A Method for Decision Making of Barrier-Free Service Resources Deployment in an Airport Terminal Building

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ABSTRACT

In recent years, in order to improve the convenience of air travel for people with functional disabilities such as hearing impaired, visually impaired, and mobility impaired, the airport has designed and installed many barrier-free service resource facilities in the terminal building, such as barrier-free water dispenser, barrier-free armrest, barrier-free seat, barrier-free service desk, etc., providing convenience for passengers with special functional disabilities. To improve the utilization rate and deployment rationality of barrier-free service resources and enhance the capability of guaranteeing barrier-free service in civil aviation airport, we need to provide decision support for the deployment of barrier-free service resources in the terminal building. This paper uses a clustering algorithm to obtain the cluster centers of passenger's demands, calculates the deployment range of resources in the cluster centers by using the geometric center method, combines passengers' intentions to explore the types of service resources, targets the usage frequency of each resource and the available number of people that can be served at a time, so as to generate optimized suggestions for the deployment of resources. This paper simulates passengers' demands and moving trajectory in the experiment and verifies the feasibility of applying Python tool into the deployment of barrier-free service resources.

CCS CONCEPTS

• **Computing methodologies**; • **Machine learning**; • **Machine learning algorithms**;

KEYWORDS

Barrier-free service Resources, Passengers with functional disabilities, Air travel, Deployment suggestions

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1 INTRODUCTION

Since civil aviation airport have constantly improved its capabilities of guaranteeing the travel service for passengers, more and more special passengers with functional disabilities choose to travel by air. In order to meet their needs for service, civil aviation airport continue to optimize and complete the barrier-free service resources in the terminal building. Since the airport cannot perform service feedback statistics on the deployed barrier-free service resources, we might encounter problems in optimizing the deployment planning of barrier-free service resources, such as poor pertinence and incomplete coverage. In order to avoid such circumstance in resource deployment planning, this paper will conduct research from the perspective of passengers traveling in the terminal building and provide resource deployment suggestions for an airport terminal building.

2 RESEARCH IDEAS

To generate optimized recommendations for resource planning and deployment, we should consider the following factors [1]:

1. Service coverage rate.

Any kind of barrier-free service resource has its own service scope, and the service scope mainly considers passengers' intentions in selection. The research in this paper defaults the index of effective service coverage rate of resources as no less than 95%.

2. Accuracy of resource types.

The type of resource deployed should match the type of demand from the user.

3. Economical consideration for the put volume of resource.

Service resources are deployed based on demands to reduce redundancy.

4. Accuracy of site selection for resource deployment.

The resource deployment spot should as far as possible be deployed in the central area of the demand to reduce deviation. Combined the above considerations for the deployment of service resources, the research in this paper will combine the GIS data and demand intentions in the passengers' consulting trajectory in the terminal building, analyze the types of resources in demand; use spatial clustering technology to distribute and calibrate the same types of resources, target on the coverage rate of passengers' demands, and construct a genetic algorithm to optimize decision-making model. Then we calculate the coordinates and quantity of optimal resource allocation based on parameters such as passenger intention information, intention spatial coordinate information, resource type, and resource service radius [2] [3].

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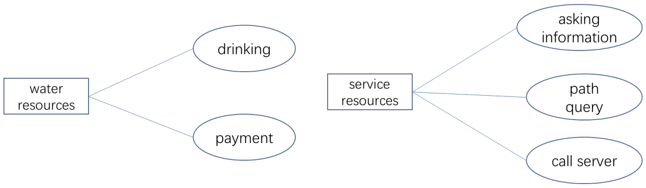


Figure 1: The Relationship between Resources and Intentions.

3 RESOURCE DEPLOYMENT ESTIMATION BASED ON CLUSTERING

This paper uses the DBSCAN clustering model to analyze the GIS trajectory data of the passengers' intention demand points, removes the noise interference data of the passengers' intentions, and determines the number of resource allocations according to the amount of clustering. Since the DBSCAN clustering center is not related to the resource service radius, the clustering results of DBSCAN cannot be directly used to plan the final resource deployment location, and DBSCAN cannot optimize the number of resource deployments and service coverage rate because it only has location attribute. Therefore, the calculation result of the DBSCAN algorithm is mainly used to estimate the deployment quantity of resource in each type [4]. The specific implementation process is as below:

Obtain the distribution of passenger intentions according to the spatial clustering results and estimate the initial optional coordinates for the deployment spot of resources.

Estimate the number of resource deployments in each type based on the spatial clustering results.

3.1 Selection of Equipment Type

Each service resource can provide different types of services for passengers, and the corresponding type of resource can be obtained through the analysis of passenger's intention. There is a one-to-many relationship between resources and intentions, that is, one resource can correspond to multiple intentions. The relationship between resources and intentions is shown in Figure 1

In the research process, virtualize the information data of resources and intentions into the program, as shown in Figure 2

3.2 Calculation of Intention Distribution

Virtualize passenger' intentions on different coordinate points in the map, filter out the needs for service resources of the same type, and use the coordinate values x and y generated by all demands as the input parameters of the algorithm DBSCAN. Figure 3 shows the virtual intention and corresponding coordinate values. The corresponding distribution of a certain service resource is shown in Figure 4

The coordinate system in Figure 4 is a rectangular plane coordinate system. The horizontal axis is the X coordinate value in the map, and the vertical axis is the Y coordinate value in the map. The distribution of these intention points can be clearly seen from the figure.

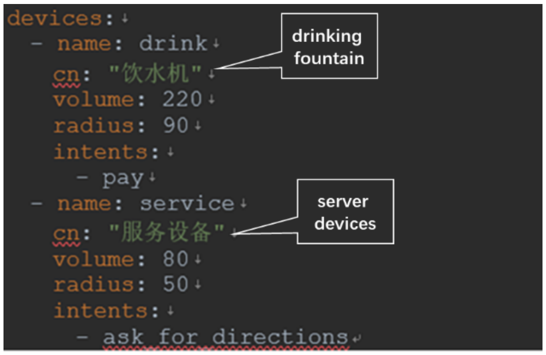
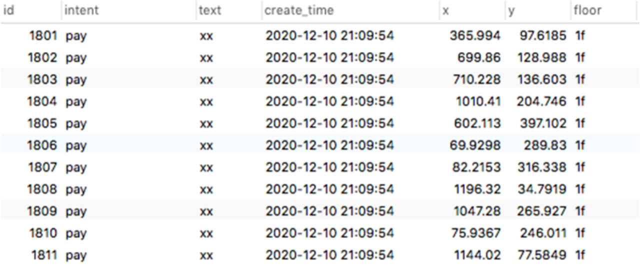

```
devices:↓
  - name: drink↓
    cn: "饮水机"↓
    volume: 220↓
    radius: 90↓
    intents:↓
      - pay↓
  - name: service↓
    cn: "服务设备"↓
    volume: 80↓
    radius: 50↓
    intents:↓
      - ask for directions↵
```

Figure 2: Information data of Resources and Intentions in the Program.



id	intent	text	create_time	x	y	floor
1801	pay	xx	2020-12-10 21:09:54	365.994	97.6185	1f
1802	pay	xx	2020-12-10 21:09:54	699.86	128.988	1f
1803	pay	xx	2020-12-10 21:09:54	710.228	136.603	1f
1804	pay	xx	2020-12-10 21:09:54	1010.41	204.746	1f
1805	pay	xx	2020-12-10 21:09:54	602.113	397.102	1f
1806	pay	xx	2020-12-10 21:09:54	69.9298	289.83	1f
1807	pay	xx	2020-12-10 21:09:54	82.2153	316.338	1f
1808	pay	xx	2020-12-10 21:09:54	1196.32	34.7919	1f
1809	pay	xx	2020-12-10 21:09:54	1047.28	265.927	1f
1810	pay	xx	2020-12-10 21:09:54	75.9367	246.011	1f
1811	pay	xx	2020-12-10 21:09:54	1144.02	77.5849	1f

Figure 3: Virtual Intention and Corresponding Coordinate Values.

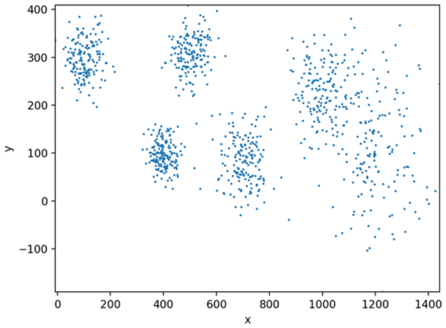


Figure 4: Distribution of a Certain Service Resource.

The clustering results of DBSCAN calculation are shown in Figure 5

The different colors in Figure 5 represent different clusters, and the dark purple dots around these clusters represent noise points. To determine a cluster, you need to use the two parameter values, epsilon as the DBSCAN domain radius and min_samples as the minimum number of cluster points, as shown in Figure 6. When the number of points in the epsilon range of point p is greater than or equal to the value of min_samples, point p is the core point, and its peripheral points are called edge points. If the number of points in the epsilon range of an edge point q (in the Figure 6, points other than point p can be regarded as point q) is also greater than or

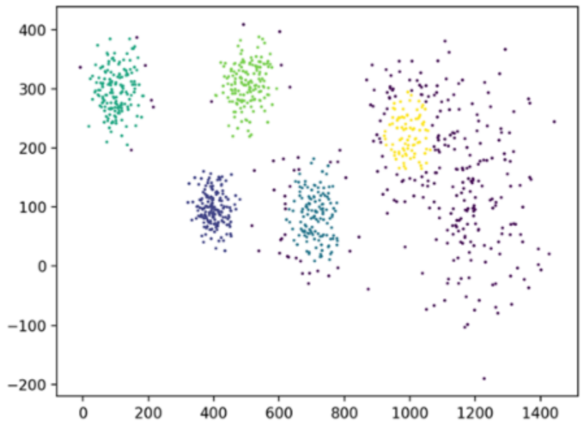


Figure 5: The Clustering Results of Dbscan Calculation.

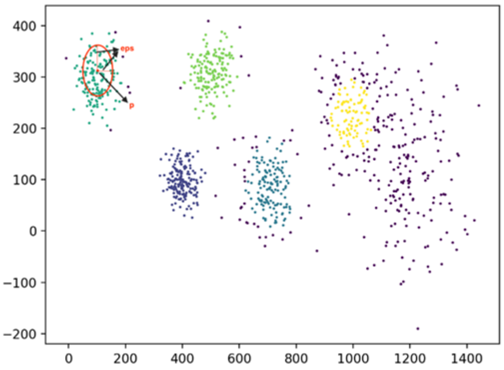


Figure 6: Description Diagram of Dbscan Clustering Cluster.

equal to the value of min_samples, the connection between point q and p is called density connection. The clustering points within the radius of neighborhood of the density connection points are called cluster.

As can be seen in Figure 5, DBSCAN clusters the intention points into 5 clusters. After removing the noise points, the total obtained number of intention points in all the clusters in the figure is 714.

Then calculate the geometric center of each cluster. Since each cluster is a finite point set, it is suitable for the geometric center algorithm of the finite point set.

To calculate the geometric center of a cluster, we add the abscissa values of all points in the cluster and divide by the number of points to get the abscissa of the geometric center, and then we add the ordinate values of all points in the cluster and divide by the number of points to get the ordinate of the geometric center [5]. The coordinate point sets of the geometric center of the five clusters in Figure 5 is shown in Figure 7

The small orange dot in the center of each cluster in Figure 7 is the geometric center of the cluster.

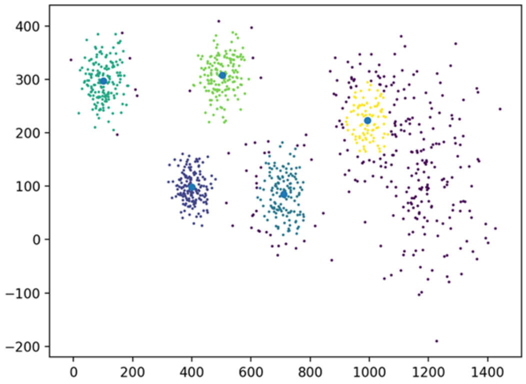


Figure 7: Coordinate Point Sets of Geometric Center of the Five Clusters.

3.3 Estimation of the Range of Resource Total Number

We regard the maximum number of passengers that can be served at one time as the service capacity of a service resource, which is set as S; the number of clustered users calculated by the DBSCAN algorithm is set as N, and the total deployment amount of resources M can be calculated by the formula (1), and the result is rounded up.

$$M = \mathrm{round}(N/S) \tag{1}$$

For example, as shown in Figure 2, volume is the service capacity of the service resource, that is, S=volume=220, and N is the number of the above clustered points, that is, N=714, so M=round(N/S)=round(714/220)≈3(sets). Therefore, it is concluded that 3 sets of service resources should be deployed.

If the calculated number of service resources still cannot meet the target coverage rate of the genetic algorithm, the number of service resources should be increased by one at a time and then calculated by successive genetic algorithm operations till the target coverage rate of the genetic algorithm is met [6].

4 LOCATION PLANNING OF RESOURCE DEPLOYMENT

Based on the calculation result of the approximate area of resource deployment calculated by the DBSCAN algorithm, it is necessary to further calculate the coverage rate through the genetic algorithm to determine the deployment location of the service resources.

4.1 Optimization of Location Selection

The main goal of service resource location selection is to meet a certain functional coverage rate in a dense area of service demand points. When performing target optimization, the final target point should be optimized according to the reference location provided by DBSCAN.

Coverage rate means that the deployed service resources can cover the users' barrier-free service requirements to the greatest extent. The coverage area of the service resource is assumed to be circle shaped, and passengers in the circular area are considered to be covered. Check the number of covered passengers, and its ratio is the coverage rate. As the types of service resources are different from each other, the area of the service coverage area is also different. The radius of the coverage area in the study can be determined by parameter settings. In the process of resource location selection, the threshold of passenger coverage to be reached can be set by parameters, and it is appointed that the algorithm can be iterated repeatedly when the coverage rate is not up to the standard until the standard is met. In this study, the radius of the coverage area is set as 90 meters, and the coverage rate threshold is set as 95%. In the research, genetic algorithm is selected to calculate the deployment location of service resources, and the requirement of passenger coverage rate threshold is met at the same time [7] [8].

4.2 Coverage Objective Function

When calculating the number of passengers covered by service resources, in order to avoid double counting problems, in the overlapping coverage area between resources, passengers in the overlapping area are only included in the set with which the distance between the passenger and the resource deployment spot is the shortest.

Service resource coverage refers to the ratio of the number of covered designated passenger demand points to the denoised total number of passenger demand points. Among them, $\overline{US}$ refers to the set of covered demand points, and the constraint condition requires the minimum number of resource sets TS. Expressed by the following formula:

$$\overline{US} = \cup_{T\in TS} C_U(T)\ \text{s.t.}\ \ \text{Min}\,|TS| \tag{2}$$

The formula (2) represents the point set covered by each resource T, and the total coverage demand point set is obtained by combing them. In the process of genetic algorithm operation, the objective function of resource coverage rate is represented by f_{CT}, and the resource service coverage rate is obtained under the premise of the known number of resource deployments [9]. If the value of the coverage rate f_{CT} can reach 1, that is to say, when the coverage rate reaches 100%, the service resource location model can reach the optimal coverage level. At this time, the resource deployment position is the optimal solution we seek, the optimal objective function f_{CT} is expressed in formula (3).

$$\text{Max} f_{CT} = \frac{\left|\overline{US}\right|}{|US|} \tag{3}$$

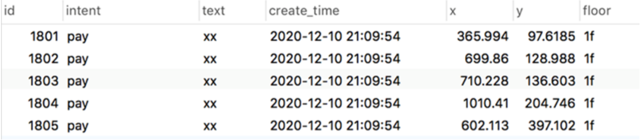
4.3 Target Optimization of Genetic Algorithm

The above content describes the mathematical model analyzed and extracted by the planning scheme, that is, a target optimized model with the goal of achieving maximum coverage rate. In this paper, the genetic algorithm calculation model is used to calculate the optimal solution through the processes of encoding, initializing the population, selecting, crossover, and mutation successively [10].

5 EXPERIMENTAL VERIFICATION

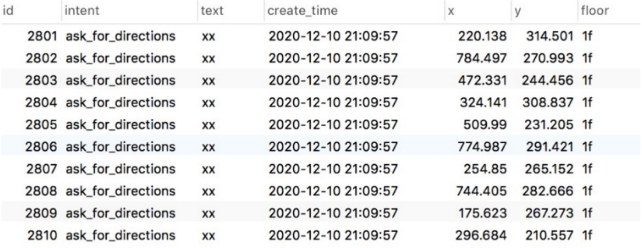
5.1 Experimental Data Preparation

In the experiment, the intention resources extracted from the user's intentions are set as water dispenser and service equipment. The water dispenser corresponds to the "pay" intention, and the service equipment corresponds to the "ask_for_directions" intention. The trajectory point coordinates of the above two resource intentions are shown in Figure 8 and Figure 9 respectively. In the figure, the intent field represents content of intention, and x and y represent the horizontal and vertical coordinates generated by the intention point.



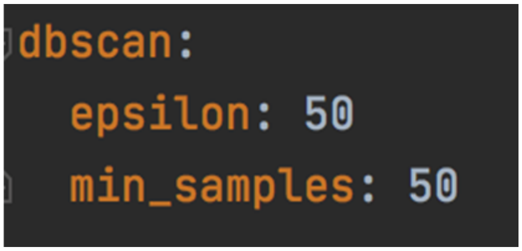
id	intent	text	create_time	x	y	floor
1801	pay	xx	2020-12-10 21:09:54	365.994	97.6185	1f
1802	pay	xx	2020-12-10 21:09:54	699.86	128.988	1f
1803	pay	xx	2020-12-10 21:09:54	710.228	136.603	1f
1804	pay	xx	2020-12-10 21:09:54	1010.41	204.746	1f
1805	pay	xx	2020-12-10 21:09:54	602.113	397.102	1f

Figure 8: The Coordinate Point Set of the "Water Dispenser" Intentions.



id	intent	text	create_time	x	y	floor
2801	ask_for_directions	xx	2020-12-10 21:09:57	220.138	314.501	1f
2802	ask_for_directions	xx	2020-12-10 21:09:57	784.497	270.993	1f
2803	ask_for_directions	xx	2020-12-10 21:09:57	472.331	244.456	1f
2804	ask_for_directions	xx	2020-12-10 21:09:57	324.141	308.837	1f
2805	ask_for_directions	xx	2020-12-10 21:09:57	509.99	231.205	1f
2806	ask_for_directions	xx	2020-12-10 21:09:57	774.987	291.421	1f
2807	ask_for_directions	xx	2020-12-10 21:09:57	254.85	265.152	1f
2808	ask_for_directions	xx	2020-12-10 21:09:57	744.405	282.666	1f
2809	ask_for_directions	xx	2020-12-10 21:09:57	175.623	267.273	1f
2810	ask_for_directions	xx	2020-12-10 21:09:57	296.684	210.557	1f

Figure 9: The Coordinate Point Set of the "Service Equipment" Intentions.



```
dbscan:
  epsilon: 50
  min_samples: 50
```

Figure 10: Service Resource Parameter Diagram.

5.2 Simulation Test

The simulation test is carried out in a Python environment, using tool libraries such as *sklearn, geatpy* and *matplotlib.*

1. DBSCAN clustering

The parameters of DBSCAN are to be set first before running. Epsilon stands for the area radius of DBSCAN, and its value is 50; min_samples stands for the minimum number of points to form clusters, and its value is 50. The service resource parameter configuration is shown in Figure 10

The resource deployment estimation diagram of "water dispenser" and "service equipment" are generated by DBSCAN and geometric center method respectively, as shown in Figure 11 and Figure 12

Genetic algorithm optimization

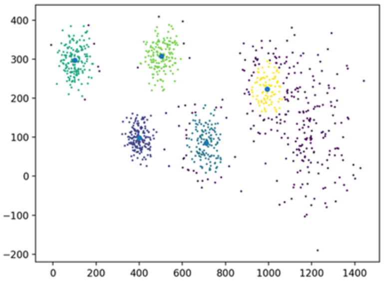


Figure 11: “Water Dispensers” Deployment Estimation Diagram.

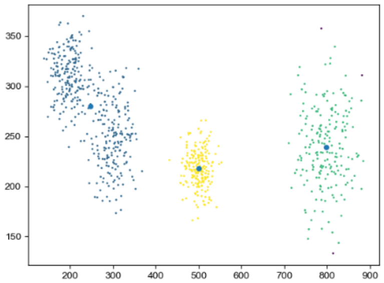


Figure 12: “Service Devices” Deployment Estimation Diagram.

Set the service radius of "water dispenser" and "service equipment" to 90 meters and 50 meters respectively; the initial population size is 100; the target coverage rate threshold is 95%. The times of iterations of the genetic algorithm does not need to be manually set, and the calculation stops automatically when the target coverage rate is reached or exceeded. When the target coverage rate cannot converge to meet the requirement of threshold value, and the limit value remains unchanged after consecutive N times of convergence, the program will automatically increase the number of resources by one in the genetic algorithm and perform genetic calculation again until the threshold requirement is reached. For the judgment of value N, the value of N in this research procedure is set as 30 through our testing and experience. After the genetic algorithm parameters are set, the algorithm starts to execute, optimizes the deployment coordinates and quantity of service resources, and provides suggestions for the planning and deployment of service resources.

For the optimization process of service resources, such as "water dispenser", "service equipment", as shown in Figure 13 and Figure 14, both figures have showed how many times algorithm optimized iterations correspondingly executed in the process of reaching the target coverage rate threshold.

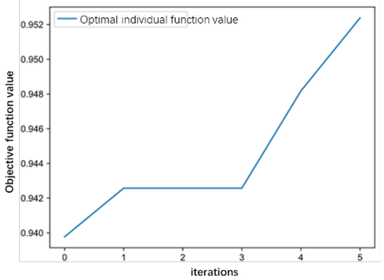


Figure 13: Estimated Diagram of “Water Dispensers” Resource Deployment.

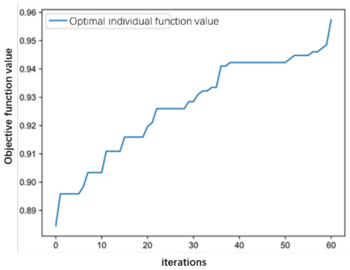


Figure 14: Estimated Diagram of “Service Equipment” Resource Deployment.

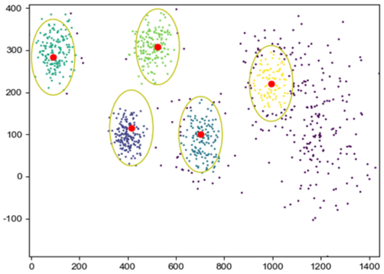


Figure 15: Plan Diagram of “Water Dispenser” Resource Deployment.

The deployment plan of the service resource "water dispenser" is shown in Figure 15, and the deployment plan of the service resource "service equipment" is shown in Figure 16. The red dots in the two figures are the deployment coordinate points of the resource, and the surrounding circles represent the service coverage of the resource. Except noise points, 95% of all intention points are included in the service coverage, and the requirement of target coverage is met.

The recommendation of deployment plan for the service resource "water dispenser" is shown in Figure 17 and the recommendation of deployment plan for the service resource "service equipment" is shown in Figure 18

6 CONCLUSION

Through the test results of the experiment, it can be seen that the method adopted in this paper can realize the decision-making of resource deployment recommendations and prove that its decision-making thinking and implementation method are feasible. The test data used in this experiment is not much, and it is simulated data. In the future, we will collect more data for decision-making in

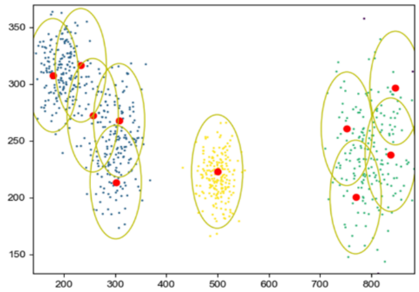


Figure 16: Plan Diagram of “Service Equipment” Resource Deployment.

```
[{’type’: ’drinking fountain’, ’count’: 5, ’location’:
[{’x’: 405.8896982428446, ’y’: 85.84170184296326},
 {’x’: 699.8418569247692, ’y’: 62.17109013221088},
 {’x’: 88.24624595808743, ’y’: 330.189823213375},
 {’x’: 528.1964833507473, ’y’: 307.1808793059232},
 {’x’: 980.2728457029525, ’y’: 208.17242044129247}]}
```

Figure 17: Recommendations for “Water Dispenser” Resource Deployment.

```
{’type’: ’server devices’, ’count’: 10, ’location’:
[{’x’: 178.23392185551737, ’y’: 307.709785733157},
 {’x’: 256.24282129419, ’y’: 272.515374351272},
 {’x’: 847.3140551012666, ’y’: 296.45924211597946},
 {’x’: 838.1315446738764, ’y’: 237.77408572414095},
 {’x’: 752.4509834576165, ’y’: 260.59411269619005},
 {’x’: 769.5938040282238, ’y’: 200.52802639814783},
 {’x’: 499.27680783517144, ’y’: 223.02042216205655},
 {’x’: 307.82301105544013, ’y’: 268.0493932755175},
 {’x’: 301.2090674516304, ’y’: 213.67759272802365},
 {’x’: 232.96728091867152, ’y’: 316.52830685223387}]}]
```

Figure 18: Recommendations for “Service Equipment” Resource Deployment.

practical applications, and it is believed that the credibility of the decision-making results will be higher.

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