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# Two-stage stochastic programming for the railroad blocking problem with uncertain demand and supply resources

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A B S T R A C T

The railroad blocking problem is classified in the tactical level of freight rail transportation problems. The objective of this problem is to determine the optimal paths for each shipment such that the railway limitations are satisfied. In this problem, the quantities of both demand and supply resource indicators are often assumed to be certain and known, but because a blocking solution is designed for a relatively long period of time, this assumption is not reasonable. In this paper, we have developed a two-stage stochastic program for this problem to consider the uncertainty inherent in demand and supply resource indicators. Due to the size and complexity of the stochastic program and the impossibility of using commercial software in even the simplest instances, two solution methods have been proposed. The first method developed is based on the L-Shaped method, and the second method is a modification of the first one that uses a new initial solution (which is obtained by adapting a side optimization model) together with the L-Shaped method. Extensive experiments on test networks show that the two methods outperform the commercial software and that the second method is superior to the first one. We finally present the application of the uncertain model and the computational results of the second method for the Railways of Iran as a real-size example, and we show that the application of the stochastic model could reduce total cost by more than 12 million dollars per three-month horizon compared with the deterministic solution.

## 1. Introduction

### 1.1. Railroad blocking problem

A rail (physical) network consists of stations and (physical) links. The stations can be origin, destination, minor, or classification stations. Origins and destinations are the starting and ending points of cars in the rail system. A minor station operates as a fueling or bypassing node where no cars are released or added to the train. Classification stations are the stations where the classification operations are performed, such as separating cars from incoming trains, sorting cars, and attaching cars to outgoing trains. Because the delay time at classification stations can be more than one day for each station (Jin, 1998), a favorite approach to avoid this delay is to group shipments (one or more cars with the same origin-destination (O-D) pair) at their origins based on their destinations to let the shipments enter some but not all of the classification stations along their routes. The railroad blocking problem is an optimization method to fulfill this approach.

Ignoring the minor stations and links, an aggregated network, also called a blocking network, is defined when considering blocking problems based on origins, destinations and classification stations. The blocking network consists of a set of stations and a set of blocks. Its stations are origin, destination, or classification stations. A block is a sequence of links in the rail network. Every block is associated with two stations: the start station, where the cars are attached to the departing train, and the end station, where the cars are released from the train. If the shipments are traveling across a block, they are not classified as long as they reach the end of that block. The blocking path for a shipment is defined as a sequence of blocks that connect the origin to the destination for that shipment. The blocking plan is the set of blocking paths for all shipments that is a feasible solution for the blocking problem.

To clarify the above definitions, consider a small rail network with one origin (node 1), two classification stations (nodes 2 and 3), one destination (node 4) and a number of minor stations. The rail network and the list of potential blocks are shown in Fig. 1a. As an example, consider block 1 → 3. In this block, a train starts moving from node 1, bypasses node 2, and finally stops at node 3. Fig. 1b illustrates the blocking network with all potential blocks and stations. Fig. 1c shows the potential blocking paths through the blocking network. For instance, blocking path 3 includes two

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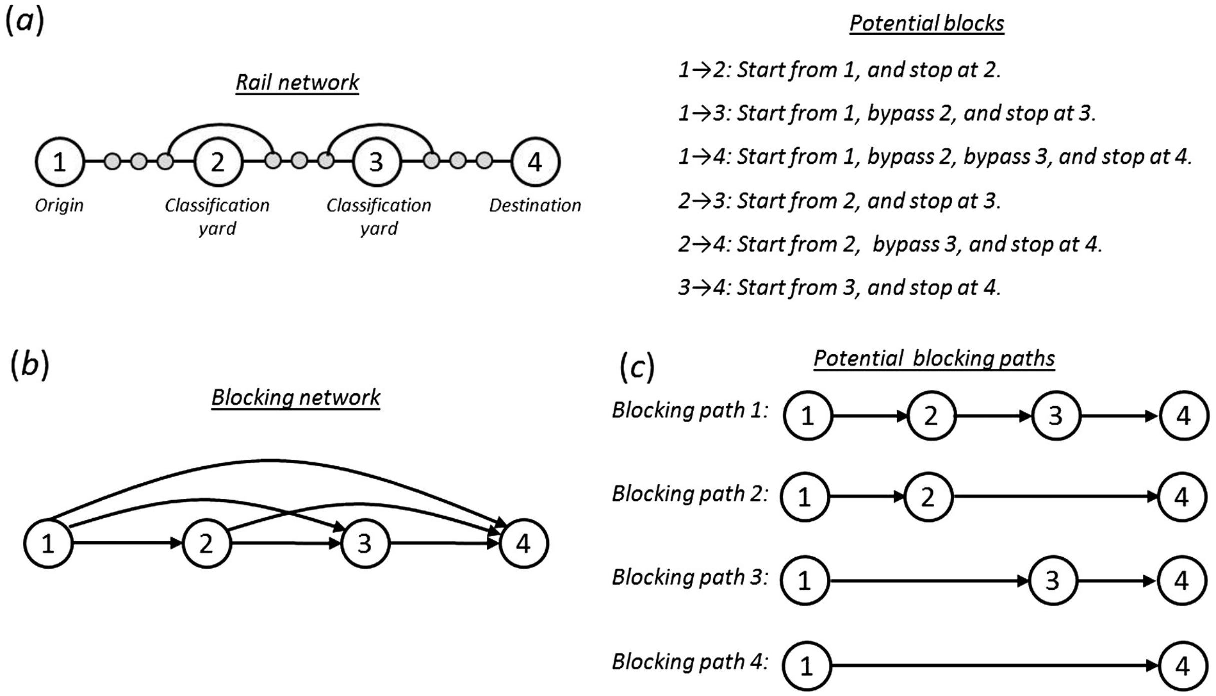

Potential blocks

1→2: Start from 1, and stop at 2.
1→3: Start from 1, bypass 2, and stop at 3.
1→4: Start from 1, bypass 2, bypass 3, and stop at 4.
2→3: Start from 2, and stop at 3.
2→4: Start from 2, bypass 3, and stop at 4.
3→4: Start from 3, and stop at 4.

**Fig. 1.** (a) The rail network, (b) the blocking network, and (c) four blocking paths through the blocking network.

blocks (1,3) and (3,4); when a train is moving through these blocks, the train continues its route until reaching nodes 3 and 4.

### 1.2. Literature review in deterministic model

Several studies have examined the railroad blocking problem. These works vary in both the objective function properties that they optimize and the constraints that they must satisfy. In the following, we provide a brief review of literature related to this problem.

Assad (1980) was among the first researchers to introduce an integer linear program for the railroad blocking problem. In this program, the objective function includes the train costs (operating and delay costs through the links) and station costs (classification and delay costs inside stations). This model contained two constraints: each shipment is shipped from its origin to its destination, and the amount of flow moving through each block is bounded above by block capacity. Many realistic limitations are not included in Assad's work. Thus, efforts to consider more limitations have been made, including a maximum limit on the number of cars that can be classified at a station (Lin, Wang, Ji, Tian, & Zhou, 2012); a maximum limit on the sum of the selected blocks that leave the stations (Keaton, 1989); a maximum limit on the amount of time required for each O-D pair to reach its destination (Hasany, Shafahi, & Kazemi, 2013); and more than one blocking path having a positive flow for each shipment (Ahuja, Jha, & Liu, 2007). In addition to the objective function of Assad's work, other functions have frequently been used. Bodin, Golden, Schuster, and William (1980) derived the delay as a function of the number of cars along blocks which is added to train costs. Marín and Salmerón (1996) considered the needed investment to purchase new fleets in addition to the train cost. The number of used infrastructures for classifying operations was introduced by Fügenschuh, Homfeld, and Schülldorf (2015) as a crucial component of the objective function.

The above studies all assumed that there is no source of uncertainty for the input data. In the following, we state the importance of uncertainty in the railroad blocking problem as a particular issue in railway planning.

### 1.3. Uncertainty in railway planning

In railway transportation, decisions can be classified into strategic, tactical, and operational levels (Crainic, 2000; Crainic & Laporte, 1997). The strategic level is concerned with long-term planning, which requires a large investment, and the decisions are made by high-level managers. Operational decisions are short-term decisions with minor investment. The connection between these two levels is the tactical level, which acts as a bridge to connect the long-term and short-term decisions.

At the strategic and tactical levels of rail planning, because the decisions are designed for long and medium time spans, the uncertainty inherent in the input parameters should be of concern. However, these parameters are often assumed to be certain and known; ignoring uncertainty leads to a clear difference between the decisions obtained by the certain and uncertain parameters (Birge & Louveaux, 2011).

The railroad blocking problem is one of the most important problems at the tactical level of planning. Typically, the values of demand and supply resource indicators (such as travel time and flow capacity of each station) are assumed to be known. In the deterministic case, the demand value is calculated using different methods (Jiang, Johnson, & Calzada, 1999; Upchurch & Kuby, 2014; Viglioni et al.; Wong, Niu, & Ferreira, 2003), but in this calculation, it can differ from the realized value (Matas, Raymond, González-Savignat, & Ruiz, 2009). This occurs because forecasting techniques are usually forced by omitting some explanatory variables (Petkova, 2007). Similarly, the supply resource indicators are severely affected by such factors as changing weather, fleet availability (for classification operations or for shipping between stations), passing or overtaking, and the movement of trains with higher priority (such as passenger trains) on the same links.