# Research on Reverse Logistics Network and Site Selection of Remanufacturing Enterprise of Waste Tires

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**Abstract.** This paper deals with the site selection of the recovery center and remanufacturing enterprise of waste tires in Heilongjiang Province. The recovery center area of waste tires in Heilongjiang Province is divided into five areas (The first area is Harbin, the second area contains Qiqihar, Daqing, and Suihua, the third area contains Yichun, Hegang, Jiamusi, and Shuangyashan, the fourth area includes Qitaihe, Jixi, and Mudanjiang, and the fifth area includes Daxinganling and Heihe). Thus, the economic conditions and the number of waste tires with high weights are essential factors for the site selection of recovery center and remanufacturing enterprise of waste tires in Heilongjiang Province. The precise gravity method is utilized to perform this site selection. Finally, it is found that the site selection of recovery centers in these five areas are Acheng, Anda, Fujin, Muling, and Nenjiang, respectively, while the site selection of remanufacturing enterprises is Harbin. The saving mileage method is employed to conduct the reasonability test of the site selection. Taking the saving distance as the inspection standard, the saving mileage of recovery centers in these five areas and the remanufacturing enterprise are obtained as 235.6km, 566.6 km, 782.7km, 741 km, 276.8km, and 903km, respectively. The reasonability of site selection of recovery center and remanufacturing enterprise is verified by precise gravity method.

**Keywords:** waste tires; site selection of recovery center; site selection of remanufacturing enterprise; reverse logistics network; precise gravity method; saving mileage method

## 1 Introduction

China is not only a large country of tire manufacturing and consumption, but also a country with scarce rubber resources. If the waste tires can be recycled scientifically, then they can be used as resources and treated harmlessly, which is of great significance for protecting the ecological environment, saving rubber resources, reducing energy consumption, developing circular economy and enhancing the sustainable development capacity of China's rubber industry. In recent years, the Heilongjiang provincial government has encouraged the development of a green circular economy system. Waste tires are the main source of recycled rubber, and their reverse recycling has attracted the attention of the government. As a national strategic emerging industry, the comprehensive utilization of waste tires has significant social benefits in the development of circular economy. According to the industrial specifications for

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the comprehensive utilization of waste tires issued by the Ministry of industry and information technology in 2020, the total output of automobile tires in China in 2021 was 750million, the domestic consumption was 400million, and the market ownership of motor vehicle tires reached 1.8 billion[1-3].The influencing factors of reverse logistics under different conditions are different, and domestic and foreign scholars have different focuses on the reverse logistics research under different conditions, and the research results will also be different, All of these can be used for reference for the location of the reverse logistics network of waste tires in Heilongjiang Province [4-7].

## 2 Precise Gravity Method and Gaussian Projection

The precise gravity method is adopted for the site selection of the recovery center and remanufacturing enterprise. This paper only considers whether the economic benefits caused by the recovery facilities are optimized. Accordingly, the optimal value of the distance between a point in the plane and the rest points multiplied by the sum of the demanded quantity can be obtained [9-12]. The equations of the precise gravity method are given as:

$$X_0 = \frac{\sum V_i R_i X_i / d_i}{\sum V_i R_i / d_i} \tag{1}$$

$$Y_0 = \frac{\sum V_i R_i Y_i / d_i}{\sum V_i R_i / d_i} \tag{2}$$

where $X_0$ and $Y_0$ are the $x$ and $y$ coordinates of the center, respectively; $V_i$ is the transportation amount at point $i$; $R_i$ stands for the shipping rate to point i; $d_i$ is the distance from ideal position to point $i$.

The distance equation between two points can be expressed as:

$$\mathrm{d} = \sum_{j=1}^{n} \sqrt{(x - x_j)^2 + (y - y_j)^2} \tag{3}$$

where $(x, y), (x_i, y_i)$describe the coordinates of two points.

The optimal position of $(X_0, Y_0)$ is obtained according to the minimum total cost. The planning and solving functions of the Excel software are employed to seek the optimal solution through an iterative process. In the calculation process of the gravity method, each city's longitude and latitude coordinates are utilized to solve the problem. This study employs the Gauss projection longitude and latitude coordinate transformation to transform longitude and latitude into x and y-axis coordinates to conveniently calculate the distance between two points [13-14]. Gaussian projection forward calculation formula is as follows:

$$\mathrm{x} = \mathrm{X} + \frac{N}{2\rho''^2} \sin B \cos B l''^2 + \frac{N}{24\rho''^4} \sin B cos^3 B (5 - t^2 + 9\eta^2) l''^4 \tag{4}$$

$$\mathrm{y} = \frac{N}{\rho''} \cos B l'' + \frac{N}{6\rho''^3} cos^3 B (1 - t^2 + \eta^2) l''^3 + \frac{N}{120\rho''^5} cos^5 B (5 - 18t^2 + t^4) l''^5 \tag{5}$$

## 3 Reasonability Test of the Recovery Center in the First Area

The recovery center in the first area is located in Acheng. Acheng is taken as the starting point in the saving mileage test, while the obtained saving mileage order is presented in Table 7. According to the route planning in Table1, priority should be given to cities that can save more mileages, and the first area should be divided into two routes, as presented in Fig. 1. For route I (Acheng - Shangzhi - Wuchang - Shuangcheng – Acheng), the distance is 110.6+95.8+109.3+61.8=377.2km, and the saving mileage is 114.1+51.8=165.9km. For route II (Acheng–Bayan–Bin Country–Acheng), the distance is 81.9+72.4+60.2=214.5km, and the saving mileage is 69.7 km. Accordingly, the total saving mileage is 165.9+69.7=235.6km[8-9].

**Table 1.** Saving mileage order in the first area.

| Order | Start-end city | Saving mileage /km |
|---|---|---|
| 1 | Shangzhi—Wuchang | 114.1 |
| 2 | Bayan—Bin Country | 69.7 |
| 3 | Shuangcheng—Wuchang | 51.8 |

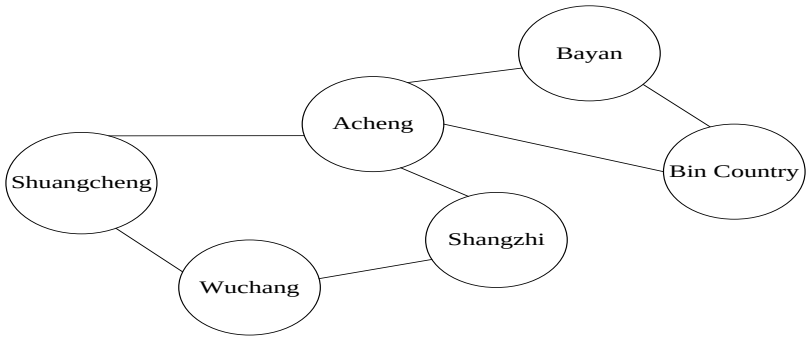


**Fig. 1** Planning route in the first area.

## 4 Reasonability Test of the Recovery Center in the Second Area

The recovery center in the second area is placed in Anda, which is taken as the starting point in the saving mileage test, while the obtained saving mileage order is given in Table 8. Based on the Bin Country route planning in Table 2, cities should be chosen that can save more mileages, and the second area can be divided into two routes, as shown in Fig 2. For route I (Anda –Neihe–Longjiang–Hailun–Anda), the distance is 315.4+217.4+422.8+204.2=1159.8km, and the saving mileage is 343.8+138.4Anda=482.2km. In contrast, for route II (Anda–Zhaozhou–Zhaodong–Anda), the distance is 82.9+72.9+74.4=230.2km, and the saving mileage is 84.4km. Thus, the whole saving mileage is 482.2+84.4=566.6km[10-11].

**Table 2.** Saving mileage order in the second area.

| Order | Start-end city | Saving mileage /km |
|---|---|---|
| 1 | Nehe—Longjiang | 343.8 |
| 2 | Hailun—Longjiang | 138.4 |
| 3 | Zhaodong—Zhaozhou | 84.4 |
| 4 | Hailun—Nehe | 42.3 |
| 5 | Zhaodong—Hailun | 23.8 |
| 6 | Zhaodong—Nehe | 9.2 |
| 7 | Zhaodong—Longjiang | 9.2 |

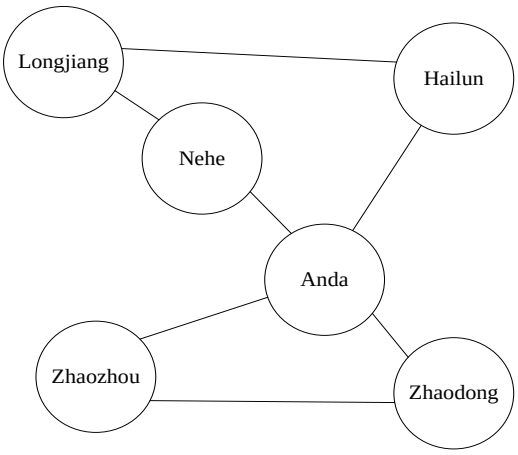


**Fig. 2** Planning route in the second area.

## 5 Reasonability Test of The Recovery Center in the Third Area

The recovery center in the third area is in Fujin, which is taken as the starting point in the saving mileage test, while the obtained saving mileage order is presented in Table 3. Route planning in Table 9 indicates that priority should be given to cities that can save more mileages, while the third area can be divided into two routes, as displayed in Fig. 3. For route I (Fujin–Luobei–Tieli–Huanan–Baoqing–Fujin), the distance is 130.5+331.2+395.4+204.2+150=1211.3km, and the saving mileage is 286.5+321.1+175.1=782.7km. For route II (Fujin–Tongjiang–Fujin), the distance is 75.7+75.7+151.4km, and the saving mileage is 0km. The total saving mileage is 782.7km[12-13].

**Table 3.** Saving mileage order in the third area.

| Order | Start-end city | Saving mileage /km |
|---|---|---|
| 1 | Huanan——Tieli | 321.1 |
| 2 | Luobei——Tieli | 286.5 |
| 3 | Huanan——Baoqing | 175.1 |
| 4 | Huanan——Luobei | 165 |
| 5 | Baoqing——Tieli | 136.2 |
| 6 | Huanan——Tongjiang | 5.4 |
| 7 | Tongjiang——Tieli | 5.1 |

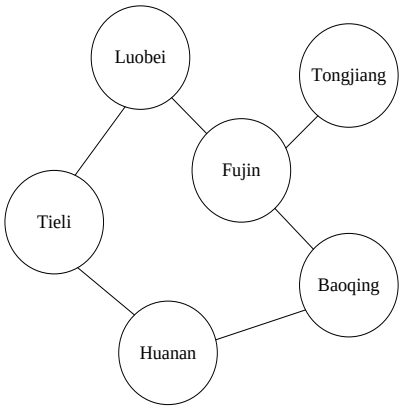


**Fig. 3** Planning route in the third area.

## 6 Reasonability Test of the Recovery Center in the Fourth Area

The recovery center in the fourth area is placed in Muling as the starting point in the saving mileage test, and the obtained saving mileage order is given in Table 4. The route planning in Table 10 shows that priority should be given to cities that save more mileages, and the fourth area can be divided into two routes, as presented in Fig. 4. For route I (Muling–Mishan–Hulin–Boli–Muling), the distance is 163.2+99.9+261.6+173.8=698.5km, and the saving mileage is 319.9+168.8=488.7km. For route II (Muling–Hailin–Ningan–Muling), the distance is 142.9+35.6+145=323.5km, and the saving mileage is 252.3km. Accordingly, the total saving mileage is 488.7+252.3=741km[14].

**Table 4.** Saving mileage order in the fourth area.

| Order | Start-end city | Saving mileage /km |
|---|---|---|
| 1 | Hulin——Mishan | 319.9 |
| 2 | Hailin——Ningan | 252.3 |
| 3 | Hulin——Boli | 168.8 |
| 4 | Mishan——Boli | 168.2 |
| 5 | Hailin——Boli | 56.7 |
| 6 | Hulin——Ningan | 29 |
| 7 | Hulin——Hailin | 27.4 |
| 8 | Mishan——Ningan | 25.8 |
| 9 | Mishan——Hailin | 25.8 |

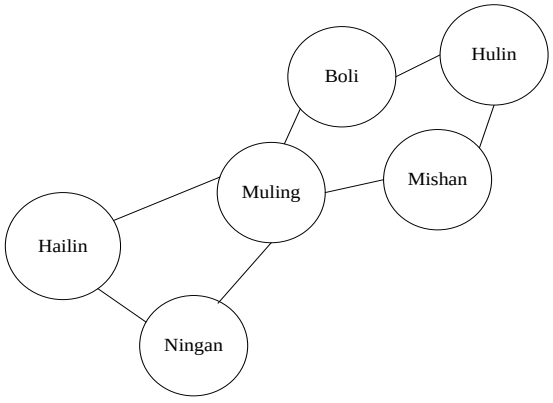


**Fig.4** Planning route in the fourth area.

## 7 Reasonability Test of The Recovery Center in the Fifth Area

The recovery center in the fifth area is located in Nenjiang, which is taken as the starting point in the saving mileage test, and the obtained saving mileage order is given in Table 5. Based on the route planning in Table 11, priority should be given to cities that can save more mileages, and there are two routes in the fifth area, as presented in Fig. 5. For route I (Nenjiang–Wudalianchi–Beian–Boli Jagdaqi–Nenjiang), the distance is 134.8+43+357.7+188.9=724.4km, and the saving mileage is 319.9+168.8=488.7km. For route II (Muling–Hailin–Ningan–Muling), the distance is 142.9+35.6+145=323.5km, and the saving mileage is 268.7+8.1=276.8km.

**Table 5.** Saving mileage order in the fifth area.

| Order | Start-end city | Saving mileage /km |
|---|---|---|
| 1 | Beian—Wudalianchi | 268.7 |
| 2 | Beian—Jagdaqi | 8.1 |
| 3 | Jagdaqi—Wudalianchi | 8 |

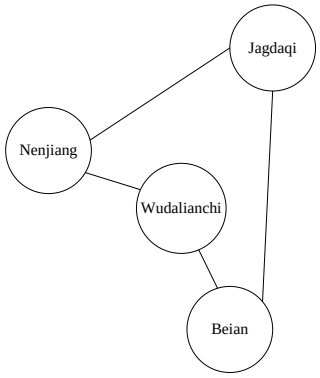


**Fig.5** Planning route in the fifth area.

## 8 Saving Mileage Test for Site Selection of Remanufacturing Enterprise

It can be concluded from the precise gravity method that the remanufacturing enterprise is located in Harbin, which is taken as the starting point in the saving mileage test, while the obtained saving mileage order is presented in Table 6. According to the route planning in Table 12, priority should be given to cities that can save more mileages, and it can be divided into two routes, as shown in Fig. 6. For route I (Harbin –Heihe–Mudanjiang–Jiamusi–Harbin), the distance is 573.4+38438+339.6+384.8=1682.6km, and the saving mileage is 523.2+379.8=903km. For route II (Harbin–Suihua–Harbin), the distance is 142.9+35.6+145=323.5km151.1+151.1=302.2km, and the saving mileage is 0km. Therefore, the total saving is 903km.

**Table 6.** Saving mileage order of remanufacturing enterprise.

| Order | Start-end city | Saving mileage /km |
|---|---|---|
| 1 | Mudanjiang—Heihe | 523.2 |
| 2 | Jiamusi—Mudanjiang | 379.8 |
| 3 | Jiamusi—Heihe | 276.4 |
| 4 | Suihua—Heihe | 240.8 |
| 5 | Suihua—Jiamusi | 65.8 |
| 6 | Suihua—Mudanjiang | 32.8 |

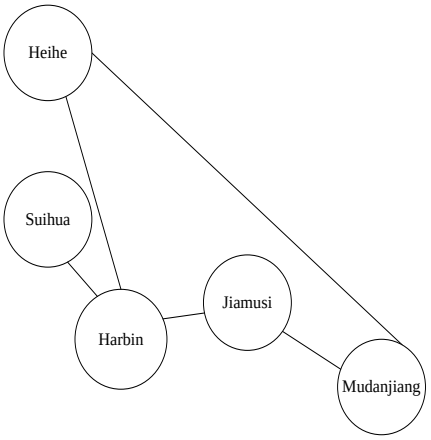


**Fig.6** The planning routes of remanufacturing enterprises.

## 9 Conclusions

This paper solves the site selection problem of a reverse logistics recovery center and remanufacturing enterprise of waste tires in Heilongjiang Province, and the main conclusions are as follows:

(1) The precise gravity method is utilized to perform site selection of reverse logistics recovery center and remanufacturing enterprise of waste tires in Heilongjiang Province. Finally, Acheng, Anda, Fujin, Muling, and Nenjiang were the site selections of the recovery center in the five areas, respectively, while Harbin was the site selection of remanufacturing enterprises.

(2) The saving mileage method is employed to perform the Reasonability test of the site selection. Taking the saving distance as the inspection standard, the site selections of the recovery center in the five areas save 235.6km, 566.6 km, 782.7km, 741km, and 276.8km, respectively, while the site selection of remanufacturing enterprise saves 903km. The reasonability of site selection of recovery center and remanufacturing enterprise is evaluated using the precise gravity method.

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