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The Storage Method of a Leaf Tobacco Warehouse in Leaf Tobacco Factory

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원료공장 잎담배 창고의 저장방법

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ABSTRACT : This study deals with the leaf tobacco assignment problem of a leaf tobacco warehouse with multiple input points and single output point. Also, the number of storage frequences is not necessary the same as that of retrieval for each leaf tobacco. A mathematical model is developed with the objective of minimizing the total travel distance associated with storage and retrieval operations. We also develop several heuristics based on the retrieval order frequency, retrieval/storage frequency ratio of leaf tobacco, and ABC curve. It is observed that the ABC curve based heuristic gives the best solution which is near optimal. Based on the test results from real world data, the ABC curve based heuristic is found to give a best performance. Comparing to current assignment method, the ABC curve based heuristic reduced total travel distance about 17.2%.

***Key words** : logistics, warehouse, leaf tobacco, heuristics*

1. Background

In manufacturing companies, logistics costs are a major portion of production costs. Logistics cost is increased rapidly by week social over head capital, aggravated traffic condition and diverse demand of customer service. In spite of this situation, manufacturing companies are not recognized the importance of logistics system. In the future, the companies which are not accomplish rational logistics system are difficult to survive in competition. Among the logistics system, warehousing is one of the key issue. Especially, warehouse layout is the key point of warehousing. An effective warehouse layout can reduce operation costs. Assignment of space to different items is one of the warehouse layout problem. Many domestic companies maximize space utilization by the application of warehouse space assignment rules which are proposed by many researchers.

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When KT&G assign the leaf tobacco purchased from farmer to warehouse, there are many problems in warehouse layout. Because the assignment of space to different items depend entirely on experience of warehouse manager, the utilization of warehouse space is not effective and material handling cost increase rapidly. Therefore, we study the leaf tobacco warehouse layout system and want to develop effective assignment method.

In this thesis, we investigate a new warehouse layout problem ; multiple input points and different storage/retrieval units. Also, we formulate the mathematical model to minimize total travel distance in a planning period. Because the mathematical model is NP-hard(Lai *et al*(1999), we develop heuristic procedure to solve this layout problem rapidly. The case study illustrates how the heuristic procedure can improve an alternative COI rule and existing layout.

2. Problem Description

In our warehouse layout problem, we assume that ;

(1) The item assigned storage cell j is stored from the colsest input point.
(2) The forklift truck travel rectilinear (retangular) distance.
(3) The input and output are performed by single command.
(4) The work-load required to pick and load items at cell is constant and thus can be ignored.

The leaf tobacco warehouse has multiple input points and single output point and the I/O point is not same.

The transported unit load volumn from input point to storage cell by forklift truck is same regardless of density of items. Also, when the demand is generated by customer(leaf tobacco manufacturing factory), the transported unit load weight from storage cell to output point is same regardless of volumn of items.

The problem is described as;

(1) The goal of the problem is to minimize the total travel distance
(2) Every item must be assigned to exactly one cell
(3) A cell can store more than one item type.

FORMULATION OF THE MATHEMATICAL MODELS

In this chapter, we formulate travel distance model for a new warehouse layout problem after introducing some assumptions and notations.

In first section, we introduce several assumptions and notations for the ease of descriptions. In the next section, we formulate travel distance model.

1. Assumptions and notations

The following assumptions and notations are introduced for the formulation of the model.

1.1 Assumptions

To formulate a travel distance model, the following assumptions are needed ;

(1) Each storage cell can store more than one item type.
(2) The forklift truck travel rectilinear (retangular) distance.
(3) The input and output are performed by single command.
(4) The work-load required to pick and load items at cell is constant and thus can be ignored.

1.2 Notations

To develop the travel distance model, the following notations are needed ;

m : the number is items to be stored in the warehouse
n : the number of cells in the warehouse
Cap_j : storage capacity of cell j
V_i : total volume of item i
C_I : volume of unit retrieval order
C_O : weight of unit retrieval order
d^I_j : distance from storage cell j to closest input point
d^O_j : distance from storage cell j to output point
ρ_i : density of item i

2. Mathematical Model

Let X_{ij} is quantity of item type i assigned to storage cell j. The objective here is to find an assignment of items to cells, such that the distance traveled by forklift truck is minimized. Therefore, mathematical model is formulated as below.

$$Min \sum_{i=1}^{m}\sum_{j=1}^{n} \left(\frac{X_{ij}}{C_I} d^I_j + \frac{X_{ij}}{C_O} \rho_i d^O_j\right)$$

s.t

$$\sum_{i=1}^{m} X_{ij} \le cap_j \text{ , for } j=1,2,.....,n$$

$$\sum_{j=1}^{n} X_{ij} = V_i \text{ , for } i=1,2,.....,m$$

$$X_{ij} \ge 0 \text{ , for } i=1,2,.....,m : j=1,2,.....,n$$

The total distance traveled form input point to storage cell and from storage cell to output point is sum of two terms. Constrains set (1) restricts that no cell capacity is violated, constraint (2) ensure that every item should be stored.

DEVELOPMENT OF HEURISTICS

This chapter presents a heuristic procedure for determining warehouse layout in a forklift truck pallet storage and portable rack retrieval environment.

1. Notations

To develop heuristic procedure, the following notations are needed ;

f^I_i : storage frequency of item i
f^O_i : retrieval frequency of item i
f^{IO}_i : sum of storage and retrieval frequency of item i
$FR^{O/I}_i$: retrieval/storage frequency ratio
d^I_j : distance from storage cell j to closest input point
d^O_j : distance from storage cell j to output point
d^{IO}_j : sum of input and output distance
$DR^{O/I}_j$: output/input distance ratio

2. Frequency ratio based heuristic

2.1 General flow of heuristic

The frequency ratio based heuristic starts with reading the input frequency from the input point to storage cell and output frequency from cell to output point. Using frequency data, we calculate and arrange frequency ratio of each items.

Also, we calculate and arrange travel distance from input point to storage cell, travel distance from storage cell to output point and distance ratio, respectively. Using calculated frequency ratio, travel distance and distance ratio data (1) we assign item which has large input/output frequency ratio, namely input rate is relatively frequent related to other items, to cell which has short travel distance to input point amount to cell capacity. (2) Conversely, item which has large output/ input frequency ratio, namely output rate is relatively frequent related to other items, to cell which has the shortest travel distance to output point amount to cell capacity. (3) Finally, item which has large output/input frequency ratio to cell which has small output/input distance ratio.

2.2 Computational Procedure

The computational procedure in frequency ratio based hueristic includes the following steps.

Case 1) Output point distance oriented

Step 1 : Calculate frequency ratio of items.
From input and output frequency, we calculate output/input frequency ratio
$FR^{O/I}{}_i$ $(= f^I{}_i / \ f^O{}_i)$

Step 2 : Sort frequency ratio of items with decreasing order.
$FR^{O/I}{}_1 > FR^{O/I}{}_2 > FR^{O/I}{}_3 > FR^{O/I}{}_4 > \ldots..$

Step 3 : Calculate and sort distance from storge cell to output point with decreasing order
$d^O{}_1 > d^O{}_2 > d^O{}_3 > d^O{}_4 > \ldots..$

Step 4 : Calculate storage cell capacity
Cap_j = CD(Depth of cell) X CH(Height of cell) X CW(Width of cell)

Step 5 : Assign item to storage cell

(1) The biggest frequency ratio item assigned to $cell_{1st}$ which is closest to the output point, using up as much space required to accommodate the total ratio of that item.
(2) If not enough space is available in $cell_{1st}$, the amount ratio left over goes to $cell_{2nd}$, On the other hand, if any empty space remains in $cell_{1st}$, the next biggest frequency ratio item is also placed in $cell_{1st}$ in the appropriate amount up to the capacity of $cell_{1st}$.
(3) This process continues until all items have been placed in their proper cells, successively further from the output point.

Case 2) Output/input point distance ratio oriented

Step 1 : Calculate frequency ratio of items.
From input and output frequency, we caluculate output/input frequency ratio
$FR^{O/I}{}_i$ $(= f^I{}_i / \ f^O{}_i)$

Step 2 : Sort frequency ratio of items with decreasing order.
$FR^{O/I}{}_1 > FR^{O/I}{}_2 > FR^{O/I}{}_3 > FR^{O/I}{}_4 > \ldots..$

Step 3 : Calculate and sort input/output distance ratio of cells with increasing order
$DR^{O/I}{}_1 > DR^{O/I}{}_2 > DR^{O/I}{}_3 > DR^{O/I}{}_4 > \ldots..$

Step 4 : Calculate storage cell capacity
Cap_j = CD(Depth of cell) X CH(Height of cell) X CW(Width of cell)

Step 5 : Assign item to storage cell

3. ABC curve based heuristic

3.1 General flow of heuristic

The ABC curve based heuristic starts with reading (1)the sum of input and output frequency of items (2) the sum of input and output travel distance for each cell. Using each data, we plot ABC curve for item and cell, respectively, and divide ABC curve into three sectors applying equations proposed by Paul, S.B. (1993). (1) After dividing ABC curve into three sectors, we distribute items to each sectors and sort items in a each sector using input and output frequency ratio. After sorting is completed, we assign item which has large output/input frequency ratio to cell which has small output/input distance ratio. (2) After dividing ABC curve into three sector, we distribute cells to each sectors and sort cells in a each sector using input and output distance ratio. After sorting is completed, we assign cell which has small input/ouput distance ratio to item which has large input/output frequency ratio.

3.2 Computational procedure

The computational procedure in ABC curve based hueristic includes the following phases.

<u>Phase 1. Dividing the items and cells into three sectors.</u>

The following steps summarized the activities in Phase 1.

Case 1) Item oriented

Step 1 : Calculate total frequency of items.

$f^{IO}_i = f^I_i + f^O_i$

Step 2 : Sort total frequency of items with decreasing order.

$f^{IO}_1 > f^{IO}_2 > f^{IO}_3 > f^{IO}_4 > .....$

Case 2) Cell oriented

Step 1 : Calculate total travel distance of cells.

$d^{IO}_j = d^I_j + d^O_j$

Step 2 : Sort total frequency of items with decreasing order.

$d^{IO}_1 > d^{IO}_2 > d^{IO}_3 > d^{IO}_4 > .....$

Step 3 : Plot ABC curve
Using above data, we plot ABC curve for item and cell, respectively.

Step 4 : Dividing the ABC curve into three sectors(A,B,C).

Phase 2 : Assign items to cells.

Step 1 : Apply frequency ratio based heuristic for item A group and cell A group.

Step 2 : Apply frequency ratio based heuristic for item B group and cell B group.

Step 3 : Apply frequency ratio based heuristic for item C group and cell C group.

COMPUTATIONAL EXAMPLE

In this section, we compare various heuristics to current assignment method.

Assignment methods		Total Travel Distance(m)
Current assignment		34,539,930
Retrieval frquency based heuristic		32,294,459
Output/Input frequency ratio based heuristic	Output point distance oriented	30,775,407
	Output/input point distance oriented	30,224,711
ABC curve based heuristic		28,614,914

CONCLUSION

In this paper, the warehouse layout problem with multi-input points and different storage/ retrieval units is studied. After formulating mathematical model, we propose a new heuristic procedure which is based on frequency ratio and ABC curve.

Computational examples are conducted on existing leaf tobacco warehouse layout problem. The results of comparative study indicate that ABC curve based heuristic is the most effective method to minimize total travel distance. Also, ABC curve based heuristic reduce total travel distance about 17.2% comparing to existing warehouse layout.

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