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Research on Vehicle Logistics Location Allocation Strategy Based on K-Means Clustering

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Abstract: *There are some problems in the allocation of vehicle logistics locations, such as long queuing time, low efficiency of warehousing and exiting, and unreasonable allocation of warehousing locations. Therefore, aiming at the location matching problem of vehicle logistics storage area, a partition allocation strategy model is constructed. Firstly, k-means clustering algorithm is used to analyze the location allocation strategy of partition allocation, and the clustering results of 7, 8, 9, 10 and 11 are calculated respectively. Then, based on the clustering analysis results, the location matching model is established by Flex Sim simulation software. The results show that the outbound time of the location allocation strategy based on partition allocation is reduced by about 10% compared with random allocation.*

Keywords: *Vehicle Logistics, Allocation of Storage, Cluster Analysis, Simulation*

1. Introduction

Vehicle logistics location matching is a key link in automobile logistics warehousing management, and its demand and importance are becoming increasingly prominent. With the rapid development of automobile industry and the continuous expansion of dealer network, the volume of vehicle logistics has increased substantially, and the traditional manual location management method can no longer meet the requirements of modern logistics for efficiency, cost and informatization level. At present, automobile manufacturing companies generally face problems such as low inventory turnover rate and insufficient utilization of storage space. The complexity of distribution on the dealer side is also constantly increasing, and intelligent warehouse location matching solutions are urgently needed to optimize overall operations.

There are few existing studies on the location matching of vehicle logistics, and the research on location matching mainly includes the following two aspects. One is the location matching of automated three-dimensional warehouse. Li et al. [1] put forward a dynamic location allocation strategy. The BP neural network model optimized by dragonfly algorithm predicts the vehicle stay time, and selects the garage parking space according to the vehicle stay time. Finally, contraindicated search algorithm is used to search for the most suitable parking space location in this area. Chen et al.[2] established the mathematical model of car parking priority strategy and car pickup priority strategy, combined with the system of member priority car pickup, integrated the models by weight coefficient method, and then used genetic algorithm to solve the problem of storage location allocation with the above model as the fitness function. Zhang et al. [3] took the roadway stacking automatic three-dimensional garage as an example, took the queuing theory as the theoretical basis, and took the average waiting time and average waiting team length of customers as the reference standards, and discussed the construction scheme of the number of floors and columns of the garage under two kinds of warehouse location allocation conditions: random allocation and nearby allocation. The second is the allocation of raw materials and parts. Chen [4] analyzed the influence of storage location allocation on material preparation efficiency and accuracy by two modes: allocation of storage location according to parts types and allocation of parts required for finished products. Qin [5] analyzed the location allocation of steel raw material yard based on AHP method. Liu [6] established the automatic warehouse location allocation model of iron and steel enterprises based on genetic algorithm. You et al. [7] comprehensively considered the ore input plan, ore stock in the stockyard and other factors, and designed an integer programming model for the location allocation of the stockyard. Li et al. [8] solved the problems of the shortest path and balanced storage locations in a dense four-way shuttle warehouse by combining local search and global jumping based on the Hybrid Frog Jump algorithm. Wang et al. [9] proposed a two-stage hybrid algorithm-based decision-making model for parking space allocation in multi-story parking garages by introducing the principles and methods of neural network algorithm and fruit fly algorithm: in the first stage, the neural network algorithm is used to predict the customer's parking time; in the second stage, the fruit fly algorithm is used to achieve the optimal allocation of parking spaces.To address the park-and-ride (P&R) facility location problem at a large scale,Kim et al. [10] introduced two other polyhedral approaches: variable neighborhood search (VNS) and adaptive randomized rounding (ARR).And through the actual case of transportation in the Seoul metropolitan area, it is shown that the performance of ARR is better than that of VNS.Shah et al. [11] established a mixed integer optimization model, developed a solution approach that includes solving the freight consolidation subproblem, and embedded it into a variable neighborhood search heuristic method. And the computational analysis shows that by integrating freight consolidation decisions into hub network design, an average cost saving of 16% can be achieved. Gu et al. [12] introduced an Adaptive Multi-Neighborhood Hybrid Search (AMHS) algorithm which integrates a double-sequence encoding scheme and elite solution initialization strategy to achieve efficient material handling, and it performed excellently in the case study of packaging salt storage.

Although the existing research has made remarkable progress in storage location allocation, there are still some shortcomings. For example, existing research mostly focuses on theoretical model and algorithm design, lacking in-depth discussion of practical application scenarios; Therefore, we should pay further attention to the in-depth discussion of practical application scenarios, and explore how to combine big data technology with bilateral matching theory to the matching problem of warehouse position, so as to improve the efficiency and effect of vehicle logistics warehouse position matching.

Taking FAW-Volkswagen's vehicle logistics location allocation as an example, based on k-means cluster analysis, the warehousing environment and process of the logistics park are simulated through FlexSim simulation modeling verification, and the effects and efficiency of different warehousing methods are intuitively observed and analyzed. The simulation results show that the warehousing scheme combined with k-means clustering analysis method performs better in optimizing the process, improving the efficiency and reducing the cost.

2. Method Introduction

2.1 K-Means Clustering Analysis

Cluster analysis is to divide data into different categories according to certain parameter correlation according to clustering algorithm, and the data in each category are similar to each other due to the correlation of feature attribute values. k-means clustering is a typical data partitioning clustering algorithm, which is widely used because of its simple operation and high efficiency.

Initialization. Select k value: Determine the number k of clusters that need to be divided into. This value is usually determined by the specific needs of the problem, or selected by some method (such as the elbow rule).

Initialize the centroid: k points are randomly selected as the initial centroid. These centroids can be k randomly selected points in the dataset, or the initial centroid can be selected using other methods such as k-means.

Assigning Data Points. Calculate distance: For each data point, calculate its distance to each centroid. The Euclidean distance is usually used, but other distance measures such as the Manhattan distance can also be used.

Assign clusters: Each data point is assigned to the nearest centroid, forming k clusters. The specific operation is to assign the data points to the cluster corresponding to the centroid that minimizes the distance.

Update the Centroid. Calculate the new centroid: For each cluster, the mean (centroid) of all data points in the cluster is calculated. The new centroid is the average of all data points in the cluster over each dimension.

Checking Convergence. Check centroid changes: Compare the new centroid with the old centroid. The algorithm is considered to have converged if the position of the centroid does not change significantly (or the change is within a set threshold range).

Repeat iteration: If the centroid has changed, return to "Assign Data Points", reassign the data points and update the centroid. Otherwise, end the iteration.

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2.2 FlexSim Simulation Modeling

FlexSim is an advanced 3D simulation modeling software, which is widely used in manufacturing, logistics, medical and other fields. It allows users to quickly build complex simulation models through an intuitive three-dimensional visualization interface and drag-and-drop operation. FlexSim provides powerful analysis tools, including statistical analysis, bottleneck analysis, and resource utilization analysis, to help users deeply understand system behavior and optimize performance. In addition, FlexSim supports flexible programming interfaces that allow users to customize model logic and behavior by writing scripts. Whether in line layout optimization, warehouse management, hospital operations or transportation planning, FlexSim provides effective simulation and optimization solutions.

3. Empirical analysis

3.1 Case Background

FAW Logistics Smart Logistics Park is the first stop for complete vehicles to roll off the assembly line from the OEM. It includes multiple vehicle logistics parks. The vehicle logistics parks adopt the form of two-dimensional flat parking lots. Taking W brand vehicle warehouse Area A as the research object, the management and optimization design of vehicle warehouse are carried out. Under the current layout plan, there are 2,080 warehouses in Area A, and the vehicle parking space storage area is 248 meters * 221 meters, with an area of approximately 54,808 square meters. Among them, the size of each parking space is 2.5 m * 5.5 m, and the passage of the storage area is 6 m.

The operation process of the whole vehicle warehouse area of FAW Logistics Park is basically the same as the commodity warehousing process, which is divided into two parts, namely the warehousing process and the warehousing process. Among them, vehicle warehousing is divided into the following four steps: vehicle request warehousing, system allocation of vehicle warehousing space, vehicle transportation, and vehicle entry into parking space. Vehicle departure is also divided into four steps: the system determines the departure location of the departure vehicle, the vehicle moves out of the parking space, the vehicle transportation, and the vehicle enters the standby lane.

In the process of leaving the warehouse, the largest proportion of time consumption is the vehicle moving out of the parking space and the vehicle transportation. Based on the speed limit of 20 km/h in the logistics park, when the vehicle is delivered manually and the average running speed is 4 m/s, the average time consumption of these two parts will account for more than 96% of the total running time. If an automated vehicle moving platform is used, the average running speed is reduced to 2 m/s, and the average time-consuming ratio of these two parts will increase to more than 98%. However, the movement of vehicles out of parking spaces is limited by operation in actual situations, and most of them take a fixed time. Therefore, the optimization direction of outbound warehouse should be to reduce the proportion of vehicle transportation time.

In addition, due to the limitation of running speed, the optimizable factor that affects the vehicle transportation time is the moving distance of the vehicle from the target spare lane, that is, the location allocation part in the optimized running process. The existing warehousing logic of the logistics park includes:

(1) Random allocation: when allocating warehouses, arbitrarily select an idle parking space as the target parking space in the logistics park warehouses;

(2) Allocation according to vehicle type, color and other types: according to certain rule allocation strategy, vehicles with the same attributes form clusters nearby;

In the next evaluation of garage allocation algorithm, the random allocation warehousing strategy is selected as the control.

3.2 Model Establishment and Application

Parking Space Allocation Strategy. Partition allocation strategy is a strategy that divides vehicles and storage locations into different classes and partitions through certain rules, and then allocates vehicle storage locations by matching classes and partitions.

First of all, from the perspective of the overall warehouse location, under the random allocation strategy, a class of vehicles may occupy the parking space with low departure time for a long time,

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resulting in the reduction of the departure efficiency of the logistics park. In order to improve the utilization rate of parking spaces and the efficiency of parking out, a zoning allocation strategy is proposed, which reasonably divides and matches the parking spaces and vehicles in the parking lot model. Specifically, a density-based clustering algorithm is adopted to divide vehicles into different categories according to their characteristics (such as parking time, exit frequency, etc.), and then divide parking spaces into different areas according to their characteristics (such as exit time, distance from exit, etc.). Finally, vehicles of the same category are allocated to the corresponding areas, and the vehicles are stored in the areas according to the principle of proximity. In this way, vehicles with high circulation efficiency can be preferentially allocated to parking spaces with high outbound efficiency, thereby improving the overall operation efficiency of the logistics park. The overall block diagram of the partition allocation strategy is shown in Figure 1. In the existing research, k-means clustering method is used to realize the clustering analysis of traffic data, which can effectively improve the clustering accuracy. In this section, Euclidean distance is used to calculate the similarity of all data in the cluster to the cluster center.

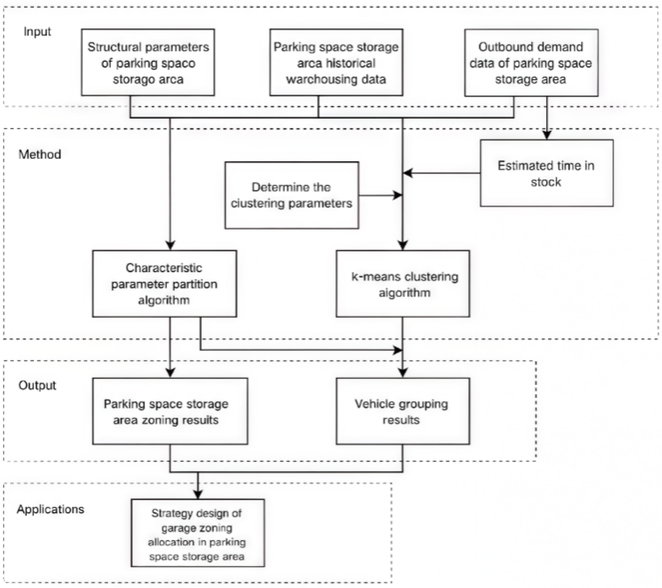

Figure 1: Overall block diagram of partition allocation strategy.

Solution Algorithm. Firstly, the vehicle clusters are divided by cluster analysis. The k-means clustering flow chart of vehicle arrival-estimated parking time is shown in Figure 2.

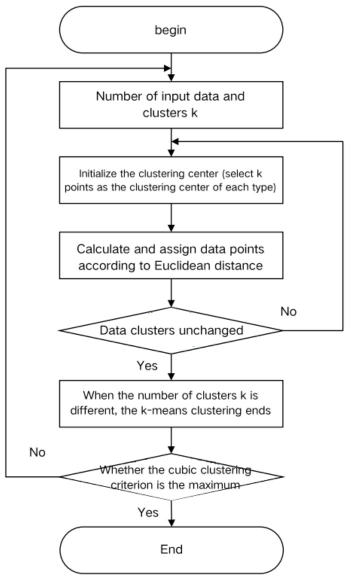

Figure 2: K-means clustering flow chart.

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By importing relevant data, the sample points corresponding to different colors of different vehicle models are set, and the quality of clustering is evaluated by the sample contour coefficients in combination with the actual situation. The following five clustering pictures are obtained, which are the results of cluster numbers 7, 8, 9, 10 and 11 respectively. In the pictures, the x coordinate is the warehousing time and the y coordinate is the expected warehousing time. By analyzing the sample contour coefficients of each clustering result, it is determined that the number of clusters is 9, which is an optimal number of clusters after combining with the actual situation. The list of sample contour coefficients for each cluster number is shown in Table 1.

Table 1: List of sample contour coefficients of each cluster number.

Number of clusters	Sample contour coefficient
7	0.390
8	0.415
9	0.426
10	0.409
11	0.423

After the clustering is completed, in order to further divide the vehicle clusters by the characteristic parameter division method and eliminate the interference caused by the actual sales change of each vehicle on the number of clusters, a new evaluation index is added, the average delivery rate on the same day. It is expressed as the ratio of the number of outbounds to the number of inbounds of a certain vehicle model on a historical day. Taking the delivery rate table for each model on June 7 as an example, the results are shown in Table 2.

Table 2: Outbound rate of each vehicle model on June 7.

Vehicle model	Quantity out	Quantity Input	Outbound rate
WDK	30	10	300.00%
WBK	80	50	160.00%
WCJ	120	100	120.00%
WEL	120	100	120.00%
WAJ	100	90	111.11%
WBJ	50	50	100.00%
WFK	100	100	100.00%
WAL	80	90	88.89%
WBL	40	50	80.00%
WCK	40	50	80.00%
WCL	40	50	80.00%
WEJ	60	100	60.00%
WEK	30	50	60.00%
WFL	60	100	60.00%
WDJ	5	10	50.00%
WDL	5	10	50.00%
WAK	20	90	22.22%
WFJ	20	100	20.00%

By summarizing the clustering results and the clustering results after characteristic parameters, it is finally determined that the warehousing vehicles are divided into four categories based on the outbound rate. The results are shown in the Table 3.

Table 3: Schematic table of grouping results.

Clustering	scope	Number of vehicles
1	0-69%	200
2	70-89%	200
3	90-119%	250
4	120+%	350

After the vehicle grouping is completed, by analyzing the distance from each parking space in the logistics park to the spare lane, the following parking space zoning Figure 3 is obtained according to the division results

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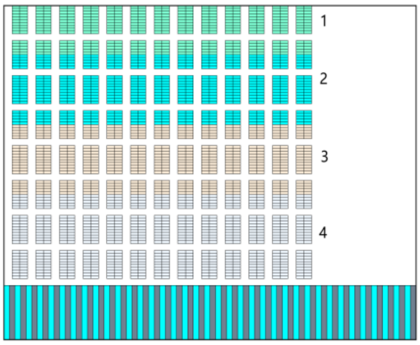

Figure 3: Schematic diagram of parking space zoning.

Among them, the cyan block represented by area 1 has a long departure time and is used to park cluster 1 vehicles with low departure probability; The departure time of the blue domain represented by area 2 is reduced, which is used to park cluster 2 vehicles with general departure probability; The light pink area represented by area 3 has less departure time and is used to park cluster 3 vehicles with high departure probability; The gray area represented by the last area 4 has the shortest outbound distance and the shortest outbound time, and is used to park vehicles with extremely high outbound probability represented by cluster 1.

Through this allocation strategy, when there are slight changes in vehicle sales, the system can accommodate these changes and keep the high efficiency of delivery. When a big change occurs, the system can also update the corresponding allocation area through the feedback of the delivery rate. When all the vehicles that were put into storage before the change are delivered, the existing allocation of the logistics park storage location will be matched with the basic logic again, with certain adaptability. Even if the change is beyond the scope of system adaptation, the location can still be updated by manually enabling reallocation. To sum up, the partition allocation strategy eliminates the necessary timing reallocation of the next day preload algorithm through the adaptability on the long-term scale, and reduces the system regulation time without excessively reducing the outbound efficiency.

3.3 FlexSim Simulation Modeling

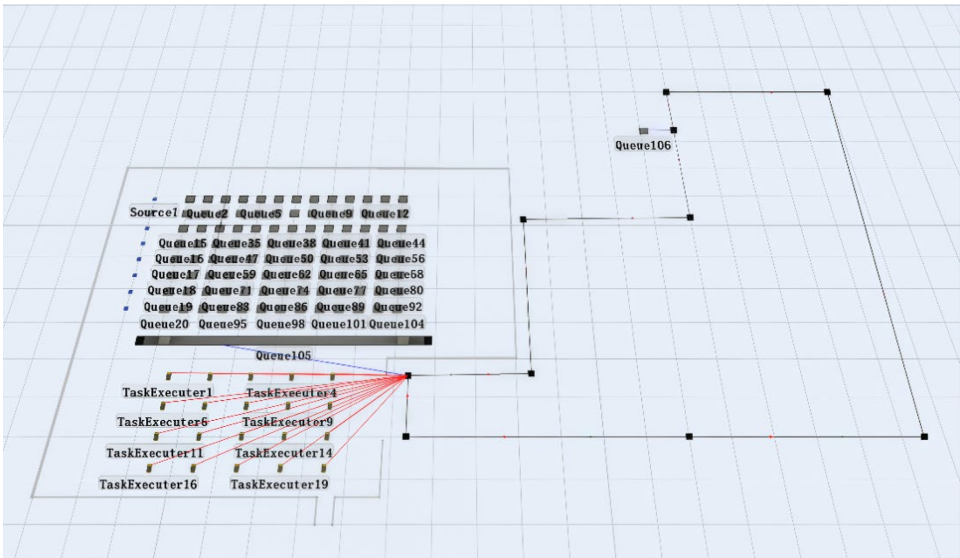

Figure 4: Initial model layout.

Random Allocation Model. According to the schematic diagram of the functional layout of Area A of FAW Logistics Smart Logistics Park described in the case given by FAW Logistics, the overall layout of Area A of the logistics park at this stage is roughly obtained, which is mainly divided into: the whole vehicle enters the storage area, the whole vehicle goes from the storage area to the spare lane, and the truck enters the loading area to load the whole vehicle for departure. Among them, there are eight generators and 104 temporary storage areas in the storage area of the whole vehicle (one temporary

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storage area represents 20 parking spaces), there are 74 trucks in the loading area, and there is a temporary storage area for trucks to load the whole vehicle for departure. The completed initial model layout is shown in Figure 4.

Partition Allocation Model Based on K-means Clustering. By running the initial model, we can see that according to the principle of random allocation and nearby allocation, the efficiency of the whole vehicle will be low, and the unnecessary cost will be increased. Therefore, by optimizing the logical structure of vehicle warehousing and storage, firstly, the case data given by FAW Logistics are integrated and input, and the characteristic parameter division method and k-means clustering algorithm are selected as the optimization method, the results of parking space storage area partition and vehicle grouping are obtained, thus reducing the time of warehousing and improving the efficiency of warehousing.

For the process of the whole vehicle entering the storage area in the model, after the whole vehicle is simulated by the generator, the whole vehicle enters the storage area through the characteristic parameter division algorithm and k-means clustering algorithm. From the above, it can be seen that the warehousing vehicles are divided into four categories based on the outbound rate, and four different color cartons are used to represent four different outbound rates in turn. The results can be obtained through simulation, as shown in Figure 5.

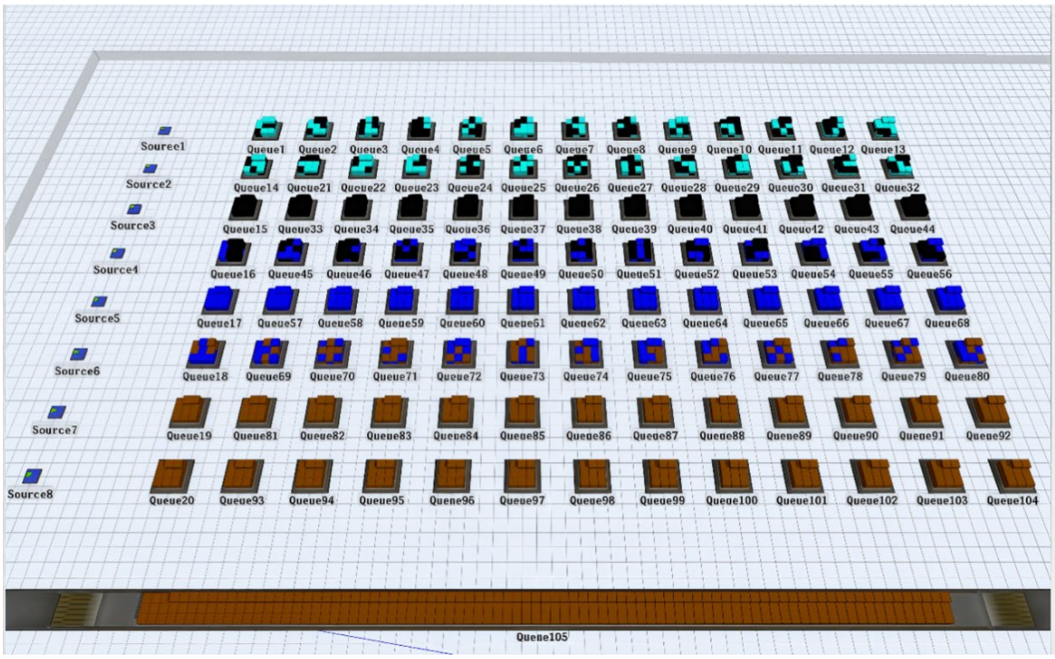

Figure 5: Optimized storage area model.

The running results of random allocation model and k-means cluster analysis partition allocation model are shown in Table 4.

Table 4: Comparison of running results.

Strategy of parking space allocation	Operational efficiency indicators
	Average vehicle departure time (min)
Random allocation strategy	3.54
Partition allocation strategy	3.19

It can be seen that the average delivery time of the smart logistics park location allocation strategy based on partition allocation is reduced by 10% compared with the nearby allocation strategy. Under the condition of ensuring the turnover rate of deposit and access cars, the utilization rate of parking spaces is considered, and the overall running efficiency of three-dimensional garage is improved, which conforms to the running characteristics of parking space zoning allocation.

4. Conclusion

The research shows that the application of k-means clustering and FlexSim simulation modeling in storage location allocation strategy shows obvious superiority and feasibility. Based on k-means

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clustering algorithm and its application in data partitioning, this algorithm can realize scientific partitioning of data and optimize the corresponding strategies. The optimized strategy was validated using FlexSim simulation software, and it also provides a reference for the research on storage location allocation strategies.

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