Solving Combined Blocking and Train Makeup Problem with Ant Colony Optimization

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Abstract: The railroad blocking problem and train makeup planning are the two important decisions in the rail freight transportation planning. The combined railroad blocking and train makeup model that is a network design model combines these two problems in a single model. There are theoretical and empirical evidences that network design models are NP-hard. In this article a metaheuristic solution method based on elitist ant system is proposed to solve this model, and with an example we show how this approach can be implemented.

Keywords: Railroad Blocking, Train Makeup, Ant Colony Optimization, Freight Transportation.

1. Introduction

In the railroad blocking problem several shipments may be grouped together to form a block to prevent shipments from being reclassified at every yard they pass through. Railroad blocking says how shipments must assign to blocks to minimize the total cost subject to the block capacity of stations [1] [2]. The train makeup plan shows the way to assign these blocks to trains to minimize total cost subject to the capacity of trains [3], [4]. In [5] a model for this combined approach was proposed to determine origin and destination and the frequencies of trains, assigning demands to blocks, and assigning blocks to trains. The combined railroad blocking and train makeup model is a network design model. There are theoretical and empirical evidences that network design models are NP-hard [6]. Hence, solving them with approximate methods (Heuristics and metaheuristics), which obtain near-optimal solutions in a relatively short time, is unavoidable. In this article, first, the combined model is presented, and then a metaheuristic solution method based on elitist ant system is proposed to solve this model. Next, with an example we show how this approach can be implemented, and we compare the solution obtained by proposed approach with that one obtained by LINGO.

2. The Combined Blocking and Makeup Model

Suppose a rail network including m stations and k trains with given demands between each pair of stations. In the combined model, a sub-network is considered for each demand p; i.e. the model considers an Origin-Destination p network for each demand p. N_p and A_p are the station and arc sets, respectively. In each sub-network, each arc is related to the type of moving demand p between each pair of stations. In the model, c_{ij}^{p} and S_{ij}^{p} values are the related cost and moving time of each arc, respectively. Each arc is related to a train with K_{ij}^{p}. Each demand has a volume of r^p and maximum moving time of σ_p. d_k, τ_k, and α_k are the cost of train formation, car capacity, and number of blocks of each train, respectively. P_k is the set of demands that can be moved by kth train. β_m is the blocking capacity of each yard and Y_m is related to the set of trains that can be originated from station m. The combined model of railroad blocking and train makeup problem can be written as follows:

$$Min \sum_{p} \sum_{(i,j)\in A_p} c_{ij}^{p} x_{ij}^{p} + \sum_{k} d_k t_k \tag{1}$$

subject to

$$\sum_{j\in N_p} x_{1j}^{p} = 1 \qquad \text{for all } O-D \text{ pairs } p \tag{2}$$

$$\sum_{j\in N_p} x_{ij}^{p} - \sum_{j\in N_p} x_{ji}^{p} = 0 \qquad \text{for } i \neq 1 \text{ and } |N_p| \tag{3}$$

$$\sum_{i\in N_p} x_{i|N_p|}^{p} = 1 \qquad \text{for all } O-D \text{ pairs } p \tag{4}$$

$$x_{ij}^{p} - t_k \leq 0 \qquad \text{for } k = K_{ij}^{p} \text{ for all } (i,j)\in A_p, \text{ for all } p \tag{5}$$

$$\sum_{p\in p_k} r^p x_{ij}^{p} \leq \tau_k \qquad \text{for } k = K_{ij}^{p} \text{ for all trains } k \tag{6}$$

$$\sum_{k\in Y_m} \alpha_k t_k \leq \beta_m \qquad \text{for all yards } m \tag{7}$$

$$\sum_{(i,j)\in A_p} S_{ij}^{p} x_{ij}^{p} \leq \sigma_p \qquad \text{for all } O-D \text{ pairs } p \tag{8}$$

$$x_{ij}^{p} \in (0,1), t_k \in (0,1) \tag{9}$$

Variable x_{ij}^{p} is 0 if arc (i, j) is selected in sub-network p and variable t_k demonstrates the formation of each train k. The objective of the model is to minimize fixed costs of train formation in addition to cars variable costs (equation (1)). Fixed costs include the wages of train crew plus the cost of a unit of motive power. A variable cost is related to each arc of sub-networks according to the number of cars that move on it. Equations (2)-(8) are the constraints of the model. Constraints (2)-(4) are the usual balancing equations of network flow problem. Constraints (5) prevent cars from moving on a train unless it is available. Constraints (6) are related to car capacity of each train. Constraints (7) limit the number of blocks, which can be formed in each yard. The operating plan must provide trip times, which meet the desired service standards. This condition is enforced by constraints (8). Finally,