The potential for saving energy by more precisely calculating station dwell times on commuter rail service

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Abstract

This paper evaluates the effectiveness of reducing scheduled station dwell time to save energy on commuter rail lines. Most commuter rail schedules include a fixed amount of dwell time (e.g. 30-seconds) at each station. For stations with higher demand the station dwell time may be up to 1 minute. Generally the station dwell time is set high enough to meet peak period passenger boarding/alighting demand and remains constant throughout the day. Therefore, station dwell times in off-peak periods are often longer than needed. The goal of this research project was to estimate the energy savings that could be achieved by re-allocating excess station dwell time to the inter-station travel time thereby enabling the train to travel at a slower top speed between stations. This was done by developing an estimate of the number of passengers boarding/alighting at the next station for each trip, precisely calculating the inter-station speed and providing this information to the train operator. The research simulated operations of an actual commuter line in Vienna to estimate the energy savings possible using this strategy. Results showed that commuter railways could reduce their energy use by approximately 1% by more precisely setting station dwell times.

Keywords
Railway energy saving, reducing station dwell time, railway simulation

1 Introduction

As energy prices rise and concerns over climate change increase railways are urgently seeking strategies for saving energy. Reducing energy use is especially important for European railways since recent market liberalisation is increasing competition.

In 2007, the Austrian Federal Railways asked Arsenal Research (www.arsenal.ac.at and the Vienna University of Technology's Institute for Railway Engineering, to evaluate strategies for reducing energy use. The "Potentiale Energiesparender Fahrweisen im S-Bahn-Verkehr" project (PEFIS) analyzed the feasibility of introducing a specific energy saving strategy on the OeBB's commuter rail operations based on Austrian regulations and boundary conditions (e.g. signalling rules, commuter train onboard-equipment).

The first step in the PEFIS study was to analyze the influence of different operating parameters on commuter rail energy use based on existing literature. These factors included acceleration and deceleration behaviour of different commuter trains, maximum speed limits of infrastructure and rolling stock, and braking behaviour (Meyer [7]).

A key parameter identified in the PEFIS study which had not been previously investigated in detail was station dwell time The PEFIS-study found that if it was possible to reduce the time allocated in the schedule for passengers to board and alight trains at stations, then that excess dwell time could be allocated to the inter-station travel time; this would enable train operators to maintain schedules while driving at a lower maximum speed. Reducing maximum speed reduces energy consumption.

The passenger boarding and alighting process takes an average of 11% of the total travel time on commuter rail systems (e.g. Rüger [6]). There are two main ways of reducing station dwell times: first, reducing the time it takes passengers to board and alight trains (through physical strategies including level-boarding, better distribution of passengers on platforms, etc.); and, second, adjusting dwell times to more closely meet actual passenger boarding/alighting demand. The first strategy has been discussed extensively in the literature (see e.g. Nash [4], Buchmüller [2]) and therefore this research focused on the second strategy.

Adjusting station dwell times is particularly interesting because it does not require significant capital investment. Furthermore, more powerful computers and more detailed railway data combined with improved railway simulation applications has made it possible to improve the quality of demand forecasts and the communication of driving instructions to train operators – two key elements needed to implement the strategy. Therefore, the Austrian Ministry of Transport and Innovation (BMVIT) provided funding to the consortium to more thoroughly evaluate the strategy. This paper presents results of the evaluation.

Section 2 of this paper presents the research methodology including a more detailed description of the typical method for setting commuter rail station dwell time. Section 3 presents the methodology used to develop revised schedules. Section 4 presents the results of a simulation analysis done to evaluate the impacts of the strategy on commuter rail energy use. Section 5 presents conclusions and recommendations for future research.

2 Research Methodology

The PEFIS project started with a detailed investigation of the theoretical basic principles that impact energy use on commuter rail operations (including driving dynamics, operation simulation, etc.). In the second step, the parameters that have a significant influence on driving dynamics were identified and evaluated. This preliminary research found that the variation in passenger boarding and alighting time at stations during the day was an important factor influencing train operating characteristics. In fact, the large variability in boarding/alighting time has a significant potential for saving energy.

Many commuter rail systems operate on regular clockface schedules (i.e. they arrive and depart from stations at the same number of minutes past the hour/half-hour throughout the day). This means that the station dwell time is constant throughout the day. Since dwell times are normally set for peak-period conditions, they will generally be longer than necessary at off-peak periods. Therefore, by reducing the actual time trains spend stopped in stations for passenger boarding/alighting in non peak periods, the saved time can be reallocated to enable trains to travel more slowly between stations, thus lowering energy consumption without extending the travel time.

The concept is to provide train operators with energy efficient driving instructions for each track section on a given run based on forecast passenger boardings and alightings at each station. In other words the system would forecast the minimum dwell time for each station and trip, than use these forecasts to set driving parameters for each track section. The number of passengers boarding and alighting could be forecast based on simulation and demand modelling or could be measured in real time using detection systems at stations and on the trains.

In this research time series data was collected on the number of passengers boarding/alighting and the total time necessary to board/alight at all stations on the S45 commuter rail route in Vienna over the course of a typical weekday. The time series data was collected by analysing and evaluating recorded images from cameras on the platforms and on-board automatic passenger counting systems. Data was collected for 10 stations over 10 days. The selected line was chosen because it had a low level of mixed traffic making it easier to identify commuter rail passengers.

As outlined above, the time needed to board/alight is a function of physical conditions at the station and vehicle, passenger waiting patterns and number of passengers. By holding the train types and stations constant it was possible to evaluate boarding/alighting times for each station and each train departure. This boarding/alighting data evaluation was then used in a railway simulation program to estimate the minimum station dwell times for each train and therefore the optimal driving instructions for operating the train between two stations. Next, the simulation application was used to estimate the amount of energy that could be saved following the revised operating instructions.

3 Development of new driving strategy

The basic assumption used in this research was that a given train’s time slot could not be changed. The time slot is the amount of time allocated by the infrastructure for operating a given train; time slots are defined for specific track sections in terms of duration and start/end time. Under this assumption station departure times for all trains will be the same as before, only arrival times are allowed to vary.

Figure 1 schematically illustrates this assumption. Under all alternatives trains leave station A at the same time, but arrive at station B at different times. The figure compares speed and travel time for three different driving modes on a section between stations A and B. The technical running time is the best possible running time given the track section geometry and rolling stock performance characteristics. The slightly lower time-distance line (dashed blue line) is normally used for slot time construction; it is defined based on time reserves given in UIC Leaflet 451-1 and is approximately 95% of technical running time. The fixed station dwell time is generally added to this travel time and is shown on the figure. The third time-distance line (dashed red line) shows how maximum speed could be reduced if station dwell time is reduced.

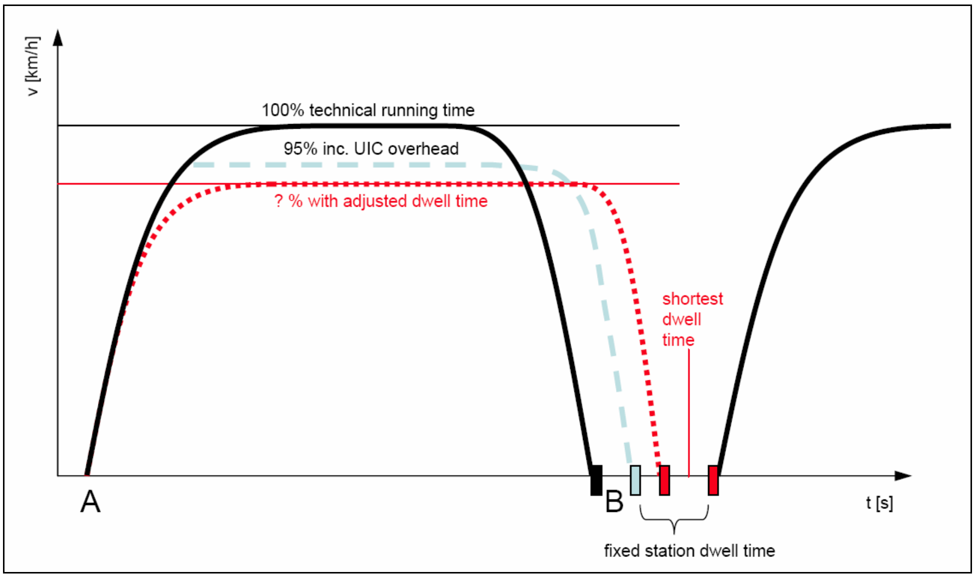

Figure 1: Time-distance graph

A second basic assumption in the research was that it must be possible to implement any recommendations without significant changes to the rolling stock and tracks. This assumption means that sophisticated real-time man-machine interfaces (eg: proposed in Lüthi [3]), which could inform train drivers of optimal speeds for a given track segment and adjusted next station dwell time, were not evaluated (however, we recommend that their impact be considered in future research). Providing more detailed information to train drivers through onboard interfaces would enable drivers to save additional energy through the use of coasting and reduced braking. The OeBB is currently working on a program to develop an electronic timetable display that could be used in this way.

Since real-time train operating instructions could not be used, the research was based on developing reduced maximum speeds for track segments; for practical reasons reductions were made in multiples of 5 km/h (speedometers in trains are calibrated in 5 km/h units). Expressed in terms of Figure 1 above: the process of reducing speed for track section A-B was repeated until the adjusted station dwell time at the Station B was the minimum necessary for the projected passenger boarding/alighting demand without delaying the train’s departure time from Station B. The result was that three maximum speeds were identified for each track section: technical maximum, constant dwell-time maximum (based on fixed schedule) and adjusted dwell-time maximum (energy saving alternative).

In actual operations this approach would mean developing an additional timetable for drivers to follow when operating a train. The new timetable would show all three maximum speeds on each section. When the train is running punctually, the adjusted dwell time maximum speed would be used; when the train is slightly delayed, the fixed-schedule maximum would be used; and, when the train is very delayed, the technical maximum speed would be used. So the normal and the new timetable sheets should be located next to each other in the operator timetable book.

4 Simulation of adjusted dwell time operating strategy

The new train operating strategy was evaluated using simulation to estimate the amount of energy savings it could provide. The SIMU-model was used in this analysis since it is the most commonly used railway simulation application used by the Austrian Federal Railways for operational studies. The SIMU-model was developed by IBS (Consulting Company for Railways Operating Systems, Hannover, Germany). The model operates synchronously so all train runs are calculated in parallel. This allows users to identify and solve conflicts (interference between train runs) automatically during the simulation run. The main result is a prediction of delays and service quality in railway operation.

The SIMU-model uses an infrastructure graph to depict the track layout. The model includes databases with timetable information and dynamic parameters of each train. The simulator calculates operating parameters (including travel time, energy use, maximum speed etc.) for each train run based on the timetable, geometric conditions and any special driving strategies.

In this research the three different operating strategies (see table 1), based on maximum speed between stations, were evaluated. These strategies were:

- Technical maximum speed (shortest time)
- Constant dwell-time maximum speed (according to planned schedule)
- Adjusted dwell-time maximum speed (energy saving alternative)

The amount of energy used for each of these three operating strategies (for each track segment) was estimated by ÖBB Traktion GmbH using the software tools DYNAMIS (e.g. Radtke [5]) and EMAT (e.g. Anthes [1]). These tools are used to calculate running times and energy consumption. The analysis assumed that energy recuperative braking would be used.

Table 1: Energy consumption for different driving strategies

	energy consumption [kWh]				energy consumption [kWh]		
section	shortest	normal	dwell-time	section	shortest	normal	dwell-time
Hak - Ht	15,092	13,543	13,128	Hf - Pz	17,277	12,822	10,938
Ht - Ht H1	19,802	19,802	19,792	Pz - Ok H1	9,923	8,62	8,136
Ht H1 - Ht H2	14,338	8,399	7,123	Ok H1 - Ok	16,46	14,765	16,46
Ht H2 - Ht H3	26,223	16,837	16,109	Ok - Hns	6,796	6,806	5,573
Ht H3 - Hns	16,953	11,033	11,033	Hns - Ht H3	7,091	7,081	7,082
Hns - Ok	19,417	9,01	9,009	Ht H3 - Ht H2	3,63	0,332	0,342
Ok - Ok H1	18,298	5,898	3,946	Ht H2 - Ht H1	3,559	2,166	0,243
Ok H1 - Pz	11,48	2,679	2,669	Ht H1 - Ht	1,375	-0,044	-0,71
Pz - Hf	39,18	18,83	18,841	Ht - Hak	12,542	9,916	9,286
sum	180,783	106,031	101,65	sum	78,653	62,464	57,35

Once the energy requirements for individual trips were available, the SIMU-model was used to simulate a variety of possible scenarios. The first scenario consisted of a perfect schedule (i.e. no delays to any trains). This scenario was used to determine which track sections could benefit from the energy saving operating strategy.

After the first scenario had been evaluated, several other scenarios were tested that included initial delays and/or delays (given by measured delay distributions for each station and direction) to trains while operating. In these scenarios the simulation used the energy-saving operating strategy in case of no delay, the constant dwell time schedule strategy when a train is slightly delayed (less than 12 seconds) leaving a station, and the technical maximum speed in the case of higher delays.

In total 100 simulation runs (representing 100 days of operation) were completed to better understand the influence of delays on the ability of the adjusted dwell time strategy to reduce energy consumption. The delays were simulated using stochastic perturbations (e.g. initial delays are stopping time extensions) that are executed in following simulation steps. After these simulation-runs of perturbed timetables each delay and realised driving strategy can be statistically analysed. This made it possible to compare the expected quality of railway operations when using energy saving driving strategies to normal train operating strategies and therefore to assess the effectiveness of the strategy in actually saving energy.

Figure 2 presents the simulation results. The figure shows the percentage of runs in which trains could be operated under each operating strategy (technical maximum speed, planned schedule or energy saving alternative) on each segment of the modelled commuter rail line. As shown in Figure 2, there are very few cases where the technical maximum speed must be used (i.e. delays of more than 60 seconds) and between 20% and 40% of trips are able to choose the energy efficient driving mode depending on track section.

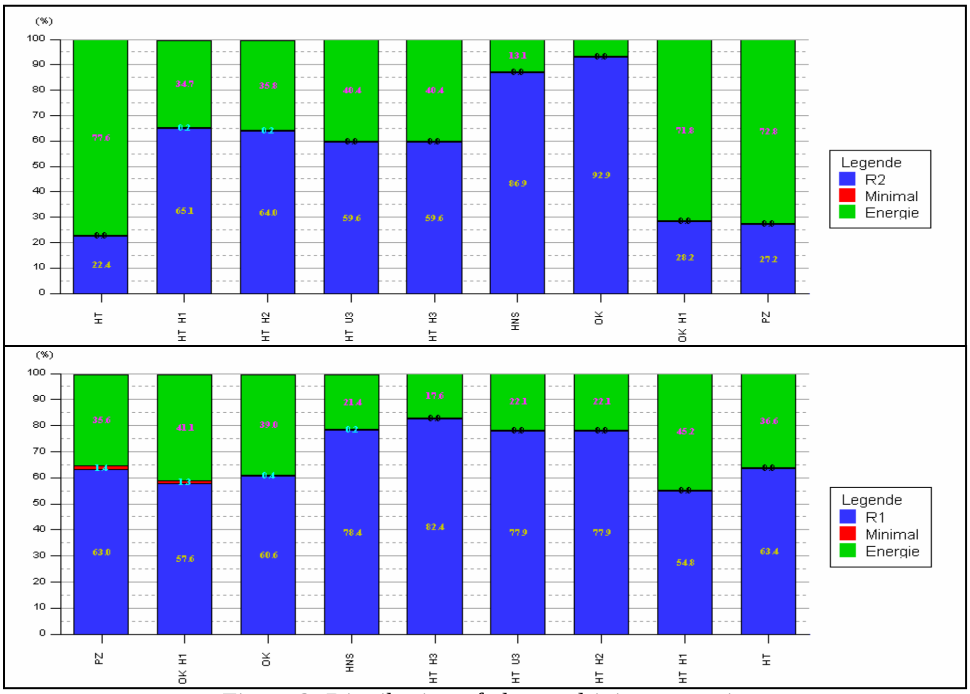

Figure 2: Distribution of chosen driving strategies

The simulation results were used to make an estimate of the energy saving potential for the adjusted dwell time operating strategy (i.e. energy saving strategy). This was done by multiplying the percentage of trips that could be operated using the energy saving strategy on a given segment by the energy savings per train on that segment, and then summing over all segments for the entire day.

The research found that the energy saving strategy could reduce energy use by approximately 1% on a typical Vienna commuter rail line. While this figure may appear small, as energy prices increase it could lead to significant financial savings. Furthermore, combining the strategy with train-based interfaces that allow more precise train speed control could lead to further reductions in energy use.

5 Conclusions and Recommendations

The research project showed that minimizing station dwell time while maintaining the same scheduled departure time can lead to a reduction of energy use of approximately 1% for a typical commuter rail line. Additional energy could be saved through the implementation of driver interfaces that could communicate more precise driving instructions to train drivers in real time. Importantly, the method proposed in this research can be implemented by railways using mostly existing technology making the program a justifiable economic expense.

So for a first implementation stage it is possible to simply prepare a new timetable sheet for drivers which provides alternative speed limits. This approach would not require any further instruction of drivers because the concept of alternative timetable sheets is already used at Austrian Railways. Other driving strategies would require retraining drivers or changes to the infrastructure manager’s rules (e.g. signalling of breaking points).

It is also interesting to note that reducing energy use is not only beneficial for the train operating company (which pays for the energy), but also for the infrastructure owner who could reduce spending for power supply infrastructure.

There are several recommendations for additional research. First, the impact of improved operating instruction communications equipment onboard trains should be considered. Providing train drivers with more precise train operations information should lead to additional energy savings (and/or improved customer service). Second, techniques for estimating minimum station dwell time in real time (i.e. through improved platform counting systems etc.) should be considered. Finally, a comprehensive model should be developed that includes both physical dwell time reduction improvements and the type of schedule adjustments considered in this research. This model should be designed to help railways better plan their schedules, infrastructure and rolling stock to optimize energy use, economics and passenger service.

References

[1] Anthes, R., Klahn, V., Turk, M. *Berechnungen des Traktionsenergiebedarfs für eine nachfrageorientiertes Energiemanagement beim Geschäftsbereich Traktion der Österreichischen Bundesbahnen.* ZEV Glasers Annalen 128 (2004) 5 Mai. 270-276.

[2] Buchmüller, S., U. Weidmann and A. Nash; Development of a Dwell Time Calculation Model for Timetable Planning; Presented at Comprail 2008; September

2008; Toledo, Spain.

[3] Lüthi, Marco, Giorgio Medeossi, Andrew Nash; Evaluation of an Integrated Real-Time Rescheduling and Train Control System for Heavily Used Areas; Paper presented at the International Seminar on Railway Operations Modelling and Analysis (IAROR) 2007 Conference, Hannover, Germany.

[4] Nash, Andrew, Ulrich Weidmann, Stefan Buchmüller, and Stefan Bollinger; Increasing Schedule Reliability on Zurich's S-Bahn Through Computer Analysis and Simulation Transportation Research Record #1955; Transportation Research Board, Washington D.C.; pp 17-25; 2007.

[5] Radtke, A., Klahn, V., Singer, G. *Fahrdynamikberechnungen bei den Österreichischen Bundesbahnen.* EI Eisenbahningenieur. 49 (1998) 86-93.

[6] Rüger, B., Tuna, D; *Fahrzeugseitige Optimierungspotenziale zur Verkürzung der haltezeit;* ETR - Eisenbahntechnische Rundschau, **09** (2008), 09/2008; S. 526 – 532

[7] Meyer, M, Menth, S, Lerjen, M; *Potentialermitllung energieeffizienter Traktion bei den SBB, Schlussbericht;* Bundesamt für Energie, Bern, Dezember 2007.