Optimizing railway timetables with OpenTimeTable

A. Nash & M. Ullius
Swiss Federal Institute of Technology,
Institute for Transportation Planning and Systems, Switzerland

Abstract

OpenTimeTable is a computer program designed to help railway timetable planners evaluate actual schedule adherence data. The program analyzes the differences between actual and scheduled timetable data and presents this information in a variety of graphical and statistical formats. Railroad planners use this information to improve timetables, ultimately leading to a more attractive service and more efficient infrastructure utilization. Schedule planners use OpenTimeTable to download actual timetable data for a specified corridor from railroad company databases. Next they produce graphical timetables, delay distributions, capacity utilization graphs, and a variety of statistical data from the downloaded information. Generally planners perform these analyses in an interactive manner to better understand reasons for systematic schedule delays and develop measures to address them. OpenTimeTable was developed by the Swiss Federal Institute of Technology’s Institute for Transportation Planning and Systems in cooperation with the Swiss Federal Railways. The paper describes OpenTimeTable and outlines how it can be used to improve railroad schedules.

Keywords: railway scheduling, schedule data analysis, timetable development, timetable quality evaluation.

1 Introduction

Railroads are under great pressure to improve service and increase efficiency. They are being asked to simultaneously increase service and reduce costs. The main battlefield for these conflicting demands is in the development of train schedules.
Customers, whether freight shippers or passengers, want fast, frequent, and punctual train service. Railroad management wants to reduce capital and operating costs. The time-honored solution of overbuilding infrastructure to provide additional capacity is no longer possible. Instead, more trains are being scheduled on the existing network in an effort to squeeze all available capacity out of the system.

The problem with this approach is that eventually enough trains are added that the schedule becomes unstable. When this occurs small schedule disruptions can cause delays that ripple through the whole network. This problem is exacerbated by the increasing use of timed transfers for passengers at main stations. In these situations, a small disruption for one train impacts many other trains (or the passengers who wished to transfer).

Creating railroad timetables is a complicated process given the large amount of data involved and the complex inter-relationships between train operations. Computer programs are well suited to creating and refining railroad timetables. There are several basic types of programs available for this purpose including: railway simulation programs, timetable planning software, rolling stock and personnel scheduling programs, and schedule analysis programs.

Schedule analysis programs analyze actual operations data to identify and understand systematic delays. Once understood, the schedule planner can refine schedules or recommend other types of improvements (e.g. adding infrastructure) to address these problems. Furthermore, analyzing actual timetable data after implementing an improvement allows planners to assess the effectiveness of the improvement.

The key difficulty in analyzing actual schedule data in the planning process is the sheer volume of available data. OpenTimeTable has been developed to overcome this difficulty by providing a comprehensive and user-friendly tool for analysis of schedule data.

2 OpenTimeTable

OpenTimeTable is a computer program designed to analyze actual timetable data to improve the quality of railroad schedules. It helps users evaluate and understand the huge amount of actual schedule data by presenting a variety of graphical and statistical data for selected groups of trains on particular corridors. By providing schedule planners with a complete understanding of systematic schedule delays, it helps them produce better schedules.

OpenTimeTable was developed at the Swiss Federal Institute of Technology’s Institute for Transportation Planning and Systems (ETH IVT) in cooperation with the Swiss Federal Railways (SBB). The SBB has used OpenTimeTable for over four years to help improve their timetables. During this time OTT’s developer has worked closely with SBB personnel to improve the program.

The program runs on several different computer platforms including Macintosh (Operating System X) and Windows NT. It can also be used on networks, allowing several people to work with a single database.
OpenTimeTable is based on object oriented programming and accommodates the RailML data structure. This is a common data structure for railway computer applications designed to greatly simplify data transfers between programs. RailML is an extension of XML (eXtensible Markup Language); it is being developed by a consortium led by the Fraunhofer-Institut fuer Verkehrs- und Infrastruktursysteme in Dresden (IVI) and the ETH IVT.

The next three sections outline the main parts of the OpenTimeTable program: input data, analysis modules, and OTT’s Automatic Delay Identification System, a new program feature that automatically notifies users when certain schedule parameters are not met.

2.1 Input data

The basic input data for OpenTimeTable are continuous train-position records stored by information systems at train control centers (e.g. system SURF at SBB). The first step in preparing an OpenTimeTable analysis is to import the train position data from the railroad company database into the OpenTimeTable database.

Train position records contain data about each train operation through a timepoint (a timepoint is a specific location on the track network where data is collected such as a signal location). The combination of data for a consecutive set of timepoints consists of a train operation (or “running”). Train position records consist of:

- Train identification number;
- Day of operation;
- Arrival time at timepoint;
- Arrival delay (number of seconds that the train was late or early arriving at the timepoint);
- Departure time from timepoint; and
- Departure delay (number of seconds that train was late or early leaving the timepoint).

OpenTimeTable imports this train position data in ASCII-files and stores it in an OTT database file created using the FrontBase DBMS program.

Once the OTT database has been created the user creates an OTT document by specifying the particular data of interest (for example: corridor/route, train numbers, and analysis period).

2.2 Analysis

The OpenTimeTable document is the basis for preparing the various OTT evaluations. OpenTimeTable’s “Analyzer” window is used to specify which trains should be included in the evaluation and which analyses will be performed. The program allows users to select trains for analysis based on various parameters including: time period (time of day), day of week, specific train numbers, and selected stations. The amount of time it takes to perform an
evaluation depends upon the amount of data to be analyzed, the type of analyses being performed, and the computer speed, but is often a matter of seconds.

OpenTimeTable provides users with three analysis modules. The modules work by collecting data from the OTT database document, performing various statistical operations, and then displaying the results graphically and in numerical format. The three analysis modules are:

- **Graphical Timetable (Train Graph)** – A graphical timetable is a type of time-space diagram. It presents a graphical description of motion of a vehicle (in this case a train) over a specified time and space.

- **Delay Distribution** – A distribution diagram simply plots the number of observations against the observation value. In the case of a delay distribution this consists of plotting the number of trains in the observation period (on the y-axis) against the delay value (on the x-axis).

- **Capacity Distribution** – A capacity distribution diagram helps planners analyze the effective use of time-slots. It shows how many trains have been operated through the timepoint during the time period of interest.

Generally a schedule planner will use all three modules and also vary the train group selection parameters in an iterative evaluation process. As the planner learns more about the schedule problems, he can make more detailed queries to investigate the situation more completely. Chapter 3 describes the analysis modules and how they can be used.

### 2.3 Automatic Delay Identification System

OpenTimeTable’s Automatic Delay Identification System is a new feature that informs users automatically when selected trains fail to meet user-defined quality criteria. This feature allows users to enter quality criteria into a window and then the program will automatically prepare reports when trains that violate those criteria.

For example, schedule planners could specify that OTT report all trains having a 2 minute delay on 50% of trains during 30 day period at station x. Each day the program would get data for the previous day and throw out the data for the day 31 days ago and calculate if the criteria was violated. If the criteria was violated the program would send a message to the schedule planner who could then use OTT’s analysis modules to develop a better understanding of the problem.

Automatic analysis is a significant enhancement to OpenTimeTable since it allows planners to evaluate a great deal of data with minimal human involvement. Automatic analysis will increase efficiency by allowing schedule planners to focus on solving systematic delay problems identified in the automatic analysis rather than spending time searching for delay patterns. It will be especially useful in evaluating the impacts of changes to schedules and infrastructure, automatically notifying planners if the new schedules fail to meet the specified quality standard.
3 Schedule evaluation with OpenTimeTable

OpenTimeTable is intended for use in an interactive manner. In other words, the schedule planner will run the program, review the results, change some of the analysis parameters, and run the program again. The user can adjust all or some of the following: the group of trains being analyzed, the type of analysis being completed, and display formats. By analyzing the data from several different perspectives in this iterative process, the schedule planner will develop a good understanding of the schedule problems. The scheduler uses this understanding to help prepare improved timetables. This chapter describes OpenTimeTable’s analysis modules and outlines how it can be used to improve preparation and refinement of railroad timetables.

3.1 Graphical timetable (train graph)

Figure 1 presents a graphical timetable created using OpenTimeTable. It illustrates train operations on the SBB’s rail corridor between Langnau (LN) and Entlebuch (ENT) for the week June 16-20, 2003, between 8:00 am and 10:00 am. Each line on the diagram represents the running of a particular train during this period; thus there are five lines (one for each day of the week analyzed). The dashed line is the scheduled running time. Figure 1 differs from familiar graphical timetables (which have single lines showing only the scheduled running times), since it shows the actual running times for multiple trains being operated over the same corridor.

Figure 1: Graphical timetable produced using OpenTimeTable.
Figure 2: Graphical timetable with scheduled and mean running times.

Figure 3: Graphical timetable with 75% running times cover.

Figure 2 presents the scheduled running time (dashed line) and the mean running time (solid line) calculated using the actual train running data shown in
Figure 1. Median train running time could also be displayed if desired. This figure clearly illustrates the difference between planned running times and actual.

Figure 3 presents the graphical timetable with a cover added. Covers are used to indicate the band of time when trains occupy a given section of track. They are displayed based on a user-defined variable. In this example the cover illustrates that the first 75% of all trains in the analysis group occupy this section of track during the time covered by the band. Users can set covers for any percentage of trains or use the standard deviation of running times.

### 3.2 Delay distribution

A delay distribution shows the number of trains in the observation period in various delay groups. Delay distributions are prepared for a particular timepoint (generally a station) or set of timepoints. Figure 4 illustrates a delay distribution for all passenger trains at the LN station during the entire day for the week of June 16-20, 2003.

Figure 4 shows the number of trains arriving during each one-minute time-interval from 1 minute early until 10 minutes late. The figure’s black vertical line (at x = 0) shows the scheduled arrival time. The delay distribution figure can be colored to illustrate various percentages of train arrival times. For example, in Figure 4, dark shading is used to illustrate when the first 75% of trains have arrived (in this case within four minutes of scheduled).

![Distribution of Number of Arrivals in LN.](image)

**Figure 4:** Delay distribution produced using OpenTimeTable.
In addition to the graphical representation, the delay distribution diagram also presents statistical data for the selected train group. Thus, the figure presents the mean delay (2.86 minutes) in the upper left part of the graph and the time when 75% of trains have arrived (in 0 – 4 minutes) in the upper right part (note that these minutes are defined as all trains arriving in the minute before the specified minute, thus zero-minutes includes all trains that arrive between one-minute early and exactly on-time). The shading effectively illustrates how much of the total delay is attributable to the worst performing trains. (Note that in Figure 4 because the time interval selected was whole minutes, the 75% criteria is not exactly met, in fact, as shown in the upper left hand corner, 75.56% of the trains arrive within four minutes of scheduled.)

The diagram also displays the count of trains and accumulated delay for each time segment under the x-axis. In this example it shows that 15 trains had a delay between 1-minute and 2-minutes, and that the total number of minutes of delay for these trains was 21.5 minutes.

### 3.3 Capacity distribution

The third type of graphical analysis that can be prepared using OpenTimeTable is a capacity distribution diagram. The capacity distribution is a histogram that plots the number of observed events that take place in a given time period. In the case of a capacity distribution the events of interest are arrivals at a station, or occupancies of a given section of track. Capacity distributions help planners analyze the effective use of railway infrastructure time-slots.

![Capacity distribution produced using OpenTimeTable.](image-url)
Figure 5 presents an example of a capacity distribution diagram for the Langnau (LN) station. It shows how many trains have been operated through the station during a 24-hour period. As with OTT’s other graphical representations the analysis module presents summary statistics and allows users to set covers to display percentage points (e.g. 75% of trains are accounted for in this number of observations. The shaded area in Figure 5 represents the 75% level of trains.

Figure 5 also illustrates the statistical data provided in the capacity distribution. This consists of the maximum number of slots used during the time period (e.g. 3 slots were used during the one hour between 9:00 am and 10:00 am) and the number of slots needed for 75% of the observed days (2.75).

3.4 Using OpenTimeTable data

As the discussion above indicates, OpenTimeTable provides users with a wide variety of different analysis tools for evaluating actual timetable data. Normally schedule planners will use the program in an iterative process to obtain an understanding of systematic timetable problems, such as regular delays. This understanding then forms the basis for refining and improving the timetable. Some examples of how OpenTimeTable analyses can be used include:

- **Identify Empty Slots** – By adding covers to the graphical timetables, scheduler planners can see where it would be possible to add trains without having the added trains delayed. For example the 75% cover area illustrated in Figure 3 means that if a scheduler wants to add a train that will not be delayed 75% of the time, he should schedule it to operate outside the time band shown. Thus, while the theoretical headway may be 2 minutes, OpenTimeTable allows users to view availability of the line based on actual running time statistics.

- **Evaluate Dwell Times** – Using the graphical timetable it is easy to observe when actual dwell times are longer than scheduled, indicating that measures to reduce dwell time are needed.

- **Identify Underpowered Trains** – If the graphical timetable shows that actual trains travel more slowly between two stops than scheduled (i.e. if the actual mean running time slope is less than the scheduled running time slope) it could suggest that a more powerful locomotive is needed.

- **Compare Operations** – The graphical timetable can be used to compare operations under different constraints, for example, before and during construction. This provides planners with a better understanding of how activities such as construction impact service. Such information can be used to develop special schedules to minimize customer inconvenience and to better inform the public about what to expect when construction is taking place.

- **Evaluate Effectiveness of Improvements** – OpenTimeTable analyses can be used to evaluate the effectiveness of schedule and infrastructure improvements by comparing data from before the change to after the change. This will help planners develop future improvement plans.
The main objective of OpenTimeTable is to clearly present actual timetable data to assist schedule planners in improving the quality of timetables. The program is an easy to use tool that displays evaluation information in a simple and easily understood graphical and statistical format. Being able to easily analyze and visualize the actual timetable data, in turn, makes it easier to solve problems and ultimately improve schedules. Finally, easily understood graphical representations are very helpful in communicating with non-technical people.

4 Summary

The railroad industry is in the midst of great change. Railroads are being forced through government mandate and, more importantly, by customers, to provide better service and to be more efficient. Today’s railroads must provide more and better service often with fewer resources. The key to succeeding in this new world is very careful planning and scheduling – focusing on getting as much out of the existing network as possible.

OpenTimeTable is one of a series of computer programs being developed to help railroad planners in this effort. It allows users to compare actual schedule adherence data with schedule timetables in a variety of graphical displays and statistical outputs. This information can then be used by schedule planners to help determine the cause of schedule problems and to develop solutions for these problems.