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Product Layout Optimization and Simulation Model in a Multi-level Distribution Center

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Abstract

We consider the product allocation problem in logistics engineering, which allows incorporating various aspects in horizontal and vertical direction. These aspects include carrying time, the turnover rates of products, relevance of product demand, elevator waiting time, vertical transportation time, etc. we develop a 0-1 programming model with two objectives-minimization of total transportation time and maximization of relevance of product demand. In order to obtain average waiting time of every level, we establish an elevator simulation model considering the limitation of elevator capacity. The proposed optimization model can be solved using Genetic algorithm heuristically. A numerical example shows its effectiveness.

Key words: Multi-level Distribution Center; Product Layout Optimization; Elevator Simulation; Logistics engineering

1.Introduction

Distribution center operation and management is one of the essential parts of manufacturing and service operations. The product layout is a key to distribution center operations. The product layout problem is concerned with the question of positioning products to storage locations. At present literatures on single-level product layout are highly extensive. Though multi-level distribution center is more and more popular in the manufacturing and service sections, research on product layout in a multi-level distribution center has received less attention. The earliest work on the multiple-level layout problem was done by Johnson (1982). He investigated the problem of relative location of facilities in a multiple-floor building. Lai,Xue, and Zhang(2002) investigated a multi-level warehouse layout problem considering multiple storage areas in different levels of a warehouse . Lai,Xue, and Zhang(2006) considered a multi-level warehouse layout problem again and proposed a class of new heuristics by combining a genetic algorithm and path linking strategy to solve the problem. Literatures above share the same assumption - The elevator capacity is enough. That is, the vertical transportation operation is always available. However in real life it is common for product to waiting for the elevator because of the limitation of elevator capacity.

To be more practical, this paper establishes elevator simulation mode with the help of AUTOMOD software to obtain average elevator waiting time. Besides, considering other factors, such as characteristics of products, turnover rate, relevance of demand and limitation of space, the product layout optimization and simulation model is developed.

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2. The Formulation of Multi-level Product Layout Model

2.1 Assumptions and Notations

In the multi-level product layout problem, it is assumed that there is only one kind of palette. Different products are located in different storage spaces.

The distribution center has I floors. There are J rows and K columns shelves at floor 2 to floor I. Floor 1 is not for storing product. Logistics operations can be done for h hours a day, d days a year.

The following notations are introduced for the parameters of the model.

t_{ijk} : Time of carrying product located in row j, column k to the elevator at floor i;

t_i : Average waiting time at level i, which can be obtained by the simulation model;

η_{xy} : Relevance of demand between product x and product y, $0 \le \eta_{xy} \le 1$;

λ_i : Arrival interval of product at level i, which can be obtained by annual turnover rate of products;

f_l : annual turnover rate of product l;

M: total number of orders in one year;

$$a_{lijk} = \begin{cases} 1 & when \quad product \quad l \quad is \quad assigned \quad to \quad row \quad j \quad column \quad k \quad at \quad floor \quad i \\ 0 & else \end{cases}$$

$$\Phi_{xm} = \begin{cases} 1 & when \quad product \quad x \quad is \quad in \quad the \quad order \quad x \\ 0 & else \end{cases};$$

$$\Phi_{xym} = \begin{cases} 1 & when \quad product \quad x \quad or \quad y \quad is \quad in \quad the \quad order \quad m \\ 0 & else \end{cases};$$

$$b_{xy} = \begin{cases} 1 & when \quad product \quad x \quad is \quad adjacent \quad to \quad product \quad y \\ 0 & else \end{cases};$$

Where: i=2, 3…I; j=1, 2…J; k=1, 2…K;
l=1, 2…L; x=1, 2…L-1; $y = x+1$, x+2…L, m=1, 2…M,

2.2 Model Formulation

Several objectives can be formulated for the product layout problem. We will focus on two of them with the attempts of improving shipment and meeting the needs of customs as soon as possible.

2.2.1 Objective 1: Minimization of total carrying time

Different from single-level distribution center, horizontal and vertical carrying time should be considered at the same time. In order to shorten carrying time, products with high turnover rate should be closed to elevator at high floor.

First objective function is shown as follows,

$$F_1 = \min \sum_{l=1}^{L} \sum_{i=2}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} \left(t_{ijk} + t_i\right) \cdot a_{lijk} \cdot f_l \qquad (1)$$

2.2.2 Objective 2: Maximization of relevance of product demand