Scheme Design of Adding Container Operation Area in Existing Warehouse

Cheng-yuan YAO¹,a

¹School of Economics and Management, Beijing Jiaotong University, Beijing, China

¹chayayao@163.com

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Abstract. In combination with the development of the container industry, many warehousing logistics companies currently plan to add container operation areas in the existing warehouse for long-term business development needs. This paper creates a plan for adding container operation areas to the existing warehouse area, using cost-benefit analysis to determine the location of the container operation area, and combining the characteristics of the operation area to carry out the layout of functional areas, and the method of integrating system layout methods and mathematical models. A model with the smallest transportation cost and the largest comprehensive logistics relationship between functional areas is established, and finally a calculation example is analyzed with the CP company as an example.

1. Introduction

As the advanced transportation equipment of the modern logistics industry⁴, the container has a good development prospect in China. Due to the rapid increase in demand for container transportation, many companies based on the layout of the existing warehouse area and existing infrastructure, plan to add container operation areas on the original site, introduce container business, expand the company's business types, and increase company revenue. However, due to the limitation of the existing warehouse area, there is no free area for the new container operation area to carry out business, and it is necessary to vacate the corresponding area in the existing business area. Therefore, it is impossible to determine the area of the container operation area and the specific layout plan. This article analyzes the plan of adding a container operation area to the existing reservoir area under this background.

2. Literature Review

The research on layout planning can be divided into two stages. The first stage mainly relies on the designer’s experience and some qualitative research methods; the second stage is to introduce related scientific methods such as operations research and system engineering into layout optimization, making up for the lack of manual layout.

Richard Muther⁴ proposed a system layout design method based on the system analysis method. This method aims to develop the problem of layout planning from the qualitative stage to the quantitative stage. Beeky. Y. Loo⁵ tried to use heuristic algorithm to solve the layout problem of freight center; Hyun Jeung Ko⁶ established a dynamic programming model and used heuristic algorithm based on genetic algorithm to solve it.
Domestic research on this issue has also increased in recent years. Li Yuming\cite{5} proposed a facility layout design method that meets the characteristics of logistics centers; Yang Jianhua, Peng Lijing, and Yang Yongqing\cite{6} aimed at the lowest logistics handling volume, applying SLP and SHA. The method of re-arrangement design of the facilities and logistics system in the logistics enterprise department. Yao Guanxin and Liu Zhenggang\cite{7} modeled the facility layout model as a new non-linear programming target model; Li Yumin\cite{8} Li Yumin proposed a logistics center facility layout optimization design method that effectively took into account logistics cost and operation efficiency, and designed an initial population generation method based on dynamic layout technology. Recently, scholars have also used simulation technology to simulate and optimize. Sha Mei, Zhou Xin, Qin Tianbao, Yu Dayong, Qiu Hualei\cite{9} used genetic algorithm to solve the mathematical model to obtain the layout plan, and finally used simulation technology to carry out an example analysis.

3. Pre-Design

3.1. Work Volume Forecast

Since the company introduced the container business for the first time, the forecast of future container business volume lacks historical data, so it adopts a combination of qualitative forecasting and quantitative forecasting. Import the historical data of railway freight volume, through fitting comparison, it is found that it is most reasonable to use the binary polynomial function for fitting and trend prediction, so the binary polynomial function with the R-square value of 0.7228 is obtained.

\[ y = 1172.6x^2 - 5E+06x + 5E+09 \]

Through forecasting, the total amount of national railway freight traffic in the future is obtained. With reference to the predicted container business volume of the same type of company and the operating capacity of different types of container yards, combined with the company's special geographic location and future development space, the company's annual average throughput of container business is preliminarily predicted.

3.2. Location Determination

The later addition of container operation areas requires reconstruction of the existing warehouse area, which is a long-term decision of the enterprise. Therefore, it is necessary to fully consider the costs and benefits of the business change process and determine the location of the container operation area through the net present value.

\[ NPV = \text{Total present value of future rewards} - \text{Present value of investment} \]

Among them, Total present value of future rewards = \[ \sum_{i=1}^{n} \frac{\text{Annual cash inflow} - \text{Annual cash outflow}}{(1+i)^t} \]

Determine the total investment cost of adding a container yard as

\[ C_{\text{investment}} = C_{\text{remove}} + C_{\text{newly constructed}} + tC_{\text{opportunity}} \]

The expected income is the expected annual income from developing the container business, let it be R.
NPV = \sum_{t=1}^{n} \frac{R - C_{operation}}{(1 + i)^t} - \left( C_{remove} + C_{newly constructed} + tC_{opportunity} \right)

Through the above analysis and calculation, according to the size of the work area, this article determines the area that needs to be replaced.

3.3. Functional Partition

Through the analysis of container operation process and the functional zoning of general railway container handling stations, the functional areas of the container operation area are divided.

4. Model Building

4.1. Principle

a) The shortest distance principle: Minimize the flow of containers in the operation area.

b) Layout optimization principle: The functional areas with the most relevance are close, try to avoid detours and backflows.

c) Satisfy the principle of process flow: Satisfy the functional requirements, loading and unloading technology and workflow in the work area.

d) System optimization principle: Considering the mechanization, high efficiency, integration and systemization inside the work area and the highest overall efficiency, the final cost is minimized.

e) Flexibility principle: The layout must adapt to future changes, meet customer needs to the greatest extent, while leaving a certain space for future development.

4.2. Influencing Factors

a) Container transportation cost

In the layout process, the transportation cost of containers inside the operation area is determined by the container transportation volume, container transportation distance and fuel consumption per unit distance of the container. The transportation volume and fuel consumption cost are generally fixed values and need to be determined through investigation.

b) Workflow

In the layout process, the operation process is a very important factor affecting the internal layout of the container, and the layout plan must comply with the regulations of the operation process.

c) Relevance between functional areas

In the layout process, the maximum degree of association between functional areas should be ensured. The degree of association means that the greater the comprehensive relationship between the functional areas, the smaller the distance between the functional areas. The shorter the distance, the greater the proximity, the specific conversion relationship is shown in the table:
Table 1. Distance and proximity conversion table.

| Distance between functional areas | Proximity between functional areas |
|---------------------------------|-----------------------------------|
| \([0,d_{max}/6]\)               | 1                                 |
| \([d_{max}/6,d_{max}/3]\)       | 0.8                               |
| \([d_{max}/3,d_{max}/2]\)       | 0.6                               |
| \([d_{max}/2,2d_{max}/3]\)      | 0.4                               |
| \([2d_{max}/3,5d_{max}/6]\)     | 0.2                               |
| \([5d_{max}/6,d_{max})\)       | 0                                 |

d) Road width in operation area

The road width of a general logistics park is determined by the width of the traffic road, the width of the sidewalk and the safety distance on both sides. Due to the particularity of the length of the container vehicles passing through the container operation area, the width of the road in the operation area must take into account the maximum turning radius of the container vehicle. The above values are determined according to the actual survey.

4.3. Hypothesis

Since the functional areas in the work area are unequal in area and can be arranged in multiple rows, this paper determines that the unequal area separation and multi-row layout are used as the modeling basis.

a) The additional container operation area is a standard rectangle with a certain area and length and width and can be divided into several rows;

b) The layout of each functional area is carried out on the same plane, and the shape is square or rectangular;

c) The areas occupied by different functional areas cannot overlap;

d) There is a certain width of roads and green belts reserved between functional areas, and their area is not considered;

e) The unit cost of container handling within the container operation area is fixed.

f) Assuming that the sides of each functional area are respectively parallel to the X-axis and Y-axis of the overall layout coordinate map of the container operation area, \((x_i, x_j)\) and \((y_i, y_j)\) are the coordinate axes of the center of functional area i and the center of functional area j, respectively.
4.4. Objective Function

a) Minimum cost goal: \( \text{Min} F_1 = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Q_{ij} d_{ij} C \)

b) Most relevant goal: \( \text{Max} F_2 = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} u_{ij} v_{ij} \)

This model is a multi-objective programming problem, but the multi-objective function is not easy to solve directly, so it is necessary to convert the multi-objective function into a single objective function. Through objective function transformation, unified dimensions, and reasonable weight coefficients, the following objective function expressions are obtained:

\[
\text{Min} Z = \frac{1}{\text{max} F_1} \omega_1 \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Q_{ij} d_{ij} C + \frac{1}{\text{max} F_2} \omega_2 \left( V - \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} u_{ij} v_{ij} \right)
\]

4.5. Restrictions

a) The area occupied by each functional area does not overlap.

\[
|x_i - x_j| \geq \frac{1}{2} [l_i + l_j]; \quad |y_i - y_j| \geq \frac{1}{2} [b_i + b_j]
\]

b) The layout of the functional area does not exceed the planned boundary of the container operation area.

\[
x_i + \frac{1}{2} l_i \leq L; \quad y_i + \frac{1}{2} b_i \leq B
\]

c) The aspect ratio of each functional area must be within the proper range.

\[
\frac{1}{\alpha} \leq \theta_i \leq \alpha
\]

Among them, \( F_1 \): Minimum cost objective function; \( F_2 \): Maximum correlation objective function; \( i \): Functional area i; \( j \): Functional area j; \( Q_{ij} \): Number of containers transported between functional area i and functional area j; \( d_{ij} \): The rectangular distance between the i coordinate of the functional area and the j coordinate of the functional area; \( C \): Average annual unit cost of transporting containers between functional areas; \( u_{ij} \): The proximity between functional areas i and j, the parameter value is corresponding to \( d_{ij} \); \( v_{ij} \): The correlation degree between functional area i and j, the parameter value is obtained by comprehensive correlation analysis; \( x_i, x_j \): The distance between the center of the functional area i, j and the coordinate axis Y; \( y_i, y_j \): The distance between the center of the functional area i, j and the coordinate axis X; \( l_i, l_j \)—The length of functional area i
and functional area \( j \); \( b_i, b_j \): The width of functional area \( i \) and functional area \( j \); \( L, B \): The length and width of the container operation area to be deployed; \( \theta_i \): The aspect ratio of each functional area, based on past experience, the value of this article is 3.

5. Model Solving and Program Evaluation

5.1. Case Analysis

Bring the actual data of CP company into the above steps and model, the total area of the container operation area is approximately 14,460 square meters. The container operation area is mainly placed in the area where the small customer loading, unloading and handling business was originally carried out, the old warehouse area is used as a spare change area. Then using genetic algorithm to calculate, and using R language to solve, and getting the optimal solution.

|   | j     | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     |
|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| i |       | Send box area | Transfer box area | Arrive box area | Auxiliary box area | Loading and unloading inspection area | Freight station | parking lot | Reserve land |
| 1 | Send box area | - | 20.8837 3 | 9.2427 66 | 28.42435 | 45.55867 | 3.0397 66 | 16.185 36 | 24.80183 |
| 2 | Transfer box area | - | - | 16.344 28 | 6.199143 | 12.10266 | 46.031 45 | 47.080 56 | 38.33385 |
| 3 | Arrive box area | - | - | - | 47.86397 | 41.26565 | 45.780 41 | 1.1206 | 34.64195 |
| 4 | Auxiliary box area | - | - | - | - | 17.18506 | 13.155 22 | 45.411 38 | 12.49734 |
| 5 | Loading and unloading inspection area | - | - | - | - | - | 37.578 29 | 8.5987 26 | 43.81746 |
| 6 | Freight station | - | - | - | - | - | - | 39.713 16 | 30.99278 |

In order to facilitate the solution, it is stipulated that the loading and unloading inspection area is laid out along the loading and unloading line, the length is 100, the width is 10, and the coordinates \((x_i, y_i)\) are (5, 50). According to the optimal solution of \( d_{ij} \), the layout plan of the container operation area is shown as the following figure:
5.2. Program Evaluation

In order to evaluate the current plan, select the following indicators.

a) Economic indicators

Through the above requirements, the land utilization rate is 96%; through cost-benefit analysis, it can be seen that there are good economic prospects for the addition of container operation areas in areas where scattered customer loading and unloading operations were originally carried out; Since the layout of the operation area is close to the company's original office area, management labor costs are saved.

b) Technical indicators

This forecast may be inaccurate due to lack of data; the containers that need to be sent and the containers that arrive can flow reasonably in the operation area to meet the requirements of smooth operation.

c) Flexibility indicators

In this layout, there are still old warehouses above that can be used as spare land for the operation area, which has good scalability; the container operation area is constrained by loading and unloading lines and equipment, and its internal layout is poorly renovated.

d) Environmental indicators

The company's existing management level is relatively high, and the management of the internal facilities and equipment in the reservoir area is strict and safe. However, in this layout design, in order to simplify the establishment of the model, the scope of the green belt was not considered.

e) Social indicators

Since the layout area of the operation area is closer to the office and service facilities area, it has better comfort; and it not only meets the current social demand for railway container operation areas, but also responds to the rapid development in the future.
6. Conclusion

This article establishes a plan for adding a container operation area. First, the area of the container operation area is determined by predicting the operation volume of the operation area. Next, a cost-benefit analysis model was established. On the basis of satisfying the principle of determining the location of the container operation area, it was determined to replace the original scattered small customer storage, loading, unloading and handling services with the newly established container business, and the location of the container operation area was determined. Finally, using the system layout method to analyze the comprehensive relationship between the functional areas, a mathematical model with the lowest transportation cost and the largest comprehensive relationship between the functional areas is established, and the genetic algorithm is used to solve it. And set indicators to analyze the final layout plan.

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