Journal of Rail Transport Planning & Management xxx (2016) 1–19

Contents lists available at ScienceDirect

Journal of Rail Transport Planning & Management

journal homepage: www.elsevier.com/locate/jrtpm

Comprehensive optimization of the one-block and two-block train formation plan

Jie Xiao, Boliang Lin*

Beijing Jiaotong University, School of Traffic and Transportation, Beijing 100044, China

ARTICLE INFO

Article history:
Received 7 June 2016
Received in revised form 13 September 2016
Accepted 15 September 2016
Available online xxx

Keywords:
Two-block train
Train formation plan
Comprehensive optimization
Ant colony system

ABSTRACT

Different from the traditional multi-step train formation plan optimization, which generates the one-block train formation plan firstly and then combines some one-block trains to form two-block trains, this paper presents a comprehensive optimization model which considers the one-block train and two-block train simultaneously. The model consists of three sub-problems: shipment routing, shipment-to-block assignment and block-to-train assignment. The objective of this model is to deliver all of the commodities with the minimum car-hour consumption at the technical yards while satisfying the network capacity constraints. A heuristic optimization approach based on the ant colony system is proposed to solve the model. The test results based on practical examples in northeast China railway network show that the one-block and two-block train formation plan obtained by using the comprehensive optimization model and approach proposed in this paper can significantly reduce the total car-hour consumption at the technical yards compared with the train formation plan which only uses the one-block train. The comprehensive optimization can achieve better results than the traditional multi-step optimization.

1. Introduction

In the railway freight transportation, a shipment consisting of one or more cars with the same origin and destination (OD) may pass through several yards along its route. Each classification process at the yards causes a certain time delay to the shipment and thus becomes one of the major sources of the delay in railroad transportation. In order to avoid classifying the shipment at every yard along its route, several incoming and originating shipments may be grouped together to form a block at a certain yard. A block is defined by a fixed OD pair which may be different from the OD pair of the individual shipments in the block. Once the shipment is placed in a block, it will not be classified any more until it reaches the destination of that block. A shipment may be assigned to a direct block or a sequence of blocks along its journey. Then train schedules are made based on the blocking plan. One train can carry one or more blocks. If a train is only assigned with a single block, it is called a one-block train. The one-block train has the same origin and destination with the block. If a train carries two or more blocks, it is called a multi-block train. Different blocks in the multi-block train have different OD pairs and at least one block-swap operation needs to be done at the intermediate yards along its journey. The long-distance block which is destined for the

* Corresponding author.
E-mail addresses: xiaojie2015914@gmail.com (J. Xiao), bllin@bjtu.edu.cn (B. Lin).

http://dx.doi.org/10.1016/j.jrtpm.2016.09.002
2210-9706/

final destination of the train is called a basic block while the short-distance block which is originated from or destined for an intermediate yard is called a supplementary block.

Take the two-block train as an example. As shown in Fig. 1, *A*, *B* and *C* are three yards in a line network. Three blocks with OD pairs *A-B, B-C* and *A-C* are built and denoted as B_{AB}, B_{BC} and B_{AC}. If these blocks are carried by the one-block trains, three trains T_{AB}, T_{BC} and T_{AC} need to be arranged and each of them is assigned with one of the three blocks. Alternatively, we can dispatch a two-block train T_{ABC} to carry the three blocks. B_{AC} is taken as the basic block, and B_{AB} and B_{BC} are taken as the supplementary blocks. The cars in B_{AC} and B_{AB} accumulate separately on different tracks at the yard *A*. Once the total number of the cars reaches the size of a train, we combine them together and dispatch the train. When the train arrives at the yard *B*, instead of reclassifying the whole train, only the block B_{AB} will be dropped off. Meanwhile, the block B_{BC} which accumulated in advance will be attached to the train. After the swap operation of the complementary blocks is completed, the train will continue to the yard *C* and finally break up at the yard *C*.

In comparison with the one-block train, the multi-block train has the following advantages (Chongshuang Chen et al., 2011): (1) To reduce the accumulation delay at the train formation yard by replacing several one-block trains with one multi-block train; (2) To simplify the classification operation at the intermediate yards since classification only needs to be done on the complementary blocks instead of the whole train; (3) To speed up train service by extending the train travel distance and avoiding classification of the long-distance shipments at the intermediate yards. However, the multi-block train has more stringent requirements on the traffic organization conditions, including: (1) More tracks are required for train accumulation at the train formation yards. (2) The block-swap yard should have sufficient complementary car flow to avoid the train breaking up in advance. (3) The block-swap yards should avoid the shunting yards with longitudinal arrangements and non-through yards. (4) More efficient organization work is required at block-swap yards to make sure that the supplementary cars can accumulate in advance and be attached to the train during a short dwell time.

It needs to be noted that in North America and Europe, the multi-block train is already widely used and it is very common to have several blocks in a train along its journey. However, in China, due to historical reasons and infrastructure constraints, the one-block train is the main train organization form. The multi-block train is considered as a novel and advanced train organization form and becomes a future trend. That is why the concept of the multi-block train is seldom mentioned in North American and European literature while it is especially emphasized in China.

The two-block train is the basic and typical application of the multi-block train. It contains most of the elements that the multi-block train needs to consider: separate accumulation of the basic and complementary blocks, block-swap operation, waiting cost between different blocks and constraints on the tracks. It is reasonable to make a thorough study in the two-block train since the results can provide a theoretical basis for researches in more complicated multi-block train problems. Therefore, in this paper we will address the train formation plan (TFP) problems in China railroad freight transportation when both the two-block train and the one-block train are considered.

2. Literature review

The train formation plan occupies a central position in the railroad freight transportation. It determines which pairs of yards are to provide direct train services and how the shipments are consolidated into the available train services aiming at delivering all shipments to their destinations with the minimum cost.

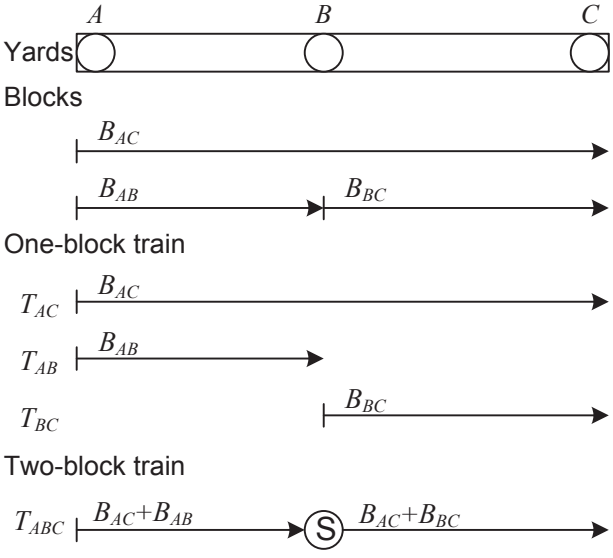

Fig. 1. The One-block train and the two-block train.

Please cite this article in press as: Xiao, J., Lin, B., Comprehensive optimization of the one-block and two-block train formation plan, Journal of Rail Transport Planning & Management (2016), http://dx.doi.org/10.1016/j.jrtpm.2016.09.002