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A novel in-Warehouse Picking Optimization Model

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Abstract:- With the rapid development of the Internet and e-commerce industry, the distribution efficiency of logistics is a key factor affecting the economic efficiency of e-commerce, while in-warehouse picking, a core step in logistics, plays an extremely important role. In this paper, we start from the in-warehouse picking problem and build the shortest path model based on the immune algorithm following the application prospect of the traveling merchant problem to be applicable to many practical social applications so as to promote the economic development.

Keywords:- *TSP problem; immune algorithm; Manhattan algorithm; queuing theory*

I. INTRODUCTION

With the rapid development of the information technology industry, the rapid rise of Internet e-commerce platforms, along with the progress of people's material life, the level of consumption continues to improve, bringing economic benefits to e-commerce companies, while constantly testing its optimization, efficiency, accuracy, and low cost in all aspects. One of the important links is logistics, and the basis of logistics is whether the goods can be accurately sorted and efficiently sorted, bridging "supply" and "demand".

The time spent on picking in the warehouse can account for a large percentage of logistics activities, and with the increasing volume of transactions, the goods in the warehouse are also increasing, so without a reasonable picking method, its efficiency will be greatly reduced, causing inconvenience and loss to both customers and the platform. This causes inconvenience and loss to both the customer and the platform. Solving problems such as the time spent in the picking process, the utilization rate of the review table and the distance of the cargo bay affects the company's warehouse layout, the time spent on the picking process, the utilization rate of the review tables and the distance between goods compartments play a crucial role. It is necessary to combine the enterprise's warehouse layout and design a reasonable mathematical model to realize that goods picking and review can be efficient, accurate and the system is organized.

II. PROBLEM DESCRIPTION

A. *Problem Statement*

- Problem 1: As pickers pick goods, they need to walk between pallets, between pallets and review tables, between review tables and review tables, and around obstacles. Based on the distribution of the given warehouse diagram, design a method to calculate the distance between 3000 pallets and 13 review tables with a total of 3013 elements.
- Problem 2: Assume that all checkpoints are working properly, task order T0001 is waiting to be picked, and picker P picks up task order T0001 at checkpoint FH10. Please plan the ideal picking route for P, including the order in which the pallets are to be accessed, the return checker, and the time required to complete the picking process. Calculate the time it takes to complete the picking process (the time it takes from the time the picker starts picking to the time it takes for all tasks to be reviewed and packed).
- Problem 3: Assume that two review stations, FH03 and FH11, are working properly and that five task orders, T0002-T0006, are waiting to be picked. Please assign a task picking order to P and plan the ideal picking order so that 49 task orders are picked. Please assign a task picking order to P, plan the ideal picking order so that the 49 task orders are ready for picking as soon as possible, and calculate the time spent.
- Problem 4: Assume that the three review stations FH01, FH03, FH10, and FH12 are working normally, and 49 task orders T0001-T0049 are waiting to be picked. 9 pickers P1-P9 are responsible for picking, assign each picker a task order, a starting picking review table, and Assign each picker to a task order, a starting picking checker, and a picking route that is ideal for completing the 49 task orders as quickly as possible, and calculate the time required to complete the picking process.

B. *Problem Analysis*

- Problem 1: To facilitate data processing, transform the position coordinates given in the question into the position coordinates represented by the midpoint of the edge. Separate several position relations according to the position diagram and discuss the minimum distance formulas between the goods compartments, between the review table and the goods compartments and between the review tables in different cases in a categorical manner. The minimum distance is solved according to the TSP problem and the Manhattan algorithm[1-2].

- Problem 2: The starting review table has been given, and the shortest distance to link each cargo compartment is considered first, and finally the ending review table is found. From the distance matrix of the first question, the distance matrix of the relevant points is isolated (by multiplying the 0-1 matrix with the distance matrix) to build a graph-theoretic model. Determine the constraints based on the unidirectional non-repetitive TSP problems. The traversal is performed by the immune algorithm, and for the last compartment obtained the distance between it and all conforming tables is compared to find the minimum distance and its minimum time, and finally, the time required for picking is determined to be 746.6s.
- Problem 3: Since there are only two review stations working and there are multiple task orders and only one picker, we have to find the best return review station for each task order based on problem 2 to find the shortest path and time for each order, and also the location where the next task order starts. The last pane of the previous order as the starting point, the next order plus a point limited to FH03 and FH11, by traversing the exhaustive search to find the appropriate return review table, in addition to finding the time is in addition to the time involved in each order in problem 2, there is a review table whether the space and the resulting time, so we should pay attention to the state of the review table.
- Problem 4: The difficulty in this paper is that the number of pickers and review tables has been increased, multiple pickers have to start working at the same time, and there is a review waiting situation. Firstly, we have to continue the third question, sort the 49 task orders and the review tables, then assign 9 pickers to the task orders with reference to the time order, and calculate the longest picker time by the queuing algorithm, taking into account the compliance time, to get the shortest time[3-4].

III. MODEL BUILDING

A. Symbol Description

Alphabet	Definition
S_{00101}- S_{20015}	Cargo compartment markings
FH_{01}- FH_{13}	Checkpoint numbering
$S_n(1\leq n\leq 3013)$	Re-labeling of pallets and review tables (3001-3013 are review tables)
d	The distance between the pallets, between the checker and the pallets and the checker
X_i	The horizontal coordinates of the pane or checker
Y_i	Longitudinal coordinates of the pallets or review tables
x_i	The horizontal coordinate of the outer midpoint of the pane or the outer midpoint of the review table
y	Vertical coordinates of the middle point of the right side of the pane or the review table
D_M	Distance matrix
M_i	Number of orders
Q_i	Decision variables
A_i	Order number for sorting inside the shelf
K	Current status of the review table
R_x	Status of the picker
P_{1-5}	Order order
N_x	Number of pieces of goods to be picked from the shelf

Explanation of terms and symbols

B. Problem 1

To facilitate a uniform representation of the cargo frame and the review table, s_{00101} - s_{20015} and FH_{01} - FH_{13}, denoted by S_n, represent the points determined by the cargo grid or review table coordinates. When n > 3000, S_n represents the coordinate position of the review table.

Each shelf is divided into two columns of 15 each, and the column in which the target pane S_i is located is counted from the bottom, and the target pane is labeled as A_i.

For the convenience of solving and comparing the distances at a later stage, the left midpoint of the left pane is used to denote the left pane, and the right midpoint of the right pane is used to denote the right pane, respectively. The right midpoint of the left review table represents the review table, and the upper midpoint of the lower register review table represents the review table, at which time the horizontal coordinate is x_i and the vertical coordinate is y_i, and the relationship between the two and the coordinates given in the title, horizontal coordinate X_i and vertical coordinate Y_i, is as follows:

When $i\leq 3000$ and $i/15=2k+1(k=0,1,\ldots\ldots,)$:

$$S_i=(x_i+y_i)=(x_i-750+y_i+400) \quad (1)$$

When $i\leq 3000$ and $i/15=2k$ $(k=0,1,\ldots\ldots,)$:

$$S_i=(x_i+y_i)=(x_i+1150+y_i+400) \quad (2)$$

When $3001\leq i\leq 3008$:

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$$S_i = (x_i + y_i) = (x_i + 500 + y_i + 1000) \quad (3)$$

When $3008 \le i \le 3013$:
4

$$S_i = (x_i + y_i) = (x_i + 1000 + y_i + 500) \quad (4)$$

Then, we classified the positional relationships between the different points.

a) Between shelf and rack.

Located on the same side of the same shelf or the same column of shelves.

as shown in Figure 1.

$$d = |y_i - y_j| + 1500 \quad (5)$$

- Removal of cases located in the same row of shelves c Distance between all points.

At this point, from one shelf to another, both pickers can go around from above and from below, comparing the two out of the shortest distance, as shown in Figure 2.

Detour from below:

$$d_1 = |x_i - x_j| + 2 * 1500 + |A_i + A_j| * 800 - 800 + 2000 \quad (6)$$

Detour from above:

$$d2 = |x_i - x_j| + 2*1500 + 30*800 - (|A_i + A_j|*800 - 800) + 2000 \quad (7)$$

Comparison, resulting in a minimum of:

$$d = min\{d1 , d2\} \quad (8)$$

- Located on the adjacent sides of two adjacent columns of shelves or on opposite sides of different columns and rows of shelves.

as shown in Figure 3:

$$d = |y_i - y_j| + |x_i - x_j| \quad (9)$$

- All cases except c where the shelves are located on both sides of different shelves in the same column, in different rows and in different columns.

as shown in Figure 4:

$$d = |y_i - y_j| + |x_i - x_j| + 2 * 1500 \quad (10)$$

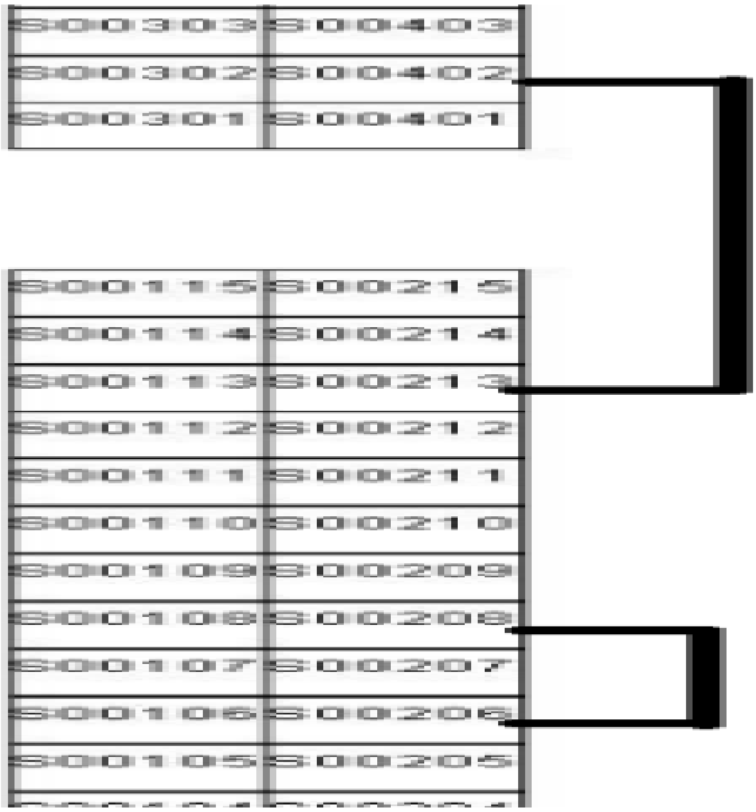

Fig.1 Shelf situation 1

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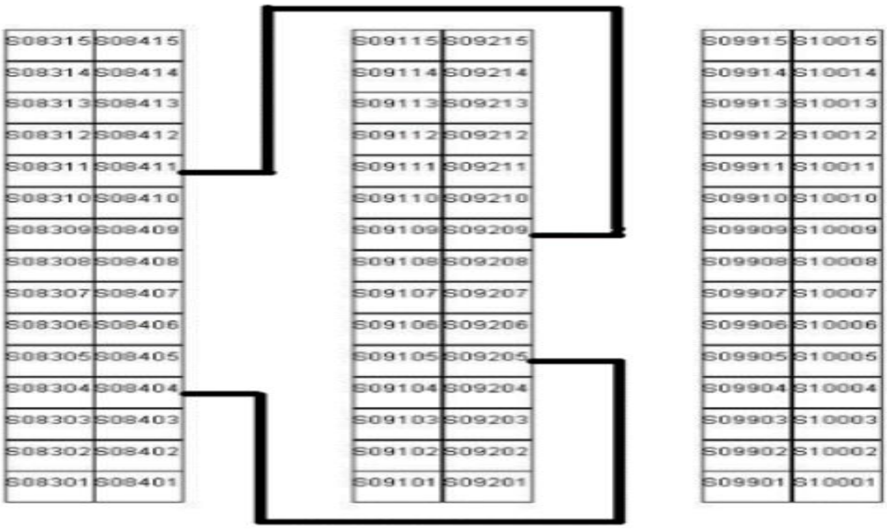

Fig. 2: Shelf situation 2

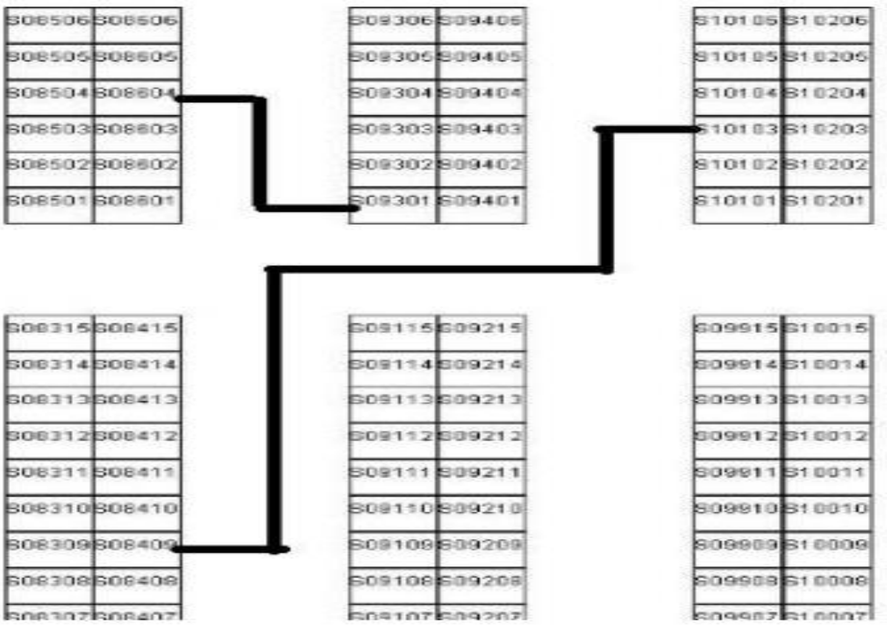

Fig. 3 Shelf situation 3

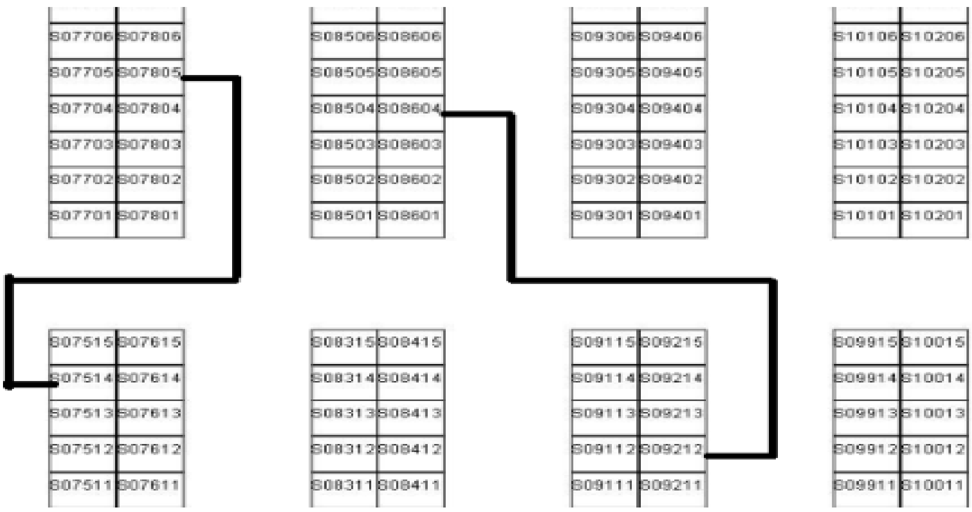

Fig..4 Shelf situation 4

b) Between shelf and review table.
- Leftmost review table with leftmost shelf.

As shown in Figure 5, and *d* is calculated by Equation (9).

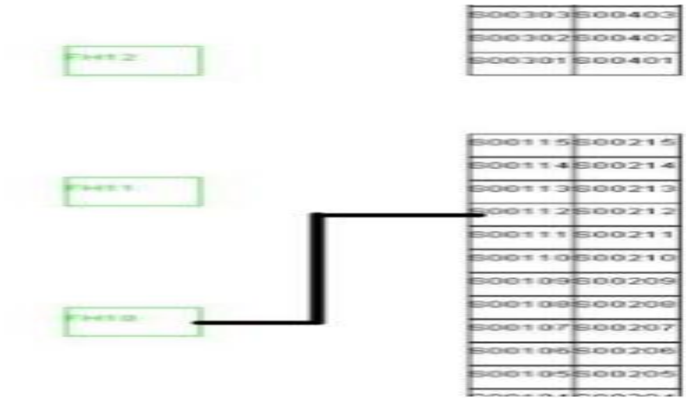

Fig. 5: Shelf situation 5

- Others

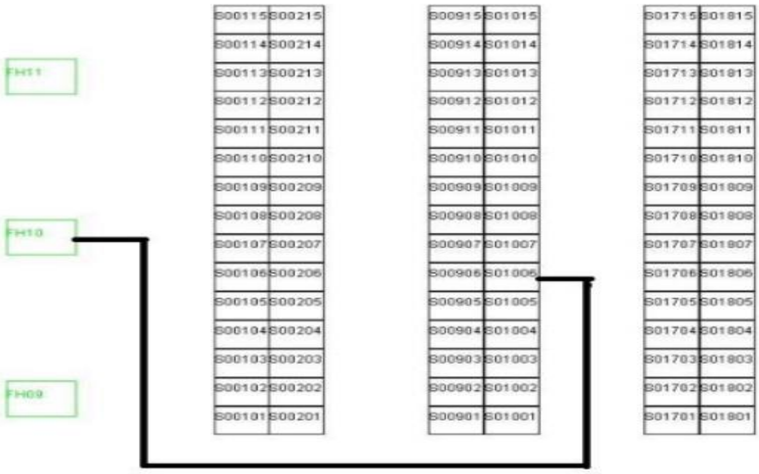

Fig. 6: Shelf situation 6

c) Between review desk and review desk.
As shown in Figure 7, and *d* is calculated by Equation (9).

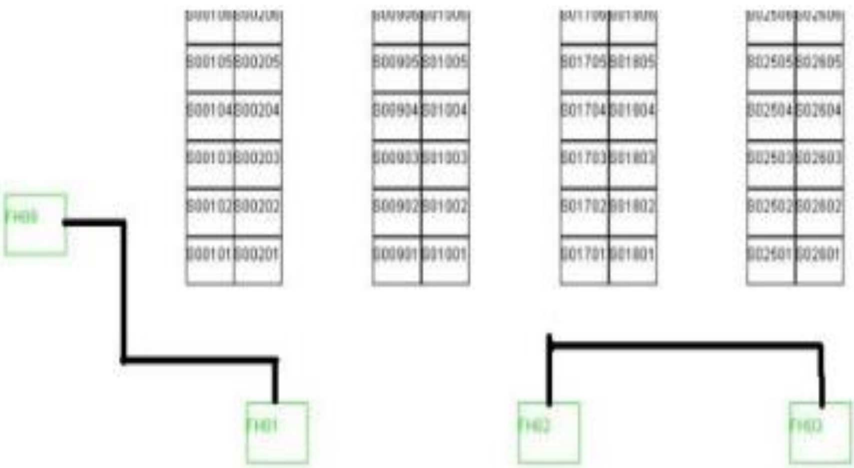

Fig. 7: Shelf situation 7

C. Problem 2

Let the starting picking point FH_{10} be s_1, the 23 pallets be s_2 - s_{24}, dij be the distance from pallets to pallets, and the total number of orders be M. The number of pieces required for each of the 23 pallets is $N2$ - $N24$.

Set 0-1 decision variables $Q_{ij} = \begin{cases} 0, s_i \text{ putting into production } s_j \\ 1, s_i \text{ not in production } s_j \end{cases}$, to determine whether the arrival grid. Set to the time required to pick up each compartment t_x.

$$t_x = \begin{cases} 4N_x(N_x = 3) \\ 5N_x(N_x < 3) \end{cases} \quad (11)$$

The final total time required to ship the number of pieces in the grid interval $t1 = \sum_{i=2}^{24} t_i$.

To avoid duplicate pickups, so let $i>j$ and ensure that the goods in each compartment will be picked up once and not repeated. The total constraint is:

$$s.t. \begin{cases} i > j, Q_{ij} = 0 \\ Q_{ij} = 0 \text{ or } 1 \\ 1 \leq \sum_{k<i} Q_{ik} + \sum_{j>1} Q_{ji} \leq 2 \\ \sum_{j>1} Q_{ij} = 1 \\ \sum_{i,j=1}^{24} Q_{ij} = 23 \end{cases} \quad (12)$$

Without considering the position of the last review station, traversal is performed by the immune algorithm to find the total time of $t = \min z/v + t_1 + M*30$.

After finding the result, then from the last cargo frame, traverse the distance to all review stations to find the minimum distance to get the last position of a review table s_{25}. further calculate the value of time t_0, the final minimum time is $\min T = t + t_0$.

D. Problem 3

First separate the distance matrix between the individual cargo compartments and the two review stations in each task order from the distance matrix obtained in Problem 1, denoted as D_x, and x take 1-5.

Using the idea of the second question, the order with the shortest time spent (which does not include the time to return to the review desk) for all task orders is found as picking order P_1, using FH_{03} as the starting point, and let then the last grid of picking task order P_1 as the starting point, restricting the next point to FH_{03} or FH_{11}, and then entering the remaining distance matrix, forming a new sort (treating the review table as the first second choice of must-pick goods) to calculate the time separately, and the task order with the shortest time is noted as P_2. Similarly, a This continues, and the order of the five task orders is obtained.

Calculate the picker's time to complete each complete order separately T_1, which includes, among other things, the time spent on the road, the time needed to pick the goods and then add the time required to review the packing within each task order $T_2 = \sum n_i*30$.

The final time is $T_{min}=T_1+T_2$.

E. Problem 4

T_{0001}-T_{0049} the number of orders is $M_i(1 \leq i \leq 49)$, respectively.

Disregarding the increase in the number of pickers, a picker is used to perform a calculation similar to the third question: taking FH_{03} as the starting point, the compartments corresponding to the goods in task order $T_{0002\text{-}6}$ are considered as route points, and the shortest traversal method is found using the method of the third question, including the traversal order, the returned review table, and the time spent out of the warehouse.

Calculate the minimum time for the task order, immunization algorithm[5-6]. Arrange the time of task orders 1-49 from shortest to longest, determine the order of task orders, and then pick the goods sequentially under the new order by nine pickers. Constraints:

The picker's state $R_x = \begin{cases} 0, idle \\ 1, busy \end{cases}$;

Status of the review table $K_x = \begin{cases} 0, idle \\ 1, busy \end{cases}$.

When the task order is not yet assigned, find the picker with the shortest time a and assign the next task order to him. If If more than one is the shortest, the picker with the shortest time is given the shortest order number.

Calculate the total time for each picker to complete the task T_x. The final outgoing time is $T_{min} = \max\{T_x\}$.

F. Model Assumptions

- It is assumed that there will be no surprises in the picking process and that the picker will not be disturbed by other matters.
- It is assumed that all goods are accurately positioned without any errors.
- It is assumed that the size, shape and weight of each item will not have any effect on the picking process and will be the same as each other.
- Assume that the picker strictly follows the specified route and ignores the volume of the actual picking carrier, i.e., the distance traveled exactly matches the length of the lines in the model.
- Assume that all review tables are working properly.
- Assume that the picker travels at a constant speed and the review packing time is constant.

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IV. EXPERIMENTAL SETTINGS

A. *Problem 1*

According to the model established in Problem 1, the discussion of the different positions in different cases, using matlab according to the constraints of the distance matrix to 3013 × 3013, and store the resulting table in an Excel sheet.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	0	2300	3100	3900	4700	5500	6300	7100	7900	8700	9500	10300	11100	11900	12700
2	2300	0	2300	3100	3900	4700	5500	6300	7100	7900	8700	9500	10300	11100	11900
3	3100	2300	0	2300	3100	3900	4700	5500	6300	7100	7900	8700	9500	10300	11100
4	3900	3100	2300	0	2300	3100	3900	4700	5500	6300	7100	7900	8700	9500	10300
5	4700	3900	3100	2300	0	2300	3100	3900	4700	5500	6300	7100	7900	8700	9500
6	5500	4700	3900	3100	2300	0	2300	3100	3900	4700	5500	6300	7100	7900	8700
7	6300	5500	4700	3900	3100	2300	0	2300	3100	3900	4700	5500	6300	7100	7900
8	7100	6300	5500	4700	3900	3100	2300	0	2300	3100	3900	4700	5500	6300	7100
9	7900	7100	6300	5500	4700	3900	3100	2300	0	2300	3100	3900	4700	5500	6300
10	8700	7900	7100	6300	5500	4700	3900	3100	2300	0	2300	3100	3900	4700	5500
11	9500	8700	7900	7100	6300	5500	4700	3900	3100	2300	0	2300	3100	3900	4700
12	10300	9500	8700	7900	7100	6300	5500	4700	3900	3100	2300	0	2300	3100	3900
13	11100	10300	9500	8700	7900	7100	6300	5500	4700	3900	3100	2300	0	2300	3100
14	11900	11100	10300	9500	8700	7900	7100	6300	5500	4700	3900	3100	2300	0	2300
15	12700	11900	11100	10300	9500	8700	7900	7100	6300	5500	4700	3900	3100	2300	0
16	6900	7700	8500	9300	10100	10900	11700	12500	13300	14100	14900	15700	16500	17300	18100
17	7700	8500	9300	10100	10900	11700	12500	13300	14100	14900	15700	16500	17300	18100	17300
18	8500	9300	10100	10900	11700	12500	13300	14100	14900	15700	16500	17300	18100	17300	16500
19	9300	10100	10900	11700	12500	13300	14100	14900	15700	16500	17300	18100	17300	16500	15700
20	10100	10900	11700	12500	13300	14100	14900	15700	16500	17300	18100	17300	16500	15700	14900
21	10900	11700	12500	13300	14100	14900	15700	16500	17300	18100	17300	16500	15700	14900	14100
22	11700	12500	13300	14100	14900	15700	16500	17300	18100	17300	16500	15700	14900	14100	13300
23	12500	13300	14100	14900	15700	16500	17300	18100	17300	16500	15700	14900	14100	13300	12500
24	13300	14100	14900	15700	16500	17300	18100	17300	16500	15700	14900	14100	13300	12500	11700
25	14100	14900	15700	16500	17300	18100	17300	16500	15700	14900	14100	13300	12500	11700	10900
26	14900	15700	16500	17300	18100	17300	16500	15700	14900	14100	13300	12500	11700	10900	10100
27	15700	16500	17300	18100	17300	16500	15700	14900	14100	13300	12500	11700	10900	10100	9300
28	16500	17300	18100	17300	16500	15700	14900	14100	13300	12500	11700	10900	10100	9300	8500

Fig. 8: Screenshot of the results of the calculation part of Problem 1.

B. *Problem 2*

Immunity algorithm: Applying the concept of immunity and its theory to genetic algorithm, while retaining the good characteristics of the original algorithm, the algorithm tries to selectively and purposefully use some characteristic information or knowledge of the problem to be solved to suppress the degradation phenomenon in the optimization process, which is called immunity algorithm (IA). Artificial immune algorithm is a swarm intelligence search algorithm with an iterative process of generation + detection. From the theoretical analysis, the iterative process, while retaining the theoretically, the immune algorithm is globally convergent, provided that the best individuals of the previous generation are retained.

First get the distance matrix for the desired point by multiplying it with the 0 and 1 matrices, the other points have zero distance.

Write a function dedicated to traversal (using the immune algorithm), enter the starting review table, the serial number of the cargo grid points, and return the order from the starting point to the last cargo grid. After several iterations, the final best fit = 4.163.

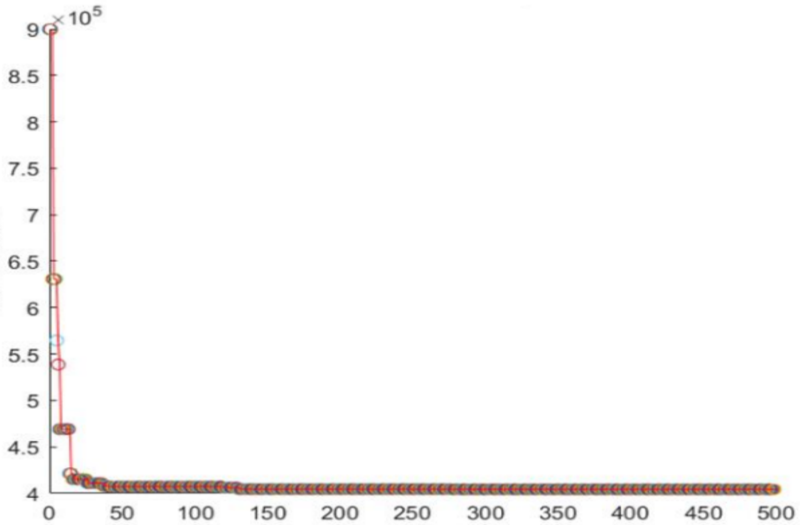

Fig. 9: Iteration Chart

As shown in Figure 9, the trend of the best fit is shown, the horizontal coordinate is the number of iterations and the vertical coordinate is the best fit. The initial route is obtained as: 3010→253→188→1262→1125→928→1077→1515→1656→1670→1883→2019→2381→ 2146→2228→2067→2170→ 2064→1939→1803→1568→1561→1085→7.

Then we find the distance between the 1068 grid and all the review stations in the distance matrix, and get the closest distance as FH13.

The last returned checker is FH13. So the total path is (FH10)3010→253→188→1125→1262→928→1077→1515→1656→1670→1883→2019→2381→2146→2228→2067→2170→2064→1939→1803→1561→1568→1561 →1085→7→FH13.

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Calculate the time for each pickup $t1=\sum_{i=2}^{24} t_i$, , and t_x is calculated by Equ(11):The number of orders is n. The order packing required time required $t2$ = n*30s.

The final scheduled time spent out of the warehouse is 725.1333s.

C. Problem 3

Based on the model building. Calculate each task order time, deposit the task order where t_{min} is located in P_1, store its path to the Excel sheet, and restrict the next point selection to FH_{03} or FH_{11} starting from the last cell. then pick up the next task order, calculate each task order time, deposit $tmin\ min$ where the task order is stored in P_2, store its path to the Excel sheet, repeat the above process until the last pane of the last order, and then compare the distance between the pane and the two review tables, and choose the smallest distance to the review table.

Using the algorithm of the second question, the immunization algorithm, while calculating T_1, T_2.

The final time T is calculated to be: 4249.1333.

A	B	C	D	E	F
1	P1	T0005	FH03	3003	0
2	P1	T0005	S09703	1443	1
3	P1	T0005	S11308	1688	1
4	P1	T0005	S13105	1955	1
5	P1	T0005	S12213	1828	2
6	P1	T0005	S13007	1942	3
7	P1	T0005	S14701	2191	3
8	P1	T0005	S14204	2119	3
9	P1	T0005	S10103	1503	1
10	P1	T0005	S07608	1133	2
11	P1	T0005	S05815	870	1
12	P1	T0005	S06515	975	1
13	P1	T0005	S06004	889	1
14	P1	T0005	S06214	929	1
15	P1	T0005	S07712	1152	2
16	P1	T0005	S07912	1182	1
17	P1	T0005	S05514	824	3
18	P1	T0005	S03202	467	1
19	P1	T0005	S03104	454	1
20	P1	T0005	S02301	331	1
21	P1	T0005	S02104	304	3

Fig. 10: Output results

D. Problem 4

Using FH03 as the starting point, the goods compartment corresponding to the goods in task order T0002-6 is regarded as a route point, and the shortest traversal method, including the traversal order, the returned review table, and the time spent for outbound storage, is found using the method of the third question.

Calculate the shortest time for a task order by the immunization algorithm. The task orders 1-49 are arranged from shortest to longest to determine the order of the task orders, and then the nine pickers pick in a new order. Then nine pickers pick the goods in order. When the task order is not finished, the picker with the shortest time is found and the next task order is assigned to him. If If more than one is the shortest, give it to the picker with the shortest number. Also, note the 0 and 1 relationship between the review table status and reviewer status variables.

Calculate the total time for each picker to complete the task Tx; The final exit time is $Tmin = max\{Tx\}$.

Due to too many constraints to realize this idea, in the middle of the real process, we use FH03 as the each task order to get the starting point.

V. CONCLUSION

This model greatly saves the time spent on picking goods in the warehouse, improves logistics efficiency, saves manpower and material resources, avoids resource wastage and economic benefits, while improving customer satisfaction and promoting the long-term stable operation of the enterprise regulations. The company has formed a picking system and a picking model. Moreover, this model is flexible and can be adjusted for different warehouse structures. The model can be adjusted accordingly for different warehouse structures. It is possible to set up a reasonable and appropriate process for the actual situation of the enterprise.

The model is not only applicable to in-warehouse picking problems, but also can be applied to a variety of shortest path problems where obstacles exist. For example, the shortest path problem for ticketing at the station and the play problem at the tourist park can be used to plan a reasonable route for travelers in different areas. It is possible to plan a reasonable route for travelers in different areas.

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REFERENCES

[1.] Chepoi, Victor, Karim Nouioua, and Yann Vaxes. "A rounding algorithm for approximating minimum Manhattan networks." Theoretical Computer Science 390.1 (2008): 56-69.
[2.] Kato, Ryo, Keiko Imai, and Takao Asano. "An improved algorithm for the minimum Manhattan network problem." International Symposium on Algorithms and Computation. Springer, Berlin, Heidelberg, 2002.
[3.] Fomundam, Samuel, and Jeffrey W. Herrmann. "A survey of queuing theory applications in healthcare." (2007).
[4.] McManus, Michael L., et al. "Queuing theory accurately models the need for critical care resources." The Journal of the American Society of Anesthesiologists 100.5 (2004): 1271-1276.
[5.] Prakash, B. Aditya, et al. "Virus propagation on time-varying networks: Theory and immunization algorithms." Joint European Conference on Machine Learning and Knowledge Discovery in Databases. Springer, Berlin, Heidelberg, 2010.
[6.] Shams, Bita. "Using network properties to evaluate targeted immunization algorithms." Network Biology 4.3 (2014): 74.