Local Hub Planning Problem

1. Introduction

SF Express is one of the largest Chinese delivery services and logistics companies based in Shenzhen, Guangdong. SF has been investing greatly to enhance its service network, based on which packages are transported, transferred and then delivered to customers. Depending on the scope of transportation, SF's service network can be divided into (1) inter-city network; and (2) intra-city network, see Figure 1. The inter-city network provides transportation service between different cities and consists of gateway hubs, and line haul vehicles. While the intra-city network, consisting of local hubs, vans, couriers, and customers, provides pickup and delivery services within one city. In this project, we only consider the planning of intra-city network. More specifically, we only plan the number, location, and function of local hubs within one city.

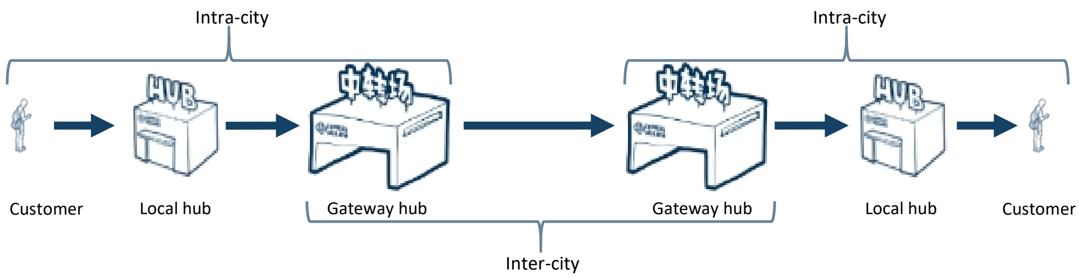

Figure 1. Package transportation process.

Local hubs (also called service centers) act as intermediate nodes connecting the gateway hubs and customers. It plays an important role in SF's intra-city network. Taking the pickup operation as an example (the delivery operation just follows an opposite transportation direction), a package's origin and destination in an intra-city network is *customer* and *gateway hub*, respectively. For economic reasons, packages are not sent from customers to gateway hubs directly, but go through some intermediate nodes, which are local hubs. An intra-city pickup operation usually goes in the following order: First, packages are picked up at the customer area. Then they are sent to a nearby local hub by couriers. Finally, packages are loaded onto a van and sent to the city gateway hub.

If there isn't enough local hubs in a city, couriers need to move a longer distance from customer areas to local hubs. On the other side, when there are too many local hubs, although the couriers move less, both the van cost between local hubs and gateway hub and the fix cost of local hubs will increase greatly. In addition, if the locations of local hubs are not planned properly, both the van cost and courier cost will increase. Therefore, the design of the number, location, and function of local hubs have a significant impact on SF's operating cost and service quality.

2. Problem description

In this project, we study the case of the intra-city pickup process (the delivery process follows the same logic), which starts from picking up packages from customers and ends up with packages arriving at its origin gateway hub. We need to work out a proper local hub plan, which minimizes the total cost and satisfies customer demands.

2.1. Customer area and customer demand

One city can be represented as a mesh of unit zones, which we define as customer areas. Customer area is a cluster of customers who are close to each other. It could be a block in the city or even a large building, which is the smallest unit considered in this project. We assume that each customer area could be a candidate for the local hub. Note that when one customer area is selected as a local hub, both the distance and transportation cost between this customer area and the local hub are considered as 0.

There are 2021 customer areas in the city we considered in this project. There are two key characteristics of each customer area, demand and location. The demand of a customer area is the total demand of all the customers in this area, see data set *demand.xlsx.* We also provide the distance matrix for each customer area, see data set *dist_matrix.txt*.

2.2. Gateway hub

In this project, we assume the location of gateway hub is fixed. There is only one gateway hub in the city we considered, denoted as "SFA". The distances between gateway hub and customer areas could be find in data set *dist_matrix.txt*.

2.3. Transportation resource

There are multiple transportation resources to choose from, including

（1）Type A Van;

（2）Type B Van;

（3）Type C Van (used by couriers),

Table 1. Vehicle information

Resource	Type A Van	Type B Van	Type C Van
Cost (Yuan)	max(70, 70+ 4.5 * (dist - 5))	max(30, 30 + 4* (dist - 5))	6*dist
Capacity (Piece)	800	200	40

PS： *dist* is the travel distance (unit: km).

Usually, type A van is used between gateway hub and local hubs; type B van is used between local hubs, if needed; type C van is used by couriers between local hub and customer area. In order to guarantee the service quality, we suggest that each package does not stop at more than two local hubs. The cost of empty driving is not considered in this project.

2.4. Local hub

All of the 2021 customer areas mentioned above could be a potential candidate for local hub. The fix cost for a local hub includes renting and personnel cost. In this project, we set the fix cost as 20 yuan per local hub.

2.5. Cost

The total cost considered in this project consists of (1) the fix cost of local hub and (2) the transportation cost of vans.

3. Project requirement

According to the introduction mentioned above, we need to choose a proper algorithm to figure out a local hub plan, which satisfies the customer demand and minimizes the total cost. A local hub plan needs to include the number, location, and function of local hubs, following with further analysis and discussion.

In the problem description section, we did not enumerate all the constraints and possible operation modes. Creative thinking and rational assumptions are welcome.

4. Data description

4.1. Customer demand (see *demand.xlsx)*

customer_code: customer area code;

demand: demand of the customer area (unit: piece).

4.2. Distance matrix (see *dist_matrix.txt)*

node_1, node2: customer code or gateway hub code;

dist: distance between node_1 and node_2 (unit: km).

4.3. Parameters

Vehicle cost and capacity: see table 1;

Fix cost of local hub: 20 yuan;

Gateway hub code: “SFA”.