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The Research of Logistics Cost and Influencing Factors Based on Cross Docking

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Abstract

For reducing the cost on logistics, Cross Docking is a very effective management mode. In this paper, we set the entire logistics system cost as the objective function, proposed and established a mathematical model of cross docking mode. And then a dynamic programming algorithm was constructed to solve the given model. The result of numerical experiments shows that cross docking mode is more suitable for longer lead times and shorter customer demand variances. Finally, the model and algorithm in the paper can provide a certain theoretical foundation for the management of the actual.

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Key Words: Cross Docking; Logistics Cost; Inventory Management;

1. Introduction

In this paper, the research is based on a new inventory management strategy: Cross Docking. Cross Docking is an operational mode of only shipping and receiving functions which eliminating the function of cargo storage capabilities in any intermediate point of the logistics (warehouse or distribution center). Cross docking is effective to increase the efficiency of the logistics system, which greatly reduces the consumption of the goods during transport is mainly to increase the moving speed of the goods in the supply chain. In this mode, the cross docking

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center unlike the traditional distribution center for storage, just simple transported, this mode of operation is similar to the railway marshalling yard.

There are many factors affect Cross-docking mode, such as: the right products; efficient and reliable suppliers; professional and reliable service provider of supply chain; process optimization and problem solving skills; skilled management and staff to operate independently; computer system; workload.

2. Establish Model of Cross Docking System

2.1. Description of Cross-docking system

In this Cross-docking mode, distributor generally not ordinary storage, but in an amount of order up to level mode, when retailer inventories fell to a certain number, the system will be issued based on historical information orders, which equivalent of a forecast of demand for the next stage of shops. Where these goods were transport to the center of cross docking and then re-allocated, which need to consume a certain amount of resources resulting in some of the spending.

![Fig. 1 Working Process of Cross Docking Center](image)

2.2. Model construction

- Basic Assumptions
  1) The system adopts the subscription model of order-up-to-level; assume that the review time of every period is $t$.
  2) Shop and Cross docking center place an order in the end of the period $t$.
  3) Each retailer customer demand is independent and meets certain function demand.
  4) In two adjacent time intervals, discontinuities occur out of stock situation.
  5) Assume that the piecewise interval $t$ is unit 1 time.
  6) Lead time $l_c$ and $l_f$ are integer multiples of $t$.

- Model Establish

  This paper studies that the total cost of cross docking system in a quite long time $T$ Inside. $T$ is divided into some period of time. With $t$ says each division time, Its length is $t$. $T$ can be expressed that $T = 1, 2, 3 \ldots t \ldots$. The cross docking system is composed of a shop and a cross docking center. In period of a separate $t$, each store in the case of goods to meet customer needs $D^s_t$. (Under the condition of no goods produced in the absence of stock loss, and in the beginning of the period $t$, The store to cross docking center delivery the order number $Q^s_t$ for supplement store goods). $I^s_t$ is the inventory for shops in the beginning of the period $t$. 
The cost of the total system is composed of three parts. The first part is the transport costs. This paper assumes that it related to transport distance, including the cost of goods from an outside supplier to the cross docking center, as well as goods from the cross docking center to every retailer. For the second part are storage costs and the necessary operating expenses in the cross docking logistics center. The third part is store cost, including storage costs and the loss of cost caused by the cross docking logistics center out of stock.

This paper studies the store for the mode of order up to level. When the store inventory quantity reaches the order up to level, the store send an order to the distribution center, the distribution center send an order to supplier, then the supplier need to transport goods to the distribution center by pass $l_c$ time. Finally, the distribution center takes $l_{t-1}$ time delivery to the j store. For convenience, $l_c$ and $l_{t-1}$ is integer times of $t$. Namely, the arrival and send of goods is the beginning or the end at the t time.

The cost of the cross docking logistics center transports goods to each store is

$$Z_{tc} = \sum_t \sum_j (l_{t}^p Q_{j(t-1)}^p + l_c D_{t-1}) q$$

(1)

Where $Q_{j(t-1)}^p$ is volume of each store j orders to the distribution center at the end of T-1 period, $q$ is the cost of transporting goods per unit of time, $D_{t-1}$ is the volume of orders distribution center at the end of the time period t-1 the number of orders placed on suppliers.

There are some necessary operational activities in cross docking center, such as receiving, sorting, retrieving, and shipping. The cost of cross-docking center in period is denoted as $Z_{cc}$.

$$Z_{cc} = \sum_t h_c D_m + \sum_t \max[(D_m - R), 0] h_r$$

(2)

For the sake of simplicity, we believe that generalized cost of cross docking only related to the volume of goods from supplier. Where R is the ordinary capacity which cross docking can operation in unit time, m equals to $l_c^t$: $h_r$ is punishment cost when the number of goods is more than operational capacity of cross docking, $h_c$ is ordinary cost of cross docking.

In fact, the demand of each store is separate, Kahn et al [1] pointed out that the store needs is a certain relationship within two adjacent time slots, Expressed by the formula below:

$$Q_{jt}^p = d + \rho Q_{jt}^p + \mu_{jt}$$

(3)

Where, $\rho$ is a constant and it greater than or equal to 0, less than 1, represents the dependencies of the demand in the two periods. $d$ is an average value of $Q_{jt}^p$ when $\rho$ is zero. $\mu_{jt}$ is independent and mean is zero, the variance is the standard normal distribution of $\sigma^2$. Lee et al [2] pointed out that the store j at the end of the time period t, the optimal reorder point quantity is:

$$l_{jt}^p = m_{jt}^p + k_p\sqrt{v_t^2}$$

(4)

In which,

$$m_{jt}^p = \frac{d}{1-\rho}\left[(1 + 1) - \frac{\rho(1-\rho)c}{1-\rho} + \frac{\rho(1-\rho)(1+t)}{1-\rho} D_{jt}^p\right]$$

(5)

$$v_t^2 = \frac{\sigma^2}{(1-\rho^2)}\sum_{i=1}^{t} (1 - \rho^i)^2$$

(6)

$$q_{jt}(C) = \frac{[K_0 + (1-K_0) A_f] \sin \phi}{\sigma_{\phi}}$$

$$\sigma_{\phi} = 1 + (2A_f - 1) \sin \phi$$

(7)
\[ k_i = \Phi^{-1}\left( \frac{\rho_s}{\rho_s + h_s} \right) \]

(8)

Where \( \Phi \) is the function of standard normal distribution. Then, the holding cost of stores in the entire system is:

\[ Z_{sc} = \sum h_s \int_{t-1}^{T} x G(x) \, dx + h_s \max \left( I_{ij(t-1)}^s - D_{ij(t)}^s, 0 \right) + q_s \int_{x}^{T} (t-x) G(X) \, dx \]

(9)

Where \( G(x) \) is Demand function which changes over time. Then, Based on above analysis, the total objective function of the model is \( Z_{sc} + Z_{cc} + Z_{sc} \), and subject to:

\[ Q_{t}^{s} \geq 0 \]

(10)

\[ D_{i}^{s} = \int_{0}^{T} G(x) \, dx \]

(11)

\[ \int_{0}^{T} G(x) \, dx = I_{i} \]

(12)

Where (10) means the number of orders sent by stores to cross docking center is positive, (11) means the store inventory is non-negative and (12) shows the relationship between order up to level of cross docking center and the customers demand function.

3. Model Solution based on DP Algorithm

In order to better study algorithm, we introduce the following symbols:

- \( x_t \): The volume of orders sent by shop to cross docking center in \( t \) period.
- \( s_t = \{0, 1, 2, ..., I^U - I^1\} \): The set of order’s volume which shop sent to supplier, and \( x_t \in s_t \).
- \( g(x) \): State transition equation.
- \( N = T/\tau \): Represent Total number of stages.

This paper design dynamic programming algorithm for this model and Specific steps of the algorithm was followed:

Step 1: \( f_0(s_0, x_0) = 0 \);

Step 2: \( i = 1, \; j = 0 \), \( k_i = I^U - I^1 \), \( s_i = \{0, 1, 2, ..., I^U - I^1\} \), \( x_i \) is the \( i \)-th element of \( s_i \), then calculate \( f_i(s_i, x_i) = f_{i-1}(s_{i-1}, x_{i-1}) + d_i(s_i, x_i) \);

Step 3: if \( i > k_i \) then go to step 4, else then set \( i = i + 1 \) and go to step 2;

Step 4: if \( t \leq N \) then \( t = t + 1 \), \( i = 0 \), else go to step 7;

Step 5: Set \( j = 0 \), \( I_{ij}^{t-1} = I_{ij}^{t-2} + Q_{ij}^{t-1} - \int_{0}^{T} G(x) \, dx \), \( s_{ij}^j = \{0, 1, 2, ..., I^U - I_{ij}^{t-1}\} \), if \( x_{ij} \) is a subset of \( s_{ij}^j \), then \( f_i(s_i, x_i) = \min \{ f_{i-1}(s_{i-1}, x_{i-1}) + d_i(s_i, x_i) \} \), \( j = j + 1 \) then go to step 5, else then go to step 6;

Step 6: set \( i = i + 1 \), if \( i \) is subset of \( s_{i-1} \) then go to step 5, else go to step 4;

Step 7: \( f_N(s_N, x_N) \) is the optimal value in stage \( N \) and \( X_N = \{x_{i_{1}}, x_{i_{2}}, ..., x_{i_{N}}\} \) is optimal decision-making process.
4. Numerical Experiment

In previous section, we establish a model and design a dynamic algorithm. Now, numerical experiment is designed to prove the result and explore new results that cannot be examined directly from analytical solutions. In order to verify the expected cost problem in a different environment of this cross docking mode. It is assumed that the customer demand is in line with the standard normal distribution. Then determine the default values: \( n = 10 \), \( l_c = 2 \), \( l_r = 3 \), \( q = 2 \), \( \sigma = 40 \), \( \rho = 0.5 \), \( h_i = 2 \), \( h_r = 10 \). When analysis one of the parameters on the total cost of the cross docking system, the other values are determined in default values. This paper use MATLAB programming language for analysis the different degree of changes in customer demand, lead time.

![Figure 2 Relationship between cost and standard deviation of demand function](image)

![Figure 3 Relationship between cost and lead time](image)

5. Conclusions

Since cross-docking system can increase the speed of the flow of goods as well as reduce the system cost, therefore it attracts more attention from industry and academia. This paper establish a mathematical model which objective is to minimum total system cost by quantitative analysis of the logistics system transportation costs, storage costs, as well as out of stock punishment cost and then design a dynamic programming algorithm to solve this model. Meanwhile, analyzed different lead times and different demand function standard deviation influence the cost of system. The result shows that cross docking mode is more suitable for longer lead times and shorter customer demand variance. Finally, through continuous research, the authors believe that cross docking will certainly get extensive applications in the future.
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