WEP Warwick Evans Publishing

Transactions on Computer Science and Intelligent Systems Research
ISSN: 2960-1800, eISSN: 2960-2238 | Volume 6
ISET 2024

A Study of Distribution Problems Based on Express Transportation Networks

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Abstract. This article uses the distribution data of rookie stations in Jinan City to explore the allocation problem of express delivery transportation networks. Firstly, in response to the uneven spatial layout of rookie Station, a corresponding evaluation index system was established based on K-means and TOPSIS models. The results showed that rookie Station exhibited characteristics of agglomeration in the central urban area and dispersion in the remote urban area. Secondly, by establishing a Floyd model to plan the route, the most reasonable transfer center was determined, and the results showed that the Shizhong District was the most suitable transfer station for Jinan City, while Zhangqiu District was selected as the second transfer station. Finally, based on the population density and express delivery demand in Jinan City, a model for express delivery allocation business points was established, and the optimal solutions for express delivery allocation business points in each district were obtained.

Keywords: Express Transportation, Rookie Station, K-means, Topsis, Floyd.

1. Introduction

In recent years, with the enhancement of environmental awareness and the rapid growth of logistics demand, the optimization of express transportation network has become a research hotspot. Changlan and Liu Pei[1] optimized a green express multimodal transportation network under the perspective of carbon trading, emphasizing the importance of environmental protection. Li Yue and Qin Wei [2] redesigned the express transportation paths based on a hybrid axle-spoke network to improve the network efficiency. Xie Xuqiang [3] studied the comprehensive optimization of express network structure and transportation path under the deep integration of manufacturing and express industry, and proposed a more effective solution. Xue Han [4], on the other hand, studied the dynamic distribution of multi-stage cargo flow for road transportation and high-speed rail intermodal transportation, providing a theoretical basis for dynamic adjustment. Shen Chen [5] constructed an air-rail intermodal transport network and optimized the transport path selection, demonstrating the advantages of combining multiple modes of transport. Zheng Changjiang et al [6] considered the impact of hub failure and designed a multimodal express network structure, which provided guidance for improving the robustness of the network. Yang Zihan [7] proposed an optimization study to adapt to the demand of time limit segmentation for high-speed rail express transportation solutions, which meets the time-sensitive needs of different customers. Deng Xiaozhen [8] studied the optimization of high-speed rail express train transportation network under the spatial evolution of express transportation demand and proposed a targeted optimization scheme. Zhang Fadong et al [9] predicted the express delivery volume between major cities in the context of air-rail intermodal transportation, providing data support for network planning. Finally, Liu Yan [10] studied the express network optimization problem based on multiple modes of transportation, comprehensively considered the advantages and disadvantages of different modes of transportation, and proposed a systematic optimization strategy. This article selects the distribution data of Rookie Station in Jinan, Shandong Province, China. The distribution of post stations is evaluated using the Topsis model and K-means model, and the shortest distance between post stations is calculated using the Floyd algorithm. Finally, the optimal transportation network is solved using simulated annealing genetic algorithm.

The data in this article is sourced from http://www.iecity.com/jinan/brand/75655.html

2. Theory and Method

2.1. TOPSIS model

TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is a multi-attribute decision-making methodology designed to determine the order of merit of given alternatives with respect to a set of indicators. The basic principle is to compare the similarity between the alternatives to the ideal solution and the negative ideal solution and then prioritize them based on this similarity. There are m a number of alternatives (objects) and n evaluation metrics (attributes), the decision matrix is $X = \left[x_{ij}\right]_{m\times n}$ where x_{ij} denotes the first i object has a score on the j index score. The decision matrix is standardized to get the standardized decision matrix $R = \left[r_{ij}\right]_{m\times n}$ where

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{1}$$

where $\sum_{i=1}^{m} x_{ij}^2$ is the sum of the squares of the elements in the first j sum of the squares of all the elements of the column. Ideal solutions $(A^\wedge +)$ and negative ideal solution $(A^\wedge -)$ consist of maximizing and minimizing the optimal value of each metric, respectively. The ideal solution $A^+ = (a_1^+, a_2^+, \dots, a_n^+)$ where a_j^+ denotes the optimal value of the first j maximum value of the metric. Negative ideal solution $A^- = (a_1^-, a_2^-, \dots, a_n^-)$ where a_j^- denotes the minimum value of the first j minimum value of the first indicator. The Euclidean distance to the ideal and negative ideal solutions is then calculated for each alternative.

Distance to the ideal solution $D^+(i)$:

$$D^+(i) = \sqrt{\sum_{j=1}^{n} \left(r_{ij} - a_j^+\right)^2} \tag{2}$$

Distance to negative ideal solution $D^-(i)$:

$$D^-(i) = \sqrt{\sum_{j=1}^{n} \left(r_{ij} - a_j^-\right)^2} \tag{3}$$

Calculate the similarity index based on the distance from the ideal and negative ideal solutions $C(i)$:

$$C(i) = \frac{D^-(i)}{D^+(i) + D^-(i)} \tag{4}$$

According to the similarity index $C(i)$ The closer the similarity index is to 0, the better the alternative is. In TOPSIS, the closer the similarity index is to 0, the closer the alternative is to the ideal solution and the better it is.

2.2. K-means model

K-Means algorithm is a kind of unsupervised learning, but also based on the division of the clustering algorithm, generally using the Euclidean distance as a measure of similarity between data objects, similarity and the distance between data objects is inversely proportional to the greater the similarity, the smaller the distance. The algorithm needs to pre-specify the initial number of clusters k and k initial clustering centers, according to the similarity between data objects and clustering centers, the position of the clustering centers is constantly updated, and the Sum of Squared Error (SSE) of the clusters is constantly reduced, and the clustering is finished when the SSE is no longer changing or the objective function is converged to get the final result. Firstly, the initial clustering centers are randomly selected from the dataset. k initial clustering centers $Ci(1 \leq i \leq k)$ The Euclidean distance between the remaining data objects and the clustering centers is calculated to find out the distance from the target center. Ci Euclidean distance between the remaining data objects and the clustering centers, find out the closest clustering center to the target data objects Ci and assign the data objects to the clusters corresponding to the clustering centers Ci and assign the data objects to the clusters corresponding to the cluster centers. Then the average value of the data objects in each cluster is calculated as the new clustering center, and the next iteration is performed until the clustering center no longer changes or the maximum number of iterations is reached. The Euclidean distance between the data objects and the clustering centers in the space is calculated as.

$$d(x, C_i) = \sqrt{\sum_{j=1}^{m} \left(x_j - C_{ij}\right)^2} \tag{5}$$

where x is the data object, and C_i is the first i center of clustering, and m is the dimension of the data object, and x_j, C_{ij} is the dimension of the x and C_i is the first attribute value of the j values of the attributes. The sum of squared errors SSE for the entire dataset is calculated by the formula

$$SSE = \sum_{i=1}^{k} \sum_{x \in C_i} |d(x, C_i)|^2 \tag{6}$$

where the size of SSE indicates the goodness of the clustering result and k is the number of clusters.

2.3. Modeling the Distribution Center of a Rookie Station

Assuming that there are A, B, C, d, e, f, g, h, m, n total of 10 express nodes in the scope of a courier network, the three central bureaus of A, B and C are elected without considering the tail volume, and the conditions of opening direct mail routes are satisfied between A, B and C two by two, and the service network is obtained as shown in Figure 1.

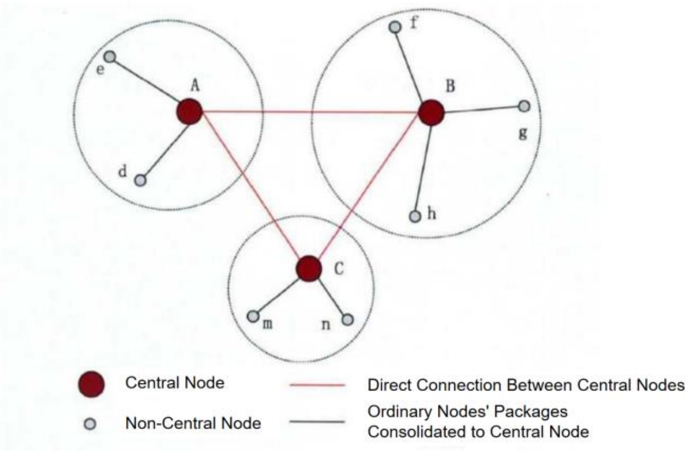

Figure 1. Service network

Floyd's algorithm is a dynamic programming algorithm for solving the shortest paths between all pairs of nodes in a graph. The main idea of the algorithm is to iteratively update the length of the shortest paths between nodes until the shortest path between all pairs of nodes is found. The following are the core formulas of Floyd's algorithm.

There is a directed graph containing n a directed graph with nodes whose set of nodes is V and the set of edges is E and the distance matrix D represents the shortest path length between any two points, initially, the elements of the distance matrix are the direct distances between the nodes, if there is no direct connection between two points, the financial distance is set to infinity.

Initialize the distance matrix.

$$\begin{cases} w_{ij} & \text{if } (i,j) \in E \\ \infty & \text{if } (i,j) \notin E \text{ and } i \neq j \\ 0 & \text{if } i=j \end{cases} \tag{7}$$

where w_{ij} denotes the node i to the node j the direct distance to the node. The shortest path length between nodes is constantly updated by recursively updating the distance matrix.

$$D_{ij}^{(k)} = min\left(D_{ij}^{(k-1)}, D_{ik}^{(k-1)} + D_{kj}^{(k-1)}\right) \tag{8}$$

where $D_{ij}^{(k)}$ denotes the node i to node j The shortest path length, using intermediate nodes limited to the first k nodes. Repeat the process of updating the distance matrix recursively until the shortest path lengths between all pairs of nodes are found (i.e., the distance matrix no longer changes). With the above steps, the Floyd algorithm solves for the shortest path lengths between all pairs of nodes in the graph. After the algorithm is executed, the distance matrix D of the distance matrix D_{ij} are the nodes i to node j of the node to the node.

2.4. Optimal Point-of-Service Layout Model

This model is a nonlinear single-objective optimization model, and the layout model needs to satisfy both revenue maximization and cost minimization. The following two optimization objectives are established

First revenue.

$$max(\sum_{i=1}^{n} \rho_i r_i n_i w_i) \tag{9}$$

Second revenue.

$$min \sum_{i=1}^{n} n_i d_i \tag{10}$$

Of which n_i is the courier distribution point of business that should be established in each district, and w_i is the monthly revenue of each district, and d_i is the monthly rent of each district, and ρ_i is the population density.

$$\rho_i = \frac{x_i}{s_i} \tag{11}$$

x_i is the total population of each district, and s_i is the area of each district. For quantitative indicators of demand

$$r_i = \frac{\sum_{i=1}^{n} x_{2i}}{1+\cdots+i} \tag{12}$$

x_{2i} is the total number of stations in each district, and $1 + \cdots + i$ is the total number of post stations in Jinan. The two optimization objectives are combined to obtain

$$max[(\sum_{i=1}^{n} \rho_i r_i n_i w_i) - (\sum_{i=1}^{n} n_i d_i)] \quad (13)$$

The constraints are $1 \leqslant n \leqslant 10, \sum w_i \geqslant 1000$ Million, $\sum d_i \leqslant 100$ million.

3. Results and Discussions

3.1. Solution of TOPSIS and K-means Model

City transportation is crucial to logistics distribution, and the degree of transportation convenience not only accelerates the efficiency of logistics distribution, but also increases the accessibility of express pickup sites, saving time costs for residents traveling to pick up. In order to explore the transportation convenience of Jinan Rookie Stages, the distance between each Rookie Stage and the subway entrance is calculated using TOPSIS, and the transportation convenience of Rookie Stages is analyzed. In order to study the convenience of each district in Jinan City to pick up express delivery at the Rai Bird Stage, the following TOPSIS algorithm solves and analyzes the distance from each district to the Rai Bird Stage, and analyzes the convenience of picking up express delivery in the districts. The distance between each Rai Bird Station and each subway station and neighborhood is shown in Figure 2.

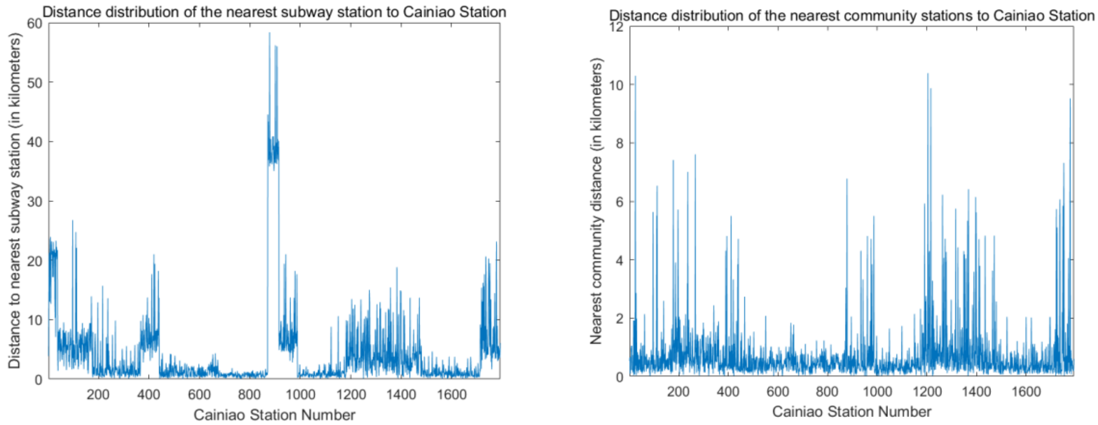

Figure 2. Distance of each Rookie Station from each subway entrance and neighborhood

Using K_mean clustering to cluster all the locations of the rookie stations into 12 points, it is found that these 12 center points are distributed in all 12 districts and counties in Jinan, indicating that there is a central rookie station point in each district. Afterwards, the TOPSIS evaluation model is used to evaluate the distance of subway stations and districts from each RBTS, according to the degree of proximity and the score, the distribution of districts has a high impact on the RBTS, and the distance of the nearest RBTS is selected, and the data is used to draw the distance of RBTS from districts is less than 10 kilometers, and the subway stations are not in the same order as the RBTS, to sum up, the distribution location of RBTS is still more than 10 kilometers. In summary, the distribution location of the nearest station is still reasonable.

3.2. Model Solving for Distribution Centers of Rookie Stations

The centroid results and discussion of the distribution of Rookie Stations within each district are shown in Table 1.

Table 1. latitude and longitude of the center point of Rai Bird Station in each district

City	Latitude	Longitude
Gangcheng	36.19846221	117.8027218
Huaiyin	36.68243539	116.8917798
Jiyang	36.97929295	117.1673824
Laiwu	36.24279757	117.6697304
Licheng	36.51968377	116.960093
Lixia	36.65617746	117.1047502
Pingyin	36.29158824	116.4560944
Shanghe	37.35968355	117.1112991
Shizhong	36.57975799	116.9334252
Tianqiao	36.67263152	117.0160605
Zhangqiu	36.66007797	117.5034011
Changqing	36.44599058	116.6509791

According to the center site selection scheme obtained from the model solution, the sum of the shortest distances between each center site and the other 11 center sites is shown in Figure 3.

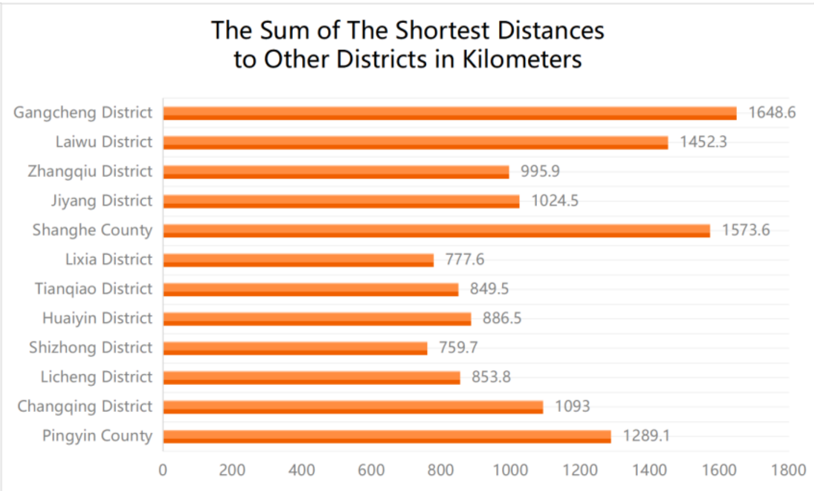

Figure 3. sum of shortest kilometers from each zone center to other zone centers

From the results of the model solution, it can be seen that: the center of the city's central district to the center of the other districts of the minimum sum of the number of kilometers, due to the shortest distance and the smaller the sum, indicating that the center of the center of the other districts of the Rookie Stage is more convenient, so take the city's central district as the transfer station in Jinan. Since the population of Jinan is mainly distributed in the center area near Lixia District, considering the residents in remote areas, after taking the center point, a small transit point is set for the districts outside the center area, so Zhangqiu District is taken as the second transit point.

3.3. Optimal Business Point Layout Model Solving

Solving for the quantitative indicators yields a demand for express delivery in 2021 as shown in Figure 4.

Figure 4. T2021 Share of Express Demand by Zone, Number of Express Allocation Points of Operation

Through the above population density of Jinan districts in 2021, the demand for express delivery in 2021 from the quantitative indicators, and the X3 fitting of the number of express delivery points in 2021 according to the official website of Caijiao Yiyou, the relationship between the number of express delivery points, the population density of Jinan districts and the demand for express delivery is shown in Figure 5.

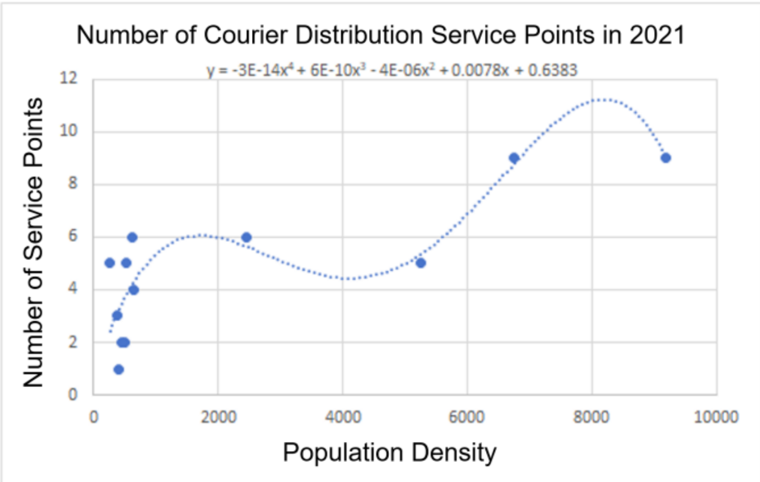

Figure 5. Population density versus number of operations and quantitative demand indicators versus number of operations

As can be seen from the figure, the model fitting results are better, i.e., the function model is reasonable. By constructing the optimal business point layout model, the optimal solution is solved using simulated annealing genetic algorithm as shown in Figure 6.

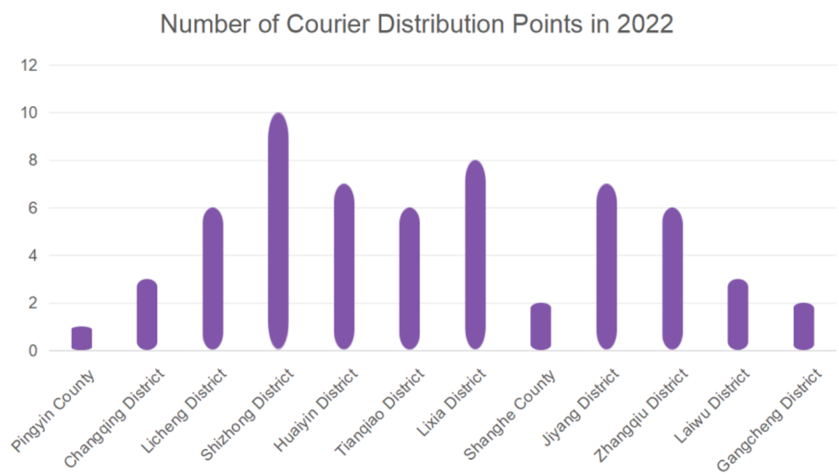

Figure 6. 2022 Number of Express Distribution Business Points by District

As can be seen from the figure, the central area of Jinan City (Shizhong District, Huiyin District, Lixia District, Tianqiao District) has a higher number of express delivery distribution business points due to dense population distribution and high population density. In the outer areas of Jinan City (Pingyin County, Gangcheng District, Shanghe County, etc.), the number of express distribution business points is low due to sparse population distribution and remote location. Meanwhile, some of the peripheral areas (Jiyang District, Zhangqiu District, etc.), with sparse population distribution, have a large administrative area, and thus have more express delivery distribution points.

4. Conclusion

This article uses relevant data from rookie Station to obtain the optimal transportation network for express delivery distribution business points. It is concluded that brand building and market promotion should focus on brand image positioning and multi-channel promotion, and technological innovation should focus on logistics management systems and data analysis and prediction. At the same time, attention should also be paid to establishing training mechanisms and optimizing welfare benefits for talent cultivation, and partnership relationships can improve service scope by expanding cooperation outlets and cross-border cooperation. Finally, in terms of sustainable development and social responsibility, green environmental protection initiatives and participation in public welfare activities should be promoted, and customer service experience and logistics operations should ensure customer first and provide cost-effective express delivery services.

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