CETRA2010 17–18 May 2010, Opatija, Croatia
First International Conference on Road and Rail Infrastructure

SIMULATION OF MODIFIED TIMETABLES FOR HIGH SPEED TRAINS STOCKHOLM – GÖTEBORG

Hans Sipilä
Division of Traffic and Logistics, Department of Transport and Economics,
Royal Institute of Technology (KTH), Stockholm, Sweden

Abstract

In this research project, involving KTH, Swedish Rail Administration and train operating company SJ, timetable simulation is used on different areas in the Swedish rail network. The objective is to develop methods and strategies which can be useful for both long and short term timetable planning in the future.
This study presents some of the result from simulations done on the Western main line in Sweden. Traffic is mixed with significant differences in average speeds. This makes the high speed passenger trains (X2000) sensitive for small delays and disturbances caused by other, much slower trains.
Simulation software RailSys was used to evaluate how increased and decreased time supplements for high speed trains affect punctuality. Also buffer times were increased between X2000 and other trains. Delay distributions from previous projects were implemented in order to model entry delays together with dwell and run time extensions.
Results show that increased buffer times can have a significant effect on punctuality. Some of the studied trains have a situation with dense traffic and high occurrence of overtakings. This clearly increases average delays and contributes to a lower punctuality.

Keywords: train traffic, timetable, simulation

1 Introduction

The Western main line is a highly utilized double track line between Sweden's two biggest cities Stockholm and Göteborg (Fig. 1). High speed trains (X2000), commuter train systems together with several regional and InterCity systems share sections of the approximately 450 km long line. Freight traffic is also dense, especially between Hallsberg (H) and Göteborg. The Southern main line connects at Katrineholm (K) which gives a significant inflow and outflow of trains.

1.1 Background

Train slot demand has increased for both passenger and freight trains which makes the capacity stretched. The mixture of trains with different speeds contributes to delay propagation. High speed trains are sensitive to this, due to relatively large speed reductions which can result from disturbances. Punctuality is a widely used reliability measure. It calculates the percentage of trains arriving or departing within a certain number of minutes from scheduled time. In this study a 5-minute margin is used. Punctuality for high speed trains (X2000) between Stockholm and Göteborg drops with 15–20 percentage points depending on the direction. In an ongoing research project, methods and strategies for simulation based timetable planning are investigated. The project is a cooperation between KTH, Swedish Rail Administration and Sweden's largest passenger train operating company SJ.

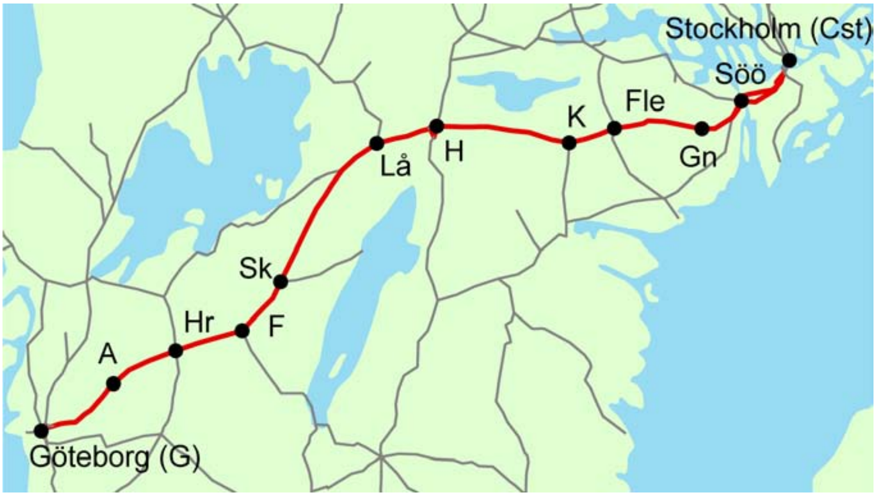

Figure 1 Western main line, Stockholm – Göteborg, with signatures for intermediate stations used in punctuality diagrams.

1.2 Aim

The research project aims in investigating how simulation of networks with disturbed traffic can be used to improve timetable planning. This study focuses on how timetable changes, e.g. increased or decreased supplements, affect punctuality for a specific train group and what actions can be taken to improve performance. Simulation software RailSys has been used at KTH in several research projects and capacity studies. In 2005 Swedish Rail Administration decided to implement RailSys as a tool for capacity studies and extend it to timetable planning in the future. This paper presents some of the results from a more comprehensive research report [1].

2 Method

Synchronous simulation models, where all events happen in the same order as in reality, offers a powerful tool in evaluating and analyzing rail network performance. This means that dependencies between train runs, connections and vehicle circulation can be included in the simulation [2]. It is also possible to perform changes in infrastructure, timetable, dispatching strategies and evaluate different setups. This can give further input to both short and long term planning. In the performed simulations only the timetable is varied. Infrastructure, vehicle models, delay distributions and other settings are kept unchanged.

2.1 Infrastructure model

The infrastructure model consists of tracks, stations, signalling system, speed profiles etc. Track and signalling plans used by Swedish Rail Administration provide detailed data to the infrastructure model. Some connecting lines are included in the network to make inflows and outflows more realistic. With this approach, influence of crossing train runs is included in the simulations. This is important, especially if the traffic is frequent.

2.2 Modelling of primary delays

To reflect real operation different type of disturbances are assigned to the trains. Entry delays, dwell time and run time extensions affect trains at relevant locations in the network. An important part is therefore to construct realistic delay distributions which can be used in RailSys. A previous project focused on reducing disturbance levels caused by infrastructure and vehicle malfunctions combined with operator related errors. In that study delay distributions were designed from real operational data based on year 2006 [3].
Entry delays are applied at stations where trains are created in the simulation model. These delays are quite easy to obtain from delay statistics. The whole set of trains is divided into smaller groups which gives more precise disturbance levels.
Dwell time extensions model variable boarding and alighting time for passengers at stations. Data for these delay distributions were compiled from manual measurements (performed by SJ) of passenger exchange times. Representative measured stations were chosen to model large, medium and small stations from an exchange time view. Dwell time extensions are difficult to estimate from registered delay statistics [4].
An important part of the simulation setup is to apply realistic run time extensions which potentially affect trains network wide. Since these extensions are meant to represent primary delays, registered data needs to be filtered by available cause-reported delays. This may be difficult to analyze since cause reports are made manually by dispatchers and do not cover run time extensions less than 6 minutes on single inter-station distances.
A slow growing delay, which for example could be the result of decreased vehicle performance, can lack a cause report even if the delay eventually becomes large. The network was divided into subsections, where larger stations or junctions are used as border points. Run time extensions are applied roughly in the middle of these subsections.
An ideal situation is to use distributions for run time extensions which represent only primary delays. Knock-on delays are created in the simulations and can later be evaluated. When delay variance is high, which is common for freight trains, it may be difficult to construct subgroups of trains and to adjust the delay distribution levels acting on them [3, 5]. High primary delays, originating from major infrastructure or vehicle breakdowns in the registered data, are avoided by truncating the distributions at some levels. These events usually require advanced dispatching measures, e.g. rerouting through other line sections.

2.3 Timetable

Passenger train configurations are usually well known. However, this does not apply for freight trains which mostly have a large variance in both length and weight. Also day to day variation for specific train numbers can be significant. Most of the freight trains were modelled with weight 1000 tons, length 400m and with maximum speed 90–100 km/h. Average length and weight values for freight trains running on weekdays in October 2008 between Hallsberg and Göteborg were 410m and 880 tons [6]. Usage of running time allowances to compensate for delays was limited to a certain percentage of the excess time and applied differently to passenger and freight trains [5].
Recovery times can decrease or avoid delays for specific trains. These are obtained by adding allowances or supplements to the minimum running time. Buffer times are added to minimum headway between two trains and act as recovery times of the timetable [7]. Most of the timetable changes made on other trains are minor adjustments. However, some trains (mostly freight) are completely rescheduled. Simulated timetables are:

- Reference timetable for year 2009 (T09)
- Decreased timetable supplements with 4 minutes for X2000
- Increased timetable supplements with 4 minutes for X2000
- Increased buffer times between X2000 and other trains

The simulated reference timetable was created according to scheduled train plan valid for Thursday 29th January 2009, which was a normal weekday and not linked to any public holiday. Some preplanned freight trains were cancelled, this was compensated with additional scheduled extra trains. X2000 trains are, with a few exceptions, running every hour with departures between 5 and 21, most of them make four intermediate stops. The stopping pattern shows some variance regarding to which stations are used, however all trains have a scheduled stop in Skövde (Sk). In addition non-stop trains operate during morning and afternoon peak hours.

3 Results

First approach was to analyze the X2000 trains on aggregated level where results are calculated for the whole group in each direction. It is also of interest to study individual trains. This requires that the number of simulated cycles is sufficient in regard to output variance when different sets of random numbers for generated primary delays are used. Performed simulations were done with 1600 cycles, which gave an acceptable variance in output data.

3.1 Aggregated level

The simulated reference timetable shows that some sections are problematic in both directions, especially regarding to relative distance (Fig. 2). This is partly explained by dense traffic on some sections and also by tightly scheduled supplements or allowances. X2000 trains have usually some extra timetable supplements when approaching Göteborg and Stockholm, which may reduce delays. Whether this feature can be used or not depends on the traffic situation further ahead.

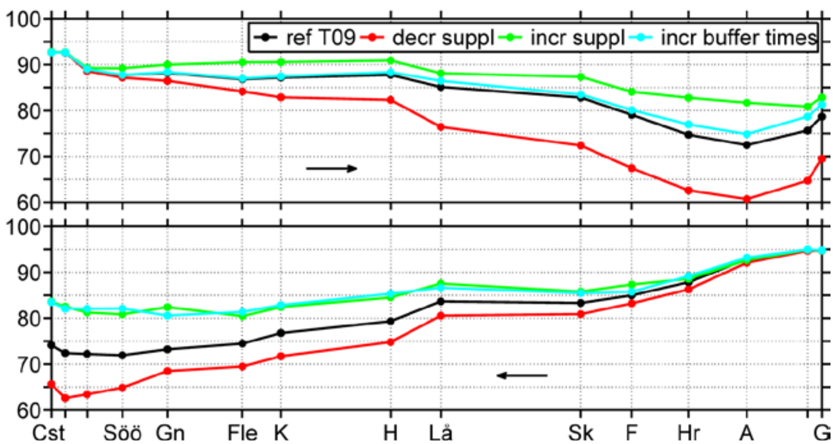

Figure 2 Simulated punctuality (%) on 5-minute level for X2000 trains. Reference timetable T09 with three alternatives. Relative scale on station axis.

If timetable supplements are decreased arrival punctuality at end stations drops with 10 percentage points. Approximately the opposite occurs for increased supplements, trains bound for Stockholm have a larger improvement (Fig. 2). A considerable number of timetable changes was performed in order to adjust other trains when supplements were changed for X2000. As mentioned before primary delays are fixed, meaning that all trains experience the same frequency and level of primary disturbances in each simulated variant.

In the third variant buffer times between X2000 and other potentially conflicting trains were increased to 5 minutes. This holds both for line sections and for crossing train movements at stations, except on the Stockholm bottleneck. Simulated punctuality improved significantly for trains bound for Stockholm. Results in the other direction showed only marginal improvements (Fig. 2). The amount of changes applied in the timetable was also less in this direction, therefore potential improvement was smaller.

3.2 Individual level

Punctuality gives only limited information about train delays. The large number of small delays is not fully described by the quite rough punctuality measure. A more comprehensive picture can be obtained if means and standard deviations are studied [4]. It can also be valuable to break up aggregated groups and present each train individually. This gives insight in whether trains in a group have equal or spread performance. Poor performance for one or a few trains could imply low quality train slots with risk for high disturbances, timetable and running time mismatch or problems with dispatching measures in the simulations.

Simulated mean arrival delays and standard deviations are lower for trains arriving in Stockholm compared to Göteborg (Fig. 3). One probable explanation is that if a late train approaching Alingsås ends up behind a slower train, significant delay increase will occur. Commuter trains make 10 intermediate stops on this section, overtaking possibilities are limited. Trains approaching Stockholm from the Western main line have smaller differences in scheduled average speeds. Compared to the Göteborg area, changed sequence of trains have a lighter impact on delay development.

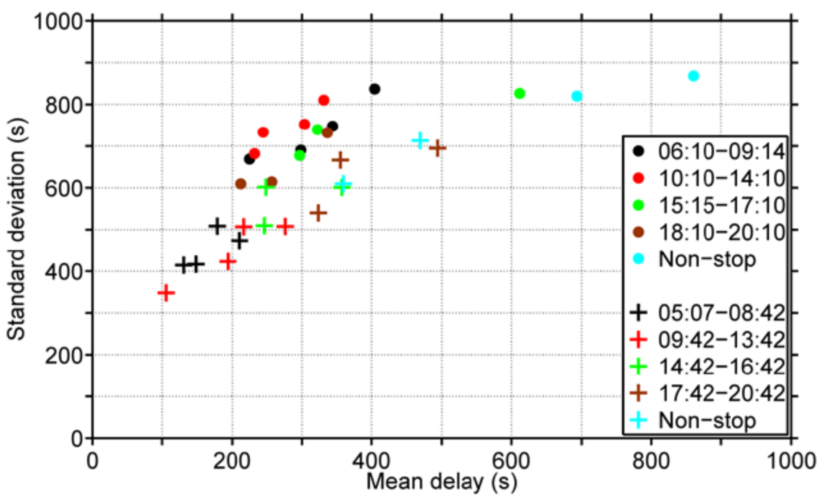

Figure 3 Arrival values in Göteborg (•) and Stockholm (+). Departure time intervals from start station in legend. Timetable T09.

Non-stop trains have generally higher mean and standard deviation values. Main causes are tight train slots, smaller supplements and lack of ability to reduce delays on scheduled stops. The variant with decreased supplements gives larger spreading in mean and standard deviation values. Increased supplements and buffer times have less spreading compared to timetable T09 in Fig. 3. However, Stockholm has smaller values in average compared to Göteborg in all variants.

An example of improved punctuality with increased buffer times for selected trains is shown in Fig. 4. Some trains with initial high punctuality performance obtain only marginal or no

improvements. An obvious reason is that these trains already have robust train slots where the probability for small disturbances caused by other trains is low. Trains with low punctuality levels have tight buffer times on several sections or stations with other trains.
Frequent scheduled overtakings of freight trains is also a disturbance source. Some trains benefit from postponed commuter train departures, thus locally creating more robust solutions. Altered overtaking stations and time adjustments for freight trains can also create better conditions.

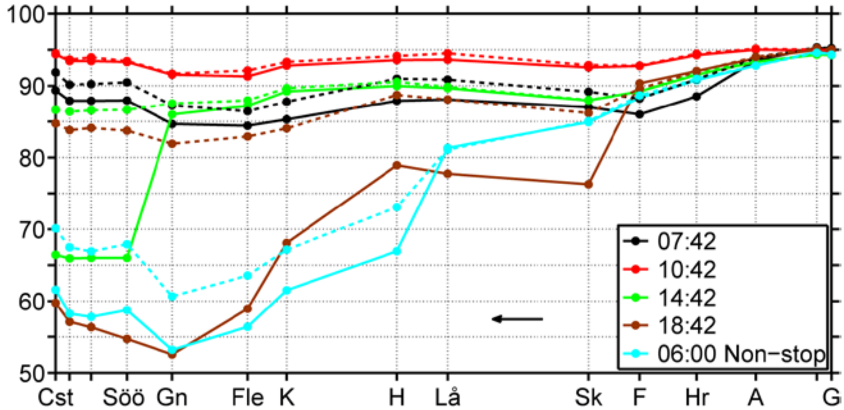

Figure 4 Simulated punctuality (%) for selected trains to Stockholm, timetable T09 (solid) and increased buffer times (dashed).

4 Conclusions

In one sense the situation for X2000 trains is better in the Stockholm area compared to Göteborg. When disturbances occur and scheduled train sequences are changed, the differences in average speeds are lower in Stockholm. The traffic is of course intensive, especially during peak hours. A substantial improvement was observed for specific trains when scheduled buffer times to departing commuter trains was increased from 2–3 to 5 minutes in Gnesta. Commuter train turnarounds at this station are also discussed in [8]. Freight train levels in Stockholm are quite small compared to Göteborg region.
On the other side of the Western main line mixture of trains with different speeds is significant. Freight traffic is intensive and even though stations with overtaking possibilities exist, initial delays are likely to increase. X2000 trains leaving Göteborg during late afternoon and evening have a higher probability for decreased punctuality compared to morning departures. In particular northbound freight train departures from Göteborg are dense during afternoon hours. Freight trains ahead of schedule are not uncommon in Sweden, which further increase the variance in real operations. This is however difficult to model, early departures are therefore assumed to be on time in delay statistics used in RailSys.
Punctuality effects on other trains in the simulated variants were small. However, this was only checked on fairly rough aggregated levels. This means that most of the trains on which these evaluations were based on, were hardly affected by the timetable changes. This kind of analysis could be performed in more detail, with emphasis on trains scheduled close in time to X2000.
High variances for arrival delays in Fig. 3 indicate that general timetable supplements are difficult to apply. Instead individual trains with poor performance could be studied to find solutions. Simulations with common random numbers show that deviation between mean delays for individual trains is approximately ±2% in average and ±6% as most. A complete

calibration and validation process was not conducted in this study, instead input was used from earlier projects performed at KTH [3, 5].

References

[1] Sipilä, H.: Tidtabellsläggning med hjälp av simulering – Effekter av olika tillägg och marginaler på X2000-tågen Stockholm – Göteborg (Simulation based timetable costruction – Effects of allowances and supplements on X2000-trains Stockholm – Göteborg). KTH, 2009. (In Swedish)

[2] Siefer, T.: Simulation. In: Hansen, I. A.; Pachl, J. (editors): Railway timetable and traffic, pp 155–169. Eurail press, 2008.

[3] Nelldal, B-L.; Lindfeldt, O.; Sipilä, H.; Wolfmaier, J.: Förbättrad punktlighet på X2000 – analys med hjälp av simulering (Improved punctuality for X2000 – a simulation approach). KTH, 2008. (In Swedish)

[4] Yuan, J.: Stochastic modelling of train delays and delay propagations in stations. PhD~thesis, Delft University of Technology, 2006.

[5] Lindfeldt, O.; Sipilä, H.: Validation of a simulation model for mixed traffic on a swedish double-track railway line. Railway Engineering – 2009, 10th International Conference, London, UK, 2009.

[6] Nelldal, B-L.; Lindfeldt, A.; Lindfeldt, O.: Kapacitetsanalys av järnvägsnätet i Sverige – Delrapport 1–3 (Capacity analysis of the Swedish rail network). KTH, 2009. (In Swedish)

[7] Rudolph, R.: Allowances and margins in railway scheduling. Proceedings of the World Congress on Railway Research, pp 230–238. Edinburgh, Scotland, 2003.

[8] Anand, N.; Anayi, M.: Improving punctuality of train traffic on Western main line of Swedish railway network: Simulation approach. Proceedings of ASME 2009 Rail Transportation Division Fall Conference, Forth Worth, USA, 2009.