Door assignment and resource management problem with truck time windows constraints in cross docks

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1 Introduction

A distribution center is a structure used to receive, temporarily store, and redistribute goods according to orders. The basic concept behind cross dock is to eliminate the most costly operation, storage, in a distribution center by transferring goods directly from receiving docks to shipping docks. The cross dock door assignment problem (CDDAP) is often formulated as a MIP model and various methods have been proposed. The most frequently-used exact approach is Branch and Bound. A number of heuristics have been also applied for solving the CDDAP, such as genetic algorithms, tabu search (A.Lim et al. [1]). Certain authors also study cross dock scheduling problems by simulation, and the most frequently-used tool is Arena. There is only one article by B.Trouillet [2] which proposes to study cross dock using Petri nets.

In this presentation, we address a door assignment and resource management problem with truck time window constraints in cross docks. The principal contributions are included in the following two aspects: (i) we consider explicitly the time as well as resources required by each operation (unloading, sorting and loading) (ii) the problem is formulated as a mixed integer programming (MIP) model, and the door assignment and the resource distribution in cross dock are optimized.

2 Method

We consider a cross dock as a rectangle parallel symmetrical structure in which each receiving door faces to one shipping door. In this terminal, we assume that the number of receiving doors is equal to the number of shipping doors. The internal transportations are performed manually by human resources. Doors on one side of the building are exclusively dedicated to inbound trucks and the other side is to outbound trucks. Time windows of each truck are predetermined. Pre-emption is not allowed. All of goods in inbound/outbound truck have to be unloaded/loaded during its arrival and departure time. Goods that cannot be shipped are allowed to be temporarily stored. We aim to optimize the door assignment and determine the resources at each work station at each time interval to minimize the total cost.

We denote index of origins $m \in \{1,\dots, M\}$, index of destinations $n \in \{1,\dots,N\}$,index of receiving doors $i \in \{1,\dots,I\}$, index of shipping doors $j \in \{1,\dots, J\}$. The goods quantity transported from m to n are denoted by w_{mn}, f_m is the total goods from m, v_n is the total goods demand by n, *and* $penalty_{mn}$is the penalty to pay if good from m is not delivered to n. Each truck arrives and leaves the cross dock within a time window. We denote a_m/d_m the arrival/depart time of m, and a_n/d_n the arrival/depart time of n. We denote t_e is the times $a_m s$, $d_m s$, $a_n s$ and $d_n s$. Instruct t_e to be ranked according to an increasing order ($t_e < t_{e+1}$). The goods transfers within the cross dock are characterized thanks to the following parameters: $\mathrm{distance_{ij}}$ is the distance between *i* and j, $\Delta\mathrm{t_{ij}}$ is transportation time from i to j, c is cost per resource, p_1 is unloading and loading velocity, p_2 is sorting velocity. We define $q_{m,n,i,j} = 1$ if $d_n \geq a_m + \Delta t_{ij}$, otherwise $q_{m,n,i,j} = 0$; $q_{m,h} = 1$ if $d_m \leq a_h$, otherwise $q_{m,h} = 0$, *m, h ∈{1,…, M}*; $q_{n,u} = 1$ if $d_n \leq a_u$, otherwise $q_{n,u} = 0$, *n, u ∈ {1,…, N}*. We define two types of decision variables: x_{mi}, y_{nj}, z_{ijmn} associated with the assignment and r_i^e , s_j^e , k_{mnij}^e for resource requirement. $x_{mi} = 1$ if *m* is assigned to *i*, otherwise $x_{mi} = 0$; $y_{nj} = 1$ if *n* is assigned to *j*, otherwise $y_{nj} = 0$; z_{ijmn} =1 if *m* is assigned to *i* and *n* is assigned to *j*, otherwise $z_{ijmn} = 0$; r_i^e resources assigned to receiving door *i* for unloading between time period t_{e+1} and t_e; s_j^e resources assigned to shipping door *j* for loading between time period t_{e+1} and t_e; k_{mnij}^e resources assigned between column *i* and *j* for internal transporting goods from origin *m* to destination *n* between time period t_{e+1} and t_e; *minResNb* is the minimal number of resources required in terminal.

The model is as follows: the objective function (1) is the combination of two terms. The first one is the total cost which includes the labor cost and the penalty generated by delivery delays. The second term is the total weighted travel distance. In order to aggregate these two terms in a hierarchical manner, we introduce a factor M_G which is the maximum value of second term.

$$Min\ M_G*(c*minResNb + \sum_m(\sum_n penalty_{mn} * w_{mn}(1 - \sum_i \sum_j q_{mnij} * z_{ijmn})))$$
$$+ \sum_m \sum_n \sum_i \sum_j w_{mn} * z_{ijmn} * distance_{ij}\ ; \quad (1)$$

$$\sum_{i=1}^{I} x_{mi} \leq 1\ ;\ \sum_{j=1}^{J} y_{nj} \leq 1; \quad (2)$$

$$z_{ijmn} \leq x_{mi}\ ;\ z_{ijmn} \leq y_{nj}\ ; z_{ijmn} \geq x_{mi} + y_{nj} - 1; \quad (3)$$

$$2(q_{m,h} + q_{h,m}) \geq x_{mi} + x_{hi} - 1;\ 2(q_{n,u} + q_{u,n}) \geq y_{nj} + y_{uj} - 1\ ; \quad (4)$$

$$f_m * x_{mi} \leq p_1 \sum_{e:a_m \leq t_e \&\ t_{e+1} \leq d_m} r_i^e\ (t_{e+1} - t_e); \quad (5)$$

$$v_n * y_{nj} \leq p_1 \sum_{e:a_n \leq t_e \&\ t_{e+1} \leq d_n} s_j^e\ (t_{e+1} - t_e); \quad (6)$$

$$w_{mn} * q_{mnij} * z_{ljmn} \leq p_2 * \sum_{e:a_m \leq t_e \& t_{e+1} \leq d_n} k_{m,n,i,j}^e * (t_{e+1} - t_e); \quad (7)$$

$$\sum_i r_i^e + \sum_j s_j^e + \sum_{i,m,n} k_{m,n,i,i+1}^e \leq minResNb\ ; \quad (8)$$

We build two types of constraints, the constraints for assignment ((2)(3)(4)) to make sure two trucks which have overlapping in time windows cannot be assigned to the same door at a given time, and the constraints for optimize resources distribution ((5)(6)(7)(8)). Constraints (2) ensure that each inbound/outbound truck is not assigned to more than one receiving/shipping door. Constraints (3) correspond to the linearization of $z_{ijmn} = x_{mi} * y_{nj}$. Constraints (4) are to make sure that one receiving/shipping door cannot be occupied by more than one inbound/outbound truck at a given time. Constraints (5) specify that goods of inbound truck *m* have to be unloaded during the period ($d_m - a_m$) at the receiving door where truck *m* is present. Constraints (6) express the same restriction for outbound trucks. Constraints (7) specify that goods from inbound truck *m* to outbound truck *n* have to be sorted during the period ($d_n - a_m$). Constraint (8) identifies the minimal resource number required.

The MIP model is implemented in CPLEX. Five classes of instances with different size are generated to identify performance of the model. The door assignment is optimized and the resources at each working station in each time period are determined. Computational results show that CPLEX is no longer efficient as the problem size grows. An effective algorithm for solving this problem will be developed in future researches.

Références

[1] Lim, A., Ma, H., & Miao, Z. (2006). Truck Dock Assignment Problem with Time Windows and Capacity Constraint in Transshipment Network Through Crossdocks. Computational Science and Its Applications-ICCSA 2006, 688–697.

[2] Trouillet, B. (2009). Petri Net Model and Mathematical Resolution for Cross Docking. *Conference on Intelligent Manufacturing Systems*, 10(1).