Multi Period Distribution Planning Problem of Crossdocking Network

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Abstract. The purpose of this study is to investigate modeling and the analysis of physical distribution of crossdocking network. Crossdocking is a new strategy which will be use to reduce inventory and also delivering time to enhance customer's responsibility. This will be done through removing storage process which leads to cost reduction and creating new opportunities. This paper deals with the multi period planning of a crossdocking distribution network where multi item freights are transported. The problem is formulated as an integer linear programming model and solved using GAMS software in different sizes. Experimental results demonstrate the ability of the proposed algorithms achieving remarkable results.

Keywords: Supply Chain, Multi Period Planning, Physical Distribution, Crossdock network.

1 INTRODUCTION

In today's global competitive environment, reduce maintenance costs and increase service levels at all stages of the supply chain with the aim of increasing responsiveness to customers is essential. In general, each supply chain is composed of three main stages namely, procurement, production and distribution, in which the phase distribution due to direct contact with customers is very important. The movement of goods process in the supply chain distribution process is called physical distribution process that encompasses the output of products from suppliers to customers. Flow of goods in these sectors may be transmitted through the networks of distribution centers to stores or directly to customers. Planning and management of the flow of goods in such a network has a direct impact on the cost of supply chain and customer satisfaction. Crossdocks are a new option in the physical logistics of goods that have been able to simultaneously cut costs and reduce delivery time, reduce the cost transferring goods and provide customers satisfaction. This study seeks to provide a programming model for implementing effective distribution crossdocks across the supply chain. Scientists have a special interest in introducing, implementing and evaluating the performance of crossdocks in recent years.

In this paper, a multi-period distribution planning problem in a supply network including multiple crossdocks is presented as an integer linear programming model and solved through GAMS software. The contents of this article are organized this way: In the next section the related literatures will be reviewed briefly. Then the problem is introduced and the mathematical model will be presented. The experimental results will be illustrated in section 4 and finally, summing up the results of the study and some directions for future research are stated in section 5.

2 LITERATURE REVIEW

Agustina et al. (2010) reviewed the mathematical models presented in the literature of the planned crossdocks and divided them according to their desired level decisions into three categories: strategic, tactical and operational. Some issues such as scheduling, assignment of trucks to docks, routing of vehicles and assignment of products are at the operational level. In tactical level the crossdocks layout design problem and in strategic-level the supply network design problem include crossdocks has been studied. Belle et al. (2012) also provided guidelines for successful implementation strategies. They also feature the difference of the variety of crossdocks with a brief statement of them. Further in this paper the studies on crossdocks are divided and briefly reviewed.

Jayaraman & Ross (2003) studied the design of production systems, logistics, post and transfer and pointed the crossdocks have been involved in the supply chain environment. Their problem includes the various product groups, a central site, several distribution centers and crossdocks and retails. Ross & Jayaramanand (2008) continues to evaluate new innovative ways of positioning the crossdock centers across the network of supply chain. Sung & Song (2003) analyzed the crossdocks location through a network of supply chain and associated service vehicles on routes between suppliers and cross docks or routes through the crossdocks and customers. Mousavi and Tavakkoli Moghaddam (2013) determined simultaneously the position of the crossdocks and routing of vehicles in a distribution network, mixed integer programming model in the form of modeling and used an innovative method of two-step to solve it.

Lim et al. (2005) investigated on the distribution of the products through a network of crossdocks across the state that sent and received in a pre-specified time intervals can be done. Optimal scheduling in the transport network and minimum delivery delay at distribution centers are both considered. Miao et al. (2010) introduced the scheduling of distributed applications on a network of suppliers and customers to serve a specified time interval with delay possibility. Chen et al. (2006) deal with a network of cross docks model based on supply and demand forecasts to minimize the total operating costs of distribution. Lee et al. (2006) have created their own hybrid models in their articles on the issue of the scheduling and routing of vehicles in a distribution network consisting of crossdocks. Liao et al. (2010) reviewed the number of vehicles required and the best scheduling and route of delivery vehicles in the network consist of crossdocks and proposed a heuristic solution method based on tabu search algorithm to solve it. Musa et al. (2010) introduced the problem of determining operational vehicles based on minimizing the total costs of transportation and crossdock network and solved it with an ant colony algorithm. Marjani et al. (2012) have introduced the scheduling problem in distributed crossdocks network through multi-commodity shipments, soft time windows and transaction between the crossdocks. Dondo and Cerda (2013) provided a solution to the problem of routing vehicles through a network that includes a crossdock with unlimited potential in a finite time horizon. Lindsey et al. (2013) also investigated on comparing the use of crossdocks or directly sending in a distribution network. This paper follows the Marjani et al. (2012) model and checks the planned distribution network that includes multi- crossdocks across several time periods. The feature of multi-periods of the problem, which have not been studied so far, is effective in determining the best distribution for long-term time horizons. While the necessity of survival the minimum in the crossdocks is one of the inherent characteristics of crossdocks, previous studies were not included in the mathematical model that can be reviewed and applied with multi-period model.

3 PROBLEM DEFINITION

The physical distribution system is a multi-stage distribution network that includes multi-supplier, multi- distribution centers and multi-retailer or stores. In this network distribution centers all use the crossdocks strategy. Therefore possibly they don't hold inventory in the stores and try to move it fast to the stores. However, it is possible to maintain a limited inventory. Distribution network includes multiple goods and any shipments received from suppliers or sent to retailers can include multiple goods. It is assumed that a 3PL is the owner of all crossdocks network or rented all of them and hence looks to manage fabric an entire network with the aim of minimizing the total cost of crossdocks. Each delivery and every pickup must be occurs in a specified time interval. In fact, delay is not permitted. Possible relationship between cross dock of inventory in the distribution network to compensate for the inadequacy of some of the products is another assumption which aims to expand the solution space and facilities to achieve feasible solutions defined and already mentioned about it in literature.

The objective of this problem is to specify the best assignment of crossdocks to both suppliers and customers and also the best scheduling of vehicles at each crossdock to minimize the total transportation and operational costs. With these definitions, the following integer programming model is formulated to describe the considered problem.

3.1 Indices

i: Index of deliveries from suppliers; $i = 1, \dots, m$

j: Index of pickups to customers; $j = 1, \dots, n$

k, k': Index of Crossdocks; $k, k' = 1, \dots, c$

r: Index of products; $r = 1, \dots, d$

t: index of Time period; $T_{min} \leq t, t', t'' \leq T_{max}$

3.2 Parameters

$M^P_{r,j}$: Amount of product r in pickup j

$M^D_{r,i}$: Amount of product r in delivery i

$C^D_{i,k}$: Transportation cost from delivery i to crossdock k

$C^P_{j,k}$: Transportation cost from crossdock k to pickup j

$C^B_{k,k'}$: Transportation cost from crossdock k to crossdock k'

TS^P_j: Starting time of pickup j

TE^P_j: Ending time of pickup j

TS^D_i: Starting time of delivery i

TE^D_i: Ending time of delivery i

CAP_k: Capacity of crossdock k

H_k: Handling cost per unit product per time unit at crossdock k

$z^w_{r,k}$: Initial Inventory of product r at crossdock k

f_r: Volume of product r

3.3 Variables

$x^D_{i,k,t}$: 1 if delivery i is bound for crossdock k at time t, 0 otherwise

$x^P_{j,k,t}$: 1 if pickup j goes to crossdock k at time t, 0 otherwise

$z_{r,k,t}$: Amount of product r at crossdock k at time t

$x^B_{k,k',t}$: 1 if there is a shipment from crossdock k to crossdock k' at time t

$M^b_{r,t,k,k'}$: Amount of product r in shipment from crossdock k to crossdock k' at time t

3.4 Model

Minimize

$$W = \sum_{k=1}^{c} H_k \sum_{r=1}^{d} \sum_{t=1}^{T_{max}} z_{r,k,t} + \sum_{i=1}^{m} \sum_{k=1}^{c} C_{i,k}^{D} \sum_{t=1}^{T_{max}} x_{i,k,t}^{D}\, t_{i,k} + \sum_{j=1}^{n} \sum_{k=1}^{c} C_{j,k}^{P} \sum_{t=1}^{T_{max}} x_{j,k,t}^{P}\, t_{j,k} + \sum_{k=1}^{c} \sum_{\substack{k'=1 \\ k' \neq k}}^{c} C_{k,k'}^{B} \sum_{t=1}^{T_{max}} x_{k,k',t}^{B}\, t_{k,k'} \tag{1}$$

Subject to:

$$\sum_{k=1}^{c} \sum_{t=TS_i^D}^{TE_i^D} x_{i,k,t}^{D} \leq 1 \quad \forall\, i \tag{2}$$

$$\sum_{k=1}^{c} \sum_{t=TS_{j''}^P}^{TE_{j''}^D} x_{j'',k,t}^{P} = 1 \quad \forall\, j \tag{3}$$

$$\sum_{r=1}^{d} f_r\, z_{r,k,t} \leq CAP_k \quad \forall\, k \ \& \ \forall\, 1 \leq t \leq T_{max} \tag{4}$$

$$z_{r,k,t} = z_{r,k,t-1} + \sum_{i=1}^{m} x_{i,k,t}^{D} M_{r,i}^{D} - \sum_{j=1}^{n} x_{j,k,t}^{P} M_{r,j}^{P} - \sum_{\substack{k'=1 \\ k' \neq k}}^{c} M_{r,t,k,k'}^{B} + \sum_{\substack{k'=1 \\ k' \neq k}}^{c} M_{r,k',k,t}^{B} \quad \forall\, r,k \ \& \ 1 \leq t \leq T_{max} \tag{5}$$

$$\sum_{r=1}^{d} M_{r,t,k,k'}^{B} \leq x_{k,k',t}^{B} \times M \qquad \forall\, k,k',\ k \neq k' \ \& \ 1 \leq t \leq T_{max} \tag{6}$$

$$z_{r,k,0} = z_{r,k}^{w} \quad \forall\, r \ \& \ k \tag{7}$$

$$z_{r,k,t} \geq 0 \ \& \ \text{Integer} \quad \forall r,k \ \& \ 1 \leq t \leq T_{max} \tag{8}$$

$$M_{r,k,k',t}^{B} \geq 0 \ \& \ \text{Integer} \quad \forall r,k,k' \ \& \ 1 \leq t \leq T_{max} \tag{9}$$

$$x_{i,k,t}^{D} \in \{0,1\} \qquad \forall\, i,k \ \& \ 1 \leq t \leq T_{max} \tag{10}$$

$$x_{j,k,t}^{P} \in \{0,1\} \qquad \forall\, j,k \ \& \ 1 \leq t \leq T_{max} \tag{11}$$

$$x_{k,k',t}^{B} \in \{0,1\} \qquad \forall\, k,k' \ \& \ 1 \leq t \leq T_{max} \tag{12}$$

Objective function (1) minimizes the total operational and material handing cost including the inventory-handling cost at crossdocks, the transportation cost from suppliers to crossdocks, the transportation cost from crossdocks to customers, and the transportation cost between crossdocks. Constraint (2) ensures that each delivery if necessary at most once is fulfilled within its specified time window. Constraint (3) describes that all pickups must be sent just within their defined time windows. The capacity constraint of the crossdocks at all times is restricted by (4). The change of inventory level of each product at each crossdock between time units is defined by equation (5). Constraint (6) is the relation between two decision variables and enforces that the amount of products in shipment between two crossdocks is positive only when the related binary variable is one; M is a big number. Equation (7) sets the initial inventory of each product at each crossdock. Constraints (8) and (9) represent the non-negativity of some integer variables and constraints (10)–(12) ensure the binary restriction of other decision variables.

4 EXPERIMENTAL RESULTS

In this section the results of some numerical experiments carried out to evaluate the performance of the proposed model is presented. The proposed integer programming model in coded in GAMS software and solved by using Cplex solver. All experiments are performed using a computer with an Intel Dual core 2.5 GHz CPU and 2GB of RAM. We generate ten different instances randomly by varying the number of deliveries, number of pickups, number of crossdocks, number of crossdocks and the planning horizon length. In each case the optimal solution of the problem is gained and the running CPU time is reported. Since the problem is NP-complete the optimal solution will be achievable just for reasonable size problems. These experiments are summarized in table 1.

Table 1: experimental results

Test Problem	**Problem size** **i × j × k × r × t**	**Optimal Solution**	**CPU Time**
P1	4 × 8 × 2 × 5 × 40	4010	3
P2	5 × 10 × 3 × 7 × 70	4090	10
P3	5 × 15 × 3 × 7 × 50	4160	15
P4	10 × 15 × 3 × 7 × 70	4170	95
P5	10 × 20 × 3 × 5 × 50	4210	115
P6	15 × 30 × 2 × 5 × 60	4270	225
P7	15 × 40 × 3 × 7 × 80	4420	346
P8	20 × 35 × 3 × 5 × 80	4320	433
P9	15 × 45 × 3 × 5 × 60	4460	465
P10	20 × 50 × 3 × 7 × 70	4490	534

5 CONCLUSIONS

In this paper the multi period distribution planning problem of crossdocking network was evaluated. The problem is defined in terms of a single objective integer programming model which seeks to minimize the total cost of the transportation and storage of goods in crossdocks across the physical distribution network. GAMS software was used to solve the problem. Introduce and test of heuristic methods that can resolve shorter time to achieve competitive results and consider planning a reverse logistics network (planning defective, corrupt or empty containers) can be recommended for future research.

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