Research on Hierarchical Layer Strategy for Power Material Warehouses---A Case Study of X-Electric Power Corporation

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Abstract: We will raise total factor productivity to make China's industrial and supply chains more resilient and secure. This paper first provides a hierarchical layer strategy and proposes a hierarchical layout model to minimize operating costs. Warehouse management of electrical materials is a critical link in power supply. This paper analyses the situation of power material warehouse layout, including the models of warehouses layout and the main functions of each warehouse. Then makes a hierarchical layer strategy for power material warehouses on X electric power corporation. Distribution Centre is needed for allocation when the power material companies transport critical production. The flow of materials is draw. Finally, built the hierarchical layer strategy model of power material warehouses, which must consider many influencing factors, such as transportation costs, warehouse maintenance costs, and time penalty costs. This serves as a foundation for research into active distribution of electrical materials.

1 Introduction

The 20th National Congress of the Communist Party of China (CPC) reported that we will move faster to build a modernized economy. We will raise total factor productivity, make China's industrial and supply chains more resilient and secure. Warehouse management of electrical materials is a critical link in power supply. Proper warehouse management can enhance the core competitiveness of the enterprise and achieve goals of cost savings, rapid responsiveness, and comprehensive business support. [1,5-6] Currently, the warehouse management of X Electric Power Corporation. is characterized by dispersed warehouse geographical distribution, low warehouse storage utilization, and a lack of modern intelligent management equipment. Therefore, this paper aims to establish an evaluation indicator system for hierarchical classification strategy for electrical material repositories and analyse the hierarchical classification strategy, thereby improving warehouse storage utilization, reducing inventory, and enhancing fault response speed.

2 The Situation of Material Warehouses layout

2.1 The models of warehouses layout

There are two models of warehouses layout typically. One is the single-level layout, the other is hierarchical layout. [2]

Single-level layout refers to establishing multiple warehouses within the organization, each operating at the same management level and centrally managed by the company's headquarters. However, in cases where production equipment needs immediate replacement of spare parts due to malfunctions. This model can often be problematic due to the distance between the warehouse and the site.

Hierarchical layout, on the other hand, involves setting up warehouses at different management levels based on geographical distribution and specific needs. This approach is beneficial for expediting warehouse repairs and maintenance, reducing equipment downtime, and improving responsiveness to equipment failure. However, hierarchical warehouse layout does not lend itself to sharing inventory information, reducing inventory levels, and minimizing warehouse space.

Material warehouses of X Electric Power Corporation are geographically widespread, covering the entire province. It is essential to transport electrical materials over long distances. It is necessary to establish a comprehensive network of warehouses to facilitate equipment maintenance and repair. According to this, we design a hierarchical layout model, including distribution canters, sub-repositories, and terminal repositories.

2.2 The main functions of each warehouse

The main functions of each warehouse are as follows:

1. Distribution Centre

First-level warehouse, centrally located, responsible for regional storage, storing essential materials, controlling material information, supplying and **distributing materials, and more.**

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2. Branch warehouse

Second-level warehouse, supplementary to the distribution centre, responsible for regional storage, considering balance with the distribution centre, and mainly storing materials required within the region, supplying materials to the terminal repository or demand sites, and more.

3. Terminal Warehouse

Third-level warehouse fundamentally positioned for storing self-purchased materials, not regional materials, primarily storing local materials and delivering materials directly to demand sites.[3]

The specific positioning of each warehouse is shown in Table 1:

Table 1. Position of Each Warehouse.

Level	Warehouse	Position
Provincial	Distribution Centre	It controls material information, unify the management of inventory levels for various warehouse. It can directly distribute required materials to demand sites, or allocate materials to branch warehouse and terminal warehouse.
Provincial	branch warehouse	It is a supplement to the distribution centre and mainly responsible for regional warehouses. It can supply to the terminal warehouse and distribute materials to sites directly.
Municipal and below	terminal warehouse	Store local materials or materials that cannot be stored at demand sites, directly deliver materials to demand sites, ensuring supply services.

2.3 Objectives

The primary objectives of the hierarchical classification of power material repositories are as follows:

1. Optimization of service

As a special type of material, power materials are the fundamental guarantee for quickly restoring power supply in the event of grid failures. Only with a reasonable layout of various warehouses can electrical materials be promptly delivered to material demand sites, significantly improving the timeliness of deliveries, thereby ensuring the efficient and stable operation of the power grid.[7]

2. Capacity improvement

Current data shows that the warehouse utilization of X-Electric Power Corporation's electrical material repositories is low. Their potential to function as storage reservoirs is not fully realized, with some warehouses having zero capacity utilization. This situation leads to significant resource wastage. Therefore, implementing a hierarchical classification strategy for X Electric Power Corporation's electrical material repositories is aimed at increasing inventory turnover and improving utilization.

3. Cost reduction

Reducing distribution costs is a crucial objective of the hierarchical classification of electrical material repositories and serves as a key measure for determining the rationality of such repositories. Cost reduction is not limited to construction costs but also includes transportation and operational costs. Thus, when establishing a hierarchical layer strategy for X Electric Power Corporation's electrical material warehouses, various costs must be fully considered to make optimal location decisions. [4,8]

3 Hierarchical Layer Strategy for Power Material Warehouse on X Electric Power Corporation

3.1 The hierarchical structure of power material warehouses

When power material companies transport critical production, such as some operation or spare parts, a **distribution centre** is needed for allocation. The materials are first transported by **suppliers** to the distribution centre, which then allocates them to **branch warehouse or terminal warehouse**. Finally, materials are delivered to the required locations. Therefore, we establish a hierarchical layer strategy model to deliver the power materials under various logistics cost constraints. The flow of materials as shown in the figure 1.

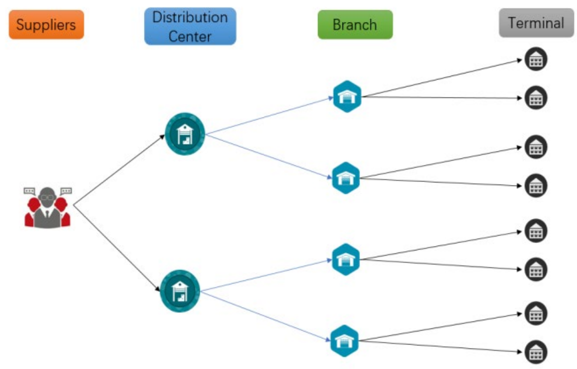

Fig. 1. The flow of materials

The assumptions for the hierarchical classification strategy model are as follows:

1. The capacity of branch meets the demand of terminal warehouse.
2. A warehouse can transport materials to multiple demand points, but a single demand point can only accept materials from one warehouse.
3. The demand quantity at each terminal warehouse is known.
4. The transportation unit cost of different types of electrical materials is the same.
5. Warehouse storage costs are not considered.
6. Alternative branches are known and will be optimized within the alternative solutions.
7. All transportation between nodes is completed in a single step, with the same vehicle transportation speed between nodes.
8. Each warehouse is subject to storage capacity constraints.

3.2 Modelling

3.2.1 Parameter Setting

The parameter settings of the model are as follows:

0: Distribution Centre **i**: the **i-**th branch warehouse.

j: the j-th terminal warehouse.

Q_{0i} : the volume of transportation from the distribution centre to the i-th branch warehouse.

Q_{0j} : the volume of transportation from the distribution centre to the j-th terminal warehouse.

Q_i : the demand of the **i-**th branch warehouse.

Q_j : the demand of the **j-**th terminal warehouse.

Q_{ij} : the volume of transportation from **i-**th branch warehouse to the **j-**th terminal warehouse . $i \neq j$

d_{0i} : the distance of transportation from the distribution center to the i-th branch warehouse.

d_{0j} : the distance of transportation from the distribution center to the **j-**th terminal warehouse.

d_{ij} : the distance of transportation from i-th branch warehouse to the **j-**th terminal warehouse. $i \neq j$

c : Transportation Rates.

S_0 : Capacity of the distribution centre.

S_i : Capacity of the **i-**th branch warehouse.

α : Storage rate of unit warehouse materials.

β : Penalty rate for unit warehouse materials

r : Service radius of the distribution centre

γ : Service radius of the branch warehouse

ϕ^1 : The service radius of the distribution centre is the distance from the distribution centre to the branch warehouse that exceeds the service radius of the distribution centre.

ϕ^2 : The service radius of the distribution centre is the distance from the distribution centre to the terminal warehouse that exceeds the service radius of the distribution centre.

ϕ^3 : The service radius of the distribution centre is the distance from the branch warehouse to the distribution centre that exceeds the service radius of the distribution centre.

3.2.2 Decision variables

$$x_i = \begin{cases} 1 & Selection\ of\ \ the\ i\_th\ branch\ warehouse \\ 0 & No\ selection\ of\ \ the\ i\_th\ branch\ warehouse \end{cases}$$

$$y_{ij} = \begin{cases} 1\ from\ i\_th\ branch\ warehouse\ to\ j\_th\ terminal\ warehouse \\ 0\ else \end{cases}$$

$$y_{0i} = \begin{cases} 1\ from\ distribution\ center\ to\ i\_th\ branch\ warehouse \\ 0\ else \end{cases}$$

$$y_{0j} = \begin{cases} 1 from\ distribution\ center\ to\ j\_th\ terminal\ warehouse \\ 0\ else \end{cases}$$

3.2.3 objective function

The hierarchical layer strategy model of power material warehouses must consider many influencing factors. Transportation costs is one of the most significant factors. This paper consider incorporates transportation costs, warehouse maintenance costs, and time penalty costs into the model to minimize operating costs.

1. Transportation Costs

$$TC_1 = \sum_i cQ_{0i}d_{0i} + \sum_j cQ_{0j}d_{0j} + \sum_i \sum_j cQ_{ij}d_{ij} \tag{1}$$

These constitute a significant portion of a company's overall costs. Warehouse location, distance from supply points and demand points, and transport capacity determine the method and means of transportation to minimize costs. In this study, transportation costs include costs incurred when materials are transported from the distribution centre to branch warehouses, from the distribution centre to terminal warehouses, and from branch warehouses to terminal warehouses.

2. Maintenance Costs

$$TC_2 = \sum_i \sum_j \alpha(Q_i + Q_{ij}) \tag{2}$$

These represent the expenses associated with managing warehouse materials and are generally related to material quantity. Larger material quantities lead to higher warehouse maintenance costs.

3. Penalty Costs

$$TC_3 = \sum_i \beta Q_{0i}\phi^1 + \sum_j \beta Q_{0j}\phi^2 + \sum_i \sum_j \beta Q_{ij}\phi^3 \tag{3}$$

While the timely transportation of electrical materials is not a high priority during normal material transportation, modern logistics has increased the demand for timeliness and customer satisfaction. In cases of emergency power failures, it is imperative that materials reach the site promptly. Therefore, to create a comprehensive hierarchical classification strategy model, time penalty costs are considered. When the demand quantity at the destination is low and the distance from the warehouse is far, warehouse delivery timeliness is likely to decrease. Since there is no direct time measurement for warehouse delivery in electrical grid warehouses, delivery time is converted into a service range of the warehouse. If the distance from the demand point to the warehouse exceeds the service radius of the warehouse, a penalty cost is imposed on the selected warehouse location.

In conclusion, the specific expression to minimize total costs is as follows:

$$\min z = TC_1 + TC_2 + TC_3 \tag{4}$$

3.2.4 Constraint Conditions

The constraint conditions for the model are as follows:

1. The flow into the terminal warehouse equals the demand quantity.

$$\sum_j Q_{0j} + \sum_i \sum_j Q_{ij} = Q_j \qquad (5)$$

2. The flow out from the distribution centre is less than the inventory capacity.

$$Q_{0i} + Q_{0j} \le S_0 \qquad (6)$$

3. The sum of the flow out from the sub-repository and the demand quantity is less than the inventory capacity.

$$Q_{ij} + Q_i \le x_i \bullet S_i \qquad (7)$$

4. The flow into the terminal repository is less than the inventory capacity.

$$\sum_j Q_{0j} + \sum_i \sum_j Q_{ij} \le S_j \qquad (8)$$

5. The distance from the distribution centre to the sub-repository exceeds the service radius of the distribution centre is greater than or equal to zero.

$$\phi^1 = d_{0i} - r \ge 0 \qquad (9)$$

6. The distance from the distribution centre to the terminal repository exceeds the service radius of the distribution centre is greater than or equal to zero.

$$\phi^2 = d_{0j} - r \ge 0 \qquad (10)$$

7. The distance from the sub-repository to the terminal repository exceeds the service radius of the distribution centre is greater than or equal to zero.

$$\phi^3 = d_{ij} - l \ge 0 \qquad (11)$$

4 Conclusion

This paper first provides a brief overview of the layout analysis of X Electric Power Corporation's electrical material warehouses and proposes a hierarchical layout model adapted for the management of electrical materials. Based on the hierarchical layout model of electrical material repositories, it introduces a hierarchical classification management system. Finally, it establishes an evaluation indicator system for hierarchical classification strategy for electrical material repositories based on the objectives of such hierarchical classification. This serves as a foundation for research into active distribution of electrical materials.

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