2020 RAS Problem Solving Competition

Train Travel-Time Estimation

Updated Feb 27, 2020

DISCLAIMER: The problem presented here exemplifies one of several opportunities for Operations Research application in the Railway industry. We have simplified a real-life problem for this competition. More general problems and related literature is available on the competition website under the *Competitions* section.

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Definitions

Crew: For this competition, a crew is made up of a two-person team (i.e., conductor and locomotive engineer/operator) whose job is to move a train from one point within the *rail network* to another.

Crew Change: A situation in which the *crew* of one *train* is relieved of duty by another *crew* either at (1) a *station* between the origin and destination, or (2) the origin or destination *yard*. Once on duty, it is the responsibility of the relief *crew* to continue the movement of the *train* to its intended destination.

Freight Railroad: A rail transportation operator whose business objective is the use of *trains* and associated equipment/vehicles for the movement of freight cargo all or some of the way between the shippers and the intended destination.

Fueling Event: The refueling of a *locomotive* or set of *locomotives* while in a designated *yard*.

Inspection: A formal process during which *railcars* are inspected in *yards* for mechanical problems by qualified personnel prior to operating on the main track.

Locomotive: A self-propelled, rail-bound vehicle that provides the motive power for a *train*.

Main Track: A track extending through yards and between stations (i.e., other than an auxiliary track).

Maintenance Time Window: The expected time window in which roadway maintenance is expected to occur and, as such, affect normal train operations on the section of track receiving maintenance.

Multi-Track Territory: A section of the rail network which features multiple parallel main tracks upon which *trains* can operated in either one or both directions, depending on the railroad *timetable*.

Railcar: A vehicle used for the carrying of freight cargo on a rail network. Such cars, when coupled together and hauled by one or more *locomotives*, form a *train*.

Rail Network: An interconnected network of tracks making up the territory of the operating *freight railroad*, including all *sections*, *yards*, and *stations*.

Railcar Pickup: A term descriptive of a *railcar*(s) added to a *train* en route between departure and receiving *yards*.

Railcar Setout: *Railcars* left at designated points (e.g., siding track or spurs) by a *train*.

Roadway Maintenance: Scheduled or emergency maintenance of tracks or railroad right-of-way.

Section: A segment of the rail network delineated by either *signals*, *switches*, *stations*, or *yards*.

Siding: An auxiliary track, adjacent to the main track, for meeting or passing *trains*.

Signal: Fixed locations between stations at which block or interlocking signals are located that govern *train* movements within any given section of track in a *rail network*.

Single-Track Territory: A *section* of the rail network which features a single main track upon which *trains* are operated in both directions.

Slow Order: A local speed restriction on a rail line which is set below the track's normal speed limit, imposed when there is a requirement to perform roadway maintenance on a specific section of the rail network.

Spur: Short, usually dead-end section of track used to access a facility or loading/unloading ramp. It also can be used to temporarily store equipment.

Station: One of many locations within a rail network designated in a railroad *timetable* by name.

Switch: (1) Noun: A device consisting of two movable rails, necessary connections, and operating parts designed to turn a *train* from the track on which it is running to another track. (2) Verb: To move *railcars* from one place to another, usually within a defined territory.

Timetable: A publication containing instructions relating to the movement of trains or equipment and other essential information.

Tonnage: The total weight of all the *railcars* (including the commodities hauled) making up a freight *train*.

Train: A series of connected *railcars* pulled or pushed by a *locomotive*.

Train Priority: The priority in which certain *trains* have based the commodities (e.g., intermodal freight) being carried and, in turn, the expected delivery time agreed upon with the shipper.

Yard: A classification, switching, or marshalling yard, where *trains* are formed or disassembled. Freight cargo shipments originate and terminate at yards (i.e., departure and receiving yards, respectively).

Problem Description

The world is experiencing phenomenal advancements in the accuracy of travel time estimations in over-the-road and air travel modes. Many of these advancements are widely available and can predict the estimated arrival time at the destination as well as intermediate stations with a high degree of accuracy. However, the accuracy of travel-time estimations lags far behind for rail transportation, especially in freight transportation by rail. The primary reason for this lag is due to the increasingly complex, interdependent factors that govern freight train operations within a large network. This year, the Railway Application Section invites the forward-thinking researchers in the operations research (OR) community to tackle this very important topic.

The problem at hand is to determine the travel time of freight trains within a given time window, considering all important characteristics of the network and important resources required for freight train operations. Rail transportation is one of the most efficient and the most environmentally friendly modes of transportation on a per ton-mile basis because of the dedicated trackage for train movements. However, this characteristic also creates inherent cascading impact of each train's movements on the movement of other trains in the network. Combining this complex interdependency with other resource-specific restrictions makes the train travel-time estimation problem an algorithmically challenging problem. Solving this challenging problem effectively will not only have immediate benefits to freight railroads and their customers but will also enable other important decision problems affecting railroad operations to be addressed.

The train travel-time estimation problem should be solved at a point in time in the period of study in which trains are already at different stages of their journeys within the network, and more trains will start in predetermined time windows (assume this to be in days). Note that, in contrast to passenger service trains, freight trains generally have long transit times. Below we provide the details of this problem in terms of inputs, outputs, and constraints.

Inputs:

Current State of Trains: We are given the current position of freight trains in the network along with the schedules of travel to their destinations. The state of the train and its schedule include the travel direction, arrival and departure times at intermediate stations in the route, and movement restrictions.

Train Schedule: For the given time window (e.g., days), we are given the planned schedule of all freight trains which are currently already in transit as well as trains scheduled to depart within the given time window. Train schedule also specifies the activities to be performed en route (e.g., crew change, pickup or setout of railcars, crew change, inspection, fueling events). The timing of trains at important intermediate stations as well as train priorities are also provided.

Network Details: Network details we are given include the layout of the network, single/multiple track section information, switch details (i.e., orientation), station details, and the important parameters limiting train movements in the network. Network parameters can be permanent as well as of a temporary nature. For example, the permissible speed of a track section can be permanent, whereas the time window for the maintenance of any given section of track can be temporary.

Resource Availability: To operate a freight train on schedule, railroads need to align three resources: yard, crews, and locomotives. Availability of yard resources dictates whether the trains can be formed on time for departure, and availability of crews and locomotives determine whether the train can be operated in the network on time. These resources are shared by different types of trains and, hence, should be considered carefully while solving the travel-time estimation problem.

Business Priorities: Most railroads operate a heterogenous set of trains with different priorities for trains. For example, an intermodal train must have minimum delay compared to the tolerable delays for unit trains.

There are several other factors which impact the movements of trains in the network and their compliance with the published schedules. Most prominent among them are weather-related impacts as well as unplanned maintenance. However, to keep the scope of the problem for this competition manageable, these factors can be ignored.

Outputs:

For each train either in transit or to be departing within the given time window, estimate their expected time of arrival (ETA) at their respective final destinations and at the important intermediate stations along the way. The accuracy of the ETA will be determined using the historical data by comparing the model-generated ETAs with actual arrival times. In addition, the model should also be able to reassess ETAs if there are disruptions in the network in between two successive runs of the model.

Business Constraints:

To generate the above outputs, the model should be able to determine how trains will move within the network considering all the network-related factors and shared resources. Primary constraints to be considered are:

1. A train can be operated only if the relevant yard can build it, the crew is available to operate the train, and the minimum number of locomotives are available. To model these constraints, historical data sets will be provided about yard delays, crew delays, and locomotive delays with additional details relevant to this specific problem statement.

2. In a section of the network, there cannot be more than a specific number of trains at a given time. This constraint varies by the type of the track section. For example, in a double-track section, there can be two trains traveling in opposite directions between two consecutive signal points whereas, in a single-track section, there can be only one train at any given time.

3. Based on the priorities of trains, a high-priority train can overtake a lower-priority train. To overtake, the slower-moving train must stop on designated siding tracks only. Note that the priorities of trains are dynamic and, hence, also dependent upon the current delays in train operations.

4. The uninterrupted travel time of a train in a track section depends upon the combined impact of historical travel time of similar trains in the track section, temporary restrictions in the network, etc.

5. The propagating impact of train delays must be considered while estimating the arrival time of

trains. For example, stopping a train (say "Train A") at a station, may require stopping the following train (say "Train B"), which in-turn may introduce delays to its succeeding train (say "Train C"), and so on. In other words, the impact of congestions on train travel times of all impacted trains in the network must be considered.

Modeling Expectations:

We expect participating teams to come up with a pragmatic approach, which may be a combination of data science techniques and network-flow algorithms. Fast running time of the algorithms for a real-life problem is just as important as the solution quality. The expectation is that, for a rail network with a few hundred trains departing every day, the ETA of freight trains over a one-week period can be predicted in minutes on a commonly available computer. The soundness of the approach will not only be measured by the novelty of OR techniques but also by the implementation elegance.

A bonus feature of the solution approach can also be its adaptation for the incremental train travel-time estimation. This implies that, if there is a small change in train operations or network conditions or resource availability, then the model should estimate ETAs only for affected trains and not for all trains. This feature will make the modeling approach extremely useful in the real-time deviation management.

While we expect you to demonstrate the quality of your solution approach using a standard dataset to be provided to all participating teams, we also expect you to comment on how your approach may improve its solution quality over the time as more data becomes available. This implies that, if your solution approach is in use and you have the knowledge of how the model behaves and what happens over time, how this additional knowledge will make your solution approach "smarter."

We expect your modeling approach to be scalable and extendable. Scalability implies that the approach can be applied with a linear increase in the computational time for larger problem instances in terms of network size, number of trains, and the travel-time estimation time window. Extendibility implies incorporating more features without altering the fundamental concept of the solution approach. To limit the scope of the problem within the parameters of this competition, several assumptions were made. The extendibility of an approach will easily enable the incorporation of additional business requirements by removing simplifying assumptions.

Next Step:

After the problem statement is announced and made available to interested participants, we seek clarifying questions about the problem description and expectations. After these questions have been clarified and documented, we will freeze the problem statement and publish the resultant finalized version to all prospective participants.

From the time the problem statement is announced, there will be monthly webinars for participants to have a live discussion about the problem definitions and expectations. While we do not expect any change in the basic problem definitions, there may be some tweaks in the problem statement. These sessions will be recorded and made available to all participants via the RAS website (connect.informs.org/railway-applications/home).

After the problem statement is finalized, the input data format will be finalized and a sample dataset will be provided for participants to test and debug the implementation of the solution approach. At least two months prior to the final submission, another dataset will be provided to be used in the computational results section of your report.

We want this competition to be fun and exciting. Please be creative in your approaches and make it a collaborative experience between the organizing committee and the participating teams!

Timeline:

Following is the tentative timeline for this competition. We reserve the right to alter these timelines if there is a need.

Step	**Timeline**
Release Draft Problem Statement	February 28, 2020
Monthly Webinar 1	March 20, 2020
Release Final Problem Statement & Sample Dataset	April 3, 2020
Monthly Webinar 2	April 17, 2020
Registration & Abstracts Due from Participating Teams	May 8, 2020
Monthly Webinar 3	May 15, 2020
Release of Solution-Quality Assessment Dataset	May 29, 2020
Monthly Webinar 4	June 12, 2020
Quiet Period	June 26 – July 31, 2020
Final Submission of Reports	July 31, 2020
Announcement of Finalists	September 1, 2020
Presentation in RAS Session @ INFORMS Annual Meeting	November 8-11, 2020