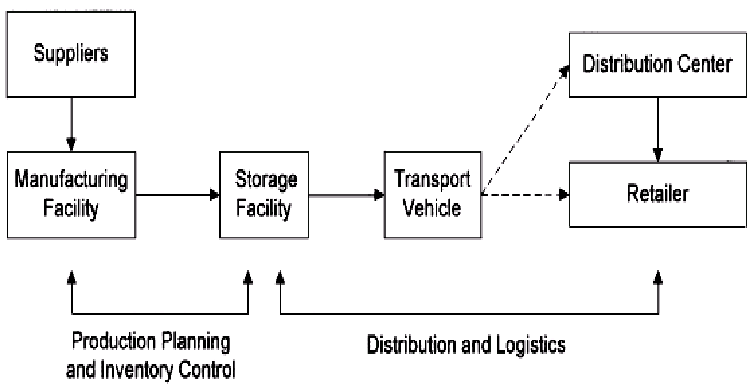

Figure 2: Supply chain.

As we know, the major issues addressed when planning or analyzing a logistics system or supply chain system is related to the cost-efficient organization of transportation and storage. Many literatures had analyzed the component of cost. Costs that may be relevant include those for: transportation; loading; storage, including opportunity costs, space, machinery and maintenance costs; handling and packaging. See Daganzo (1991) for a discussion of costs. Numerical optimization approaches to network modeling have been studied extensively (Magnanti, & Wong, 1984; Ahuja et al., 1993; Ball et al., 1995). As discussed in these and other more general references; (Nemhauser, & Wolsey, 1999), optimal solutions can be found numerically for small network problems. In general, however, as the network size increases, problems become more difficult to solve, and heuristic approaches are often necessary. A number of the numerical optimization models have been successful in solving transportation networks problems, the related literatures can be seen in Crainic (2000), Powell and Sheffi (1983), Barnhart and Schneur (1996). But demand and cost data for these models are difficult collected, and at times, it is impossible. Geoffrion (1976) advocates the use of simplified analytic models to gain insights into numerical mathematical programming models. In a similar spirit, Hall (1986) illustrates applications of discrete and continuous approximation, and notes that continuous approximations are useful to develop models that are easy for humans to interpret and comprehend. Early research for describing the data is smooth functions (Daganzo, & Newell, 1986). Daganzo (1999) gave a predictable cost, based on the former research, a new approach is proposed about the cost modeling and design techniques (Smilowitz, & Daganzo, 2002).

2. Integrated Rail-Post Package Distribution System Defined

In general, package is composed of express and deferred item. In non-integrated distribution system networks, express items have to be distributed at once; it can be transported by air. But deferred items maybe store in warehouse waiting for the collection.

Rapid growth in the package delivery industry has led carriers to offer a wide range of transportation services (i.e. & overnight delivery, two-day delivery, etc.) to capture a larger share of the package delivery market and to utilize resources more efficiently. As a result, new opportunities have emerged in the integration of operations by transportation mode (air, ground), and service level (express, deferred). They solve the problems of transportation mode integration and service level integration. However, it cannot solve the problem of door-to-door. Based on the problem, this paper proposes a new integration mode named integration agent mode to realize the integration distribution between rail and post in China.

The advantages of rail transportation are safety, enough capacity and economical. On the other hand, its service level is lower in five transportation modes. With the increasing of people's living standard, customer need the best service level and service mode in order to save the individual time. More and more people hope the forwarders can offer the service of door-to-door. However, posts can offer this services which can meet the demands of the customers. And this is a huge perspective for us to integrate the rail and the post. This is also this paper's motive. Based on the advantage of railway and post, we propose a new integrate package distribution system, as shown in Figure 3, operates in the following manner. Items first travel via local pick-up truck and local post vehicles to the nearest city or regional terminal where cargo or package within the region is consolidated for efficient long haul transportation. Items are then transported along access routes from city or regional terminals to either base station terminals, depending on the long haul or semi-long haul mode. Items travelling by truck are delivered to the nearest city or regional terminal, finally, the package are delivered to the customer by post vehicles. And this mode can realize the door-to-door service. On the other hand, it can reduce the transportation cost, raise the profit of rail and post, and integrate the social resource. In Figure 3, CT represents city logistics terminal or region logistics terminal. However, base station terminal is represented by BT. Generally, BT is built in large city or area. The operation in CT is distribution package and consolidation package in local city or the region. It can also be considered the regional post centre or warehouse. The operation in BT is distribution the packages to the CT, but for the CT and another BT, it is also a consolidation point. At the same time, BT deal with all business related to the customer, include customer information, package information, cost balance, and so on. Local consolidated packages and distribute packages are mainly done by post cars. Because the post network point is complex, it is also be divided several part of area post points which form the post distribution system.

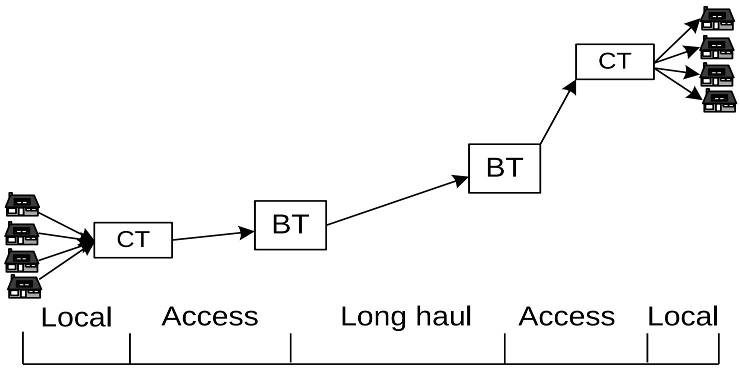

Figure 3: The trip of package.

For inbound packages, a freight forwarder or post department picks up packages from customers, make consolidation in the city or region terminal (consolidation terminal warehouse), and then transport packages to the base station as shown in Figure 4. For outbound packages, the forwarder pick up packages from the base station, deconsolidates them in the warehouse and then delivers the packages to customers as shown in Figure 5.

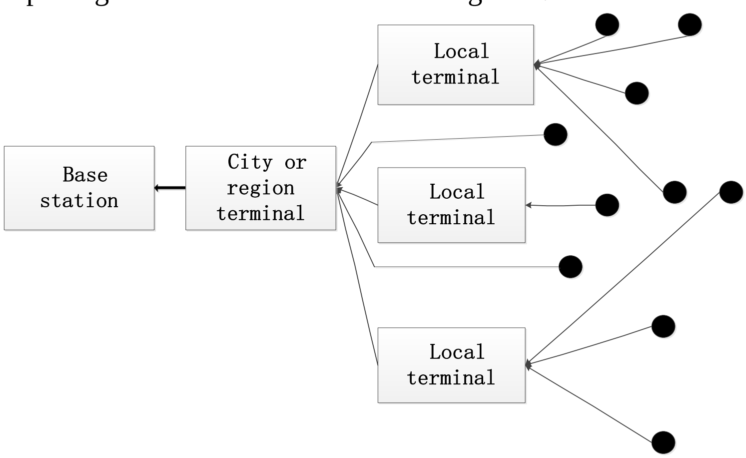

Figure 4: Flow of inbound packages.

In fact, the pick-up and delivery is mainly accomplished in CT because it is also seen as a warehouse. When packages arrive the destination station, they are transited to the CT. a part of the local packages is derived to their customers. But other packages are distributed to local terminal, and the packages are transported to the customers in time. For a given set of vehicles that are initially available at the CT, our problem is to build routes for vehicles to transport packages form the CT to customers or from customers to the CT.

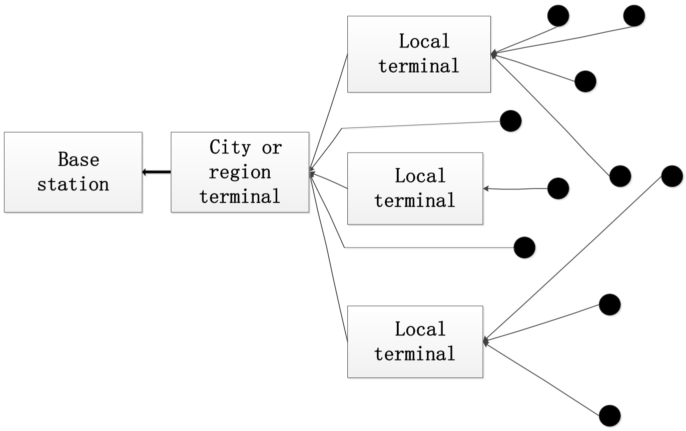

Figure 5: Flow of outbound packages.

All in all, the integrated rail-post package distribution system can be defined as the mode is integrated rail and post resource, the objectives are minimal the travel cost and time of packages, the type of package is mainly for the express and the service is door-to-door in order to satisfied the demand of the customers.

3. Notations

Package delivery firms operate very complex networks. A typical Federal Express or UPS package passes through a hierarchy of terminals en route from origin to destination, transported by several modes. This section introduces the notations necessary to describe a generic problem and derive its solution using continuous approximations. Because much notation is needed, a summary is founded in the former literature. The notation as follows:

The set of distribution levels is: $L = \{1,2,3\}$ local (1), access (2) and long haul (3). The set of terminal types is $T = \{C, B\}$ for city or region consolidation terminals (C) and base terminals (B). In this paper, two vehicle types are assumed for simplicity, $V = \{post, train\}$ for post and train. The following cost parameters are used:

$C_L(t_0, \mathbf{X})$: Total cost of distribution levels

$\mathbf{t}_{0,CT}$: Departure time vector for all vehicles from the CT,

$\mathbf{t}_{0,CT} = \{t_{l,0,CT} | l = 1, \cdots, m\}$

$\mathbf{t}_{0,BT}$: Departure time vector for all trains from the BT,

$\mathbf{t}_{0,BT} = \{t_{l,0,BT} | l = 1, \cdots, m_t\}$

$\mathbf{X}$: Assignment and order of visiting customers for all vehicles, $\mathbf{X} = \{\mathbf{x}_{l,V} | l = 1, \cdots, m\}$

$\mathbf{x}_{l,V}$: Assignment and order of visiting customers of vehicle l for vehicle type V =1; when vehicle is train, it is to say package is transported between BT

$n_{post}(i)$: The customer visited by a vehicle of post

n_{train} : =1; base station visited by a train

$d(j)$: Number of the depot (=0)

N_l : Total number of customers visited by vehicle l =1; When vehicle type is train especially

n_0 : Total number of in $\mathbf{x}_{l,V}$

c_{local} : The cost of package between customer and local post

c_{access} : The cost of package between local post and CT

$c_{longhaul}$: The cost of package between BT and BT

$c_{reposition}$: The cost of package reposition in CT

m : Maximum number of vehicles available

m_c : Maximum number of CT

m_t : Maximum number of BT

$\delta_{l,V}(\mathbf{x}_{l,V})$: =1; if vehicle l for vehicle type V is used=0; Otherwise

$c_{f,l,V}$: Fixed cost of vehicle l for vehicle type V

$C_{t,l,V}(t_{l,0,V}, \mathbf{x}_{l,V})$: Operating cost of vehicle l for vehicle type V

$C_{p,l,V}(t_{l,0,V}, \mathbf{x}_{l,V})$: Penalty cost of vehicle l for vehicle type V

$c_{t,l,V}$: Operating cost per minute of vehicle l for vehicle type V

$t_{l,n(i),V}$: Departure time of vehicle l for vehicle type V from customer/BT $n(i)$

$\bar{T}_a(\bar{t}_{l,n(i),V}, n(i), n(i+1))$: Average travel time of vehicle l for vehicle type V between customer/BT $n(i)$ and $n(i+1)$ at time $\bar{t}_{l,n(i),V}$

$t_{c,n(i),V}$: Loading/unloading time at customer/BT $n(i)$

$c_{d,n(i),V}(t)$: Delay penalty cost per minute at customer/BT $n(i)$

$c_{e,n(i),V}(t)$: Early arrival penalty cost per minute at customer/BT $n(i)$

N: Total number of customers

$D(n(i))$: Demand of customer $n(i)$

$t'_{l,0,V}$: Last arrival time of vehicle l at the depot

t_s: Earliest time for staring truck operations

t_e: Latest time for staring truck operations

$W_{l,V}(\mathbf{x}_l)$: Load of vehicle l vehicle type V

$W_{c,l,V}(\mathbf{x}_l)$: Capacity of vehicle l vehicle type V

4. Problem Formulation

In classical transportation problem of linear program, the traditional objective is one of minimizing the total cost and both levels of supply and demand are fixed. However, it is well known that supply and demand fluctuate on both seasonal and situational bases. And most of time we chase not only the minimizing total cost but also the minimizing total time weighted by the transportation quantity. Although there are some publications addressed the Time-cost trade-off transportation problem they all have the limitations (Li, 2001). The two objects just care about the interests of the suppliers. The modern marketing philosophy means that suppliers must supply the consumers with the best service and take the consumers as the dominant factor.

The path of typical item from origin to destination is illustrated in Figure 3. All items travel from an origin, to the nearest city or region terminal, to the long haul network via the closest base station, and then the process is reversed on the way to the final destination. No step is skipped in this hierarchical scheme; operating costs can be neatly separated by distribution level a terminal visited. For a specific pair of origin-destination regions, the average cost per item, is comprised of the following components:

$$c = c_{local} + c_{access} + c_{longhaul} + c_{reposition} \tag{1}$$

Equation (1) contains transportation costs for each distribution level: c_{local}, c_{access} and $c_{longhaul}$; terminal costs: c_{CT} and c_{BT}; and vehicle repositioning costs: $c_{reposition}$

However, the time each items can be written as follows:

$$t = t_{local} + t_{access} + t_{longhaul} + t_{reposition} + t_{CT} + t_{BT} \tag{2}$$

Because the time consuming is quiet short in BT, it can be ignored. Consequently, equation (2) can be modified as equation (3).

$$t = t_{local} + t_{access} + t_{longhaul} + t_{reposition} \tag{3}$$

4.1 Local Distribution Function

Local transportation costs cover pickup and delivery costs between origins/destinations and consolidation terminals. In the morning, delivery vehicles depart from a consolidation terminal and complete their deliveries. Vehicles that will be used for pick-up tours in the afternoon are then repositioned without returning to the terminal, and the rest return. In the afternoon, pick-up tours are conducted and then vehicles return to the consolidation terminal. Figure 6 illustrates the local distribution process for fully integrated networks.

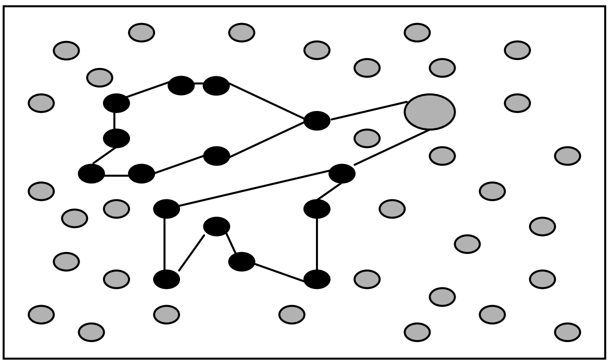

Figure 6: Local distribution.

Local transportation is fulfilled by post completely and Local time-cost function can be written as:

$$C_1(t_0, \mathbf{X}) = \sum_{l=1}^{m} c_{f,l,post} \cdot \delta_{l,train}(\mathbf{x}_{l,train}) + \sum_{l=1}^{m} c_{t,l,post}(t_{l,0}, \mathbf{x}_{l,post}) + \sum_{l=1}^{m} c_{p,l,post}(t_{l,0}, \mathbf{x}_{l,post}) \tag{4}$$

Where

$$C_{t,l,post}(t_{l,0,post}, \mathbf{x}_{l,post}) = c_{t,l,post} \sum_{i=0}^{N_l} \left\{ \overline{T}(\overline{t}_{l,n(i),post}, n(i), n(i+1)) + t_{c,n(i+1),post} \right\}$$

$$C_{p,l,post}(t_{l,0,post},\mathbf{x}_{l,post})$$
$$=\sum_{i=1}^{N_l}\left[\begin{array}{l} c_{d,n(i),post}\cdot\max\left\{0,t^{a}_{l,n(i),post}(t_{l,0,post},\mathbf{x}_{l,post})-t^{e}_{n(i),post}\right\} \\ +c_{e,n(i),post}\cdot\max\left\{0,t^{s}_{n(i),post}-t^{a}_{l,n(i),post}(t_{l,0,post},\mathbf{x}_{l,post})\right\}\end{array}\right]$$

Subject to

$$n_0 \geq 2 \tag{5}$$

$$\sum_{l=1}^{m} N_{l,post} = N_{post} \tag{6}$$

$$\sum_{n(i)\in\mathbf{x}_{l,post}} D(n(i)) = W_{l,post}(\mathbf{x}_l) \tag{7}$$

$$W_{l,post}(\mathbf{x}_{l,post}) \leq W_{c,l,post} \tag{8}$$

$$t_s \leq t_{l,0,post} \tag{9}$$

$$t^{'}_{l,0,post} \leq t_e \tag{10}$$

Where

$$t^{'}_{l,0,post} = t_{l,o,post} + \sum_{i=0}^{N_{l,post}} \left\{\bar{T}(\bar{t}_{l,n(i),post}, n(i), n(i+1) + t_{c,n(i+1),post})\right\}$$

Equation (4) represents the total local transportation cost. The first, second and third terms of the equation (4) represent the fixed cost of trucks, the operation cost of trucks and the early arrival and delay penalty, respectively. Note that there are two of costs in operating trucks; the fixed cost that is independent from the operation from the operation time and the operation cost that varies with operation time.

4.2 Access Distribution Function

Access tour between CT and BT is similar to local tours. The process and the cost function model are also similar to local transportation. Figure 7 illustrates the access distribution process for fully integrated networks.

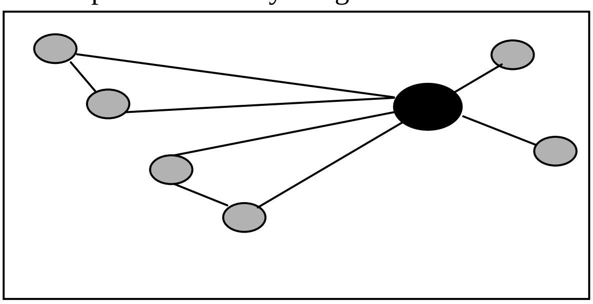

Figure 7: Access distribution.

The cost function can be written as follows:

$$C_2(t_0,\mathbf{X}) = \sum_{l=1}^{m} c_{f,l,post} \cdot \delta_{l,post}(\mathbf{x}_{l,post}) + \sum_{l=1}^{m} c_{t,l,post}(t_{l,0},\mathbf{x}_{l,post}) +$$
$$\sum_{l=1}^{m} c_{p,l,post}(t_{l,0},\mathbf{x}_{l,post})$$

4.3 Long Haul Distribution Function

Long haul transportation travel from origin to destination in which is not stop point, so there is not waiting cost in long haul distribution.

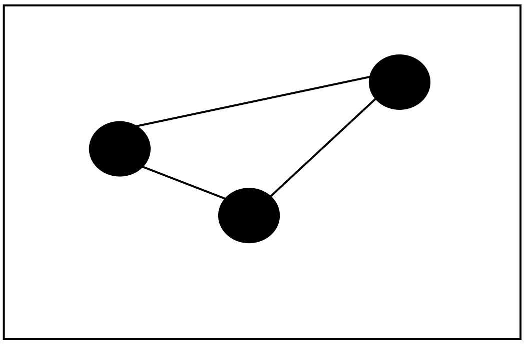

Figure 8: Long haul distribution.

Base on the above analysis, the long haul distribution function can be written as:

$$C_3(t_0,\mathbf{X}) = \sum_{l=1}^{m_t} c_{f,l,train} \cdot \delta_{l,train}(\mathbf{x}_{l,train}) + \sum_{l=1}^{m_t} c_{t,l,train}(t_{l,0},\mathbf{x}_{l,train})$$

Where

$$C_{t,l,train}(t_{l,0,train},\mathbf{x}_{l,train}) = c_{t,l,train}\overline{T}(\bar{t}_{l,train})$$

Subject to

$$\sum_{l=1}^{m_t} N_{l,train} = N_{train}$$

$$t_s \le t_{l,0,train}$$

$$t'_{l,0,train} \le t_e$$

Where

$$t'_{l,0,train} = t_{l,o,train} + \left\{\overline{T}(\bar{t}_{l,n(i),train})\right\}$$

5. Integrated Rail-Post Package Distribution Cost Functions

A complete package distribution cost function, including all transportation cost per unit time, is used to obtain optimal designs and to compare the different scenarios. To obtain this function, the cost components described in the previous sections should be integrated network. Based on the above research, the integrated rail-post distribution cost function is:

$$\sum_{l=1}^{m} c_{f,l,post} \cdot \delta_{l,post}(\mathbf{x}_{l,post}) + \sum_{l=1}^{m} c_{t,l,post}(t_{l,0}, \mathbf{x}_{l,post}) + \sum_{l=1}^{m} c_{p,l,post}(t_{l,0}, \mathbf{x}_{l,post}) +$$

$$\sum_{l=1}^{m_c} c_{f,l,post} \cdot \delta_{l,post}(\mathbf{x}_{l,post}) + \sum_{l=1}^{m_c} c_{t,l,post}(t_{l,0}, \mathbf{x}_{l,post}) + \sum_{l=1}^{m_c} c_{p,l,post}(t_{l,0}, \mathbf{x}_{l,post}) +$$

$$\sum_{l=1}^{m_t} c_{f,l,train} \cdot \delta_{l,train}(\mathbf{x}_{l,train}) + \sum_{l=1}^{m_t} c_{t,l,train}(t_{l,0}, \mathbf{x}_{l,train}) \tag{11}$$

The integrand of (11) begins with local transportation costs, summing both collection and delivery costs. The next line represents access costs for trips to and from base station terminal. The following line represents long haul costs for train transportation.

6. Integrated Rail-Post Package Distribution Cost Functions

In past, rail package distribution is always a problem for management, and railway is facing great challenge coming from other transportation types, such as road, air and so on, especially in service mode. With the development the social, it cannot meet the demand of the customer. Based on the package transportation actuality, a new approach of supply chain cost modeling for integrated rail-post package distribution systems in China is given by this paper. Local transportation and access transportation are completed by post, while the long haul transportation is dominated by railway. Furthermore, this paper gives the cost component according with the role analysis of each part and the integrated package distribution cost formulation.

Acknowledgements

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