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Scheduling and Routing Algorithms for Rail Freight Transportation

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Abstract

The paper deals with scheduling and routing rail freight transportation. There are provided mathematical descriptions of constraints in the real rail transportation such as timetables of passenger trains, safety time buffers etc. We developed an algorithm which determines the fastest route of cargo train in a railway network. It is based on Dijkstra algorithm idea. We experimentally proved that determination of the fastest route in even large railway network, where movement of a large number of trains was planned, takes place in a time acceptable for decision makers.

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Keywords: algorithm, scheduling, optimization, rail transportation

1. Introduction

Fast-growing industry requires efficient delivery of a huge amount of stuff. Transportation time is often very short and it is not easy to meet a deadline. Transportation can be accomplished by the road transportation. Unfortunately, there is a high risk of traffic jams that generates losses. However, on some roads there are weight limits imposed on vehicles so it enforces selection of longer routes or use of greater number of trucks. All these factors make road transportation uneconomic and elusive. Competitive approach employs a rail transport. Proper planning may cause lack of congestion on the railway line, it allows to carry huge amount of stuff at once, allows to

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shorten delivery time and it is more safe than road transport. Operational Research among other things deals with rail transport planning. Research focuses on formulating common problems and designing efficient methods that solve them.

The freight scheduling problem is one of the most difficult problems belonging to the family of transportation problems. Due to its complexity it poses a big challenge for modern Operational Research studies thus it is in a high demand. According to Pashchenko *et al.*(2015) it consists of three sub problems: train scheduling problem (choosing proper moment for train departure along its route), locomotive assignment problem (assigning locomotives to trains) and locomotive team assignment problem (assigning teams to locomotives in an optimal way). Planning train schedules and routes imposes execution of algorithms on quite big data sets. For instance current polish rail network consists of 999 railway lines (List of railway lines managed by PKP Polskie Linie Kolejowe S.A., 2016), 588 station buildings (PKP Polskie Koleje Państwowe S.A. – Our Stations, 2016) and more than 2500 motor engines (Camp of PKP Cargo – locomotives, 2016).

However, it can be difficult to find a feasible solution since chosen train paths may mutually exclude themselves. Trains cannot move one by one close to each other. A difficulty of finding good solution increases when it comes to rail networks with a high traffic density. Furthermore, there are many expectations related to the transportation regarding safety, speed, capacity and reliability. All mentioned factors force the use of sophisticated algorithms to solve scheduling and routing problems in a reasonable time.

State of the art

According to Cadarso *et al.* (2014) such planning problems are usually solved in two phases. First phase is called the macroscoping phase. In this phase an exact model of a rail network is not known. In this phase the problem is usually formulated as a multi-commodity network flow problem considering the scheduling of the train unit. Rolling stock assignment and train sequence problems are being solved. In the second phase, called microscoping phase, all operations are considered in details. At this level all conflict situations are detected and purged, compatibility issues are taken into account and time allowances for coupling and decoupling operations are studied.

Planning rail freight transportation takes into account activities associated with movement of trains and maintenance tasks. Lidén and Joborn (2016) were dealing with dimensioning maintenance time windows. They introduced a freight traffic cost model and a passenger traffic cost model for evaluating effects of maintenance windows on regional passenger traffic. There are also researches related to real-time algorithms intended for rapid responding on unexpected situations that can disturb the normal course of daily operations. Recent study of Samà *et al.* (2016) proposed an approach based on ant colony heuristic where the real-time train selection problem is described as an integer linear programming formulation. There are rare researches devoted to integration of production scheduling and rail transportation. In the study of Hajiaghaei - Keshteli and Aminnayeri (2014) such problem was solved using the Keshtel algorithm.

2. Problem formulation

A freight routing and scheduling problem through a rail network can be defined as follows. Let us assume that a railway network consisting of n of railway junctions from the set $\{1, \ldots, n\}$is given. Railway junction may represent a railway station, a cross dock station, an intermodal terminal, etc. A railway network can be represented as a mesh of railway tracks, which is linked in junctions. A route and a schedule of t trains from the set$T = \{1, \ldots, t\}$ are given. The goal is to determine routes and schedules for additional cargo trains.

A railway network can be modeled using directed graph$G = (V, E)$, where $V$is the set of nodes and$E$ is the set of arcs. The node$i \in V$ corresponds to railway junction i , whereas arc$e = (i, j), e \in E$denotes unidirectional railway track from junction i to junction j (bidirectional tracks are modeled as a pair of arcs $(i, j)$and (j, i)).

For each train$k \in T$a sequence of railway junctions$r_k = (r_k(1), \ldots, r_k(n_k))$ defining the route of the train is known. The schedule of train is determined by the departure time$d_k(s)$ from the railway junction$r_k(s)$, $s = 1, \ldots, n_k - 1$ and arrival time$a_k(s)$, $s = 2, \ldots, n_k$, to junction$r_k(s)$.