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Impact on driver behavior and capacity from ERTMS speed-filtering

T Rosberg and B. Thorslund

VTI, Linköping, Sweden

Abstract

In the signal planning process, the ERTMS speed profiles based on track nature needs to be complemented with additional constraints. The base profile resolving the allowed track speed, often includes several speed changes which can be difficult for the train driver to follow. One approach to deal with this problem is to filter the base profile, reducing the number of changes and giving the driver more time for attention.

This paper presents the effects of a speed profile filtering principle, based on possible time usage during a speed increase, on train energy consumption, train driver braking behavior, running time, and driver workload. In an Electrical Multiple Unit train driver simulator, 41 drivers tested three different speed profiles of a 19 km railway line. It can be concluded that differences in running time are small, that these small time-gains implies a high energy consumption cost, and that drivers tend to drive close to the indication braking curve in the beginning of the braking phase. Further, the drivers rated the driver task workload low for all filter conditions and their experienced performance highest with the most filtered profile. Accordingly, a certain filter level is required to get capacity, energy, and workload effects.

Keywords: ERTMS; ETCS; speed-filter; driving-behavior; capacity; workload

1 Introduction

Sustainable railway design plays a central role in the process of reaching the goals of traffic safety, capacity, and energy consumption. For a successful technical swift from the previous lineside based signaling systems to ERTMS, there is a need to examine the consequences of the transition on both train drivers and capacity measures.

Experiences from ERTMS implementations are still limited, and there is no established process for driveability analyses, examining both physical aspects and driver perception. Highlights from a literature review on driveability are the importance of the speed profile design to avoid negative consequences for the train driver workload, driving style, and braking behavior as well as the suggestion of filtering speed profiles presented to the drivers [1].

Applying filters by suppressing a certain amount of speed signaling information to the driver, is an important topic in the ongoing driveability assessments discussions. Traditionally, Swedish Transport Administration (TRV) have performed signal planning projects, which results in basic speed profile based on the track conditions. By removing or merging speed-changes, the driver will have more time for outside cab attention but also decreased possibility to catch up with time-table delays.

TRV suggests a time-based principle of achieving this [2], and in Figure 1 an example of a 30 second speed filter is shown. The train must reach its target speed within 30s, before starting a deceleration towards a target with a more restrictive speed. If this condition cannot be met, a lower target speed is considered. If no alternative is found, the speed increase is excluded from the static speed profile (SSP). In this study two filters, 30s (filter level 1) and 60s (filter level 2) are examined and compared with the unfiltered base profile.

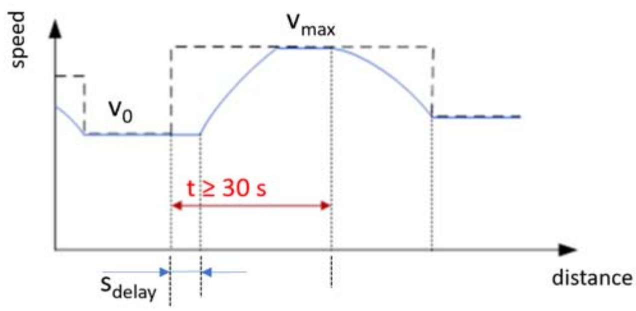

Figure 1. 30s filter principle. v_0 is the start speed. v_{max} is the proposed target speed, and s_{delay} the train length delay.

Train driving simulators offer safe and repetitive environments close to reality, which makes them important tools for efficient and valid training [3] as well as for research [1][3][4] and they have been suggested useful also for driveability analyses and evaluations [1][5].

This study aims to examine the consequences and quantify the effects of applying speed filters. For this, a train driving simulator has been used and the following research questions have been formulated:

What effects do speed-filtering have on capacity in terms of running time, brake behavior, energy consumption, and driver workload?

2 Methods

The effects of speed filtering were approached by letting train drivers run the same railway section with different filter levels in a simulator environment. The VTI train driver simulator including a vehicle model in accordance with Bombardier Regina EMU was used. This is designed as a real driver's cabin, which was mounted in a trailer and moved between the ERTMS operator driving centers in the north of Sweden.

Three different static speed profiles were implemented for the selected 19 km stretch, between Ramvik and Dynäs at the Ådal line. The base SSP was retrieved from Transport Administration ERTMS project [6]. Infrastructure data was fetched from BIS, the Swedish Transport Administration track database. This includes track coordinates, inclination, curvature, signal positions, balise positions, and ETCS marker boards positions. The environment around the track, as seen from the train cabin, was simplified compared to the real world. In Kramfors, the main station between Ramvik and Dynäs, the driver was asked to stop for passenger exchange.

The driver test group was recruited in collaboration with the train operators. In total 41 participants took part in the study, 30 men and 11 women. Upon arrival, the participants were given oral and written information about the study and agreed to participate by signing an informed consent. The simulator test was preceded by driving instructions and a training session in the simulator. Three driving conditions were then carried out by the participants with a small break for questionnaire and refreshments between each run.

3 Results

Here the effects of speed filtering on running time, brake-behavior, energy consumption, and train driver workload are presented.

3.1 Running Time

The running time for 14 km driving, measured to the station stop in Kramfors show small-time differences between the filters. Between the unfiltered speed profile and the first filter level no significant difference was revealed. Between the unfiltered condition and filter level 2, there is a significant difference of 3 seconds, see Table 1.

Table 1. Descriptive statistics for running time for the three filter levels.

Filter type	N	Mean [s]	SD [s]
Unfiltered	39	524.9	6.2
Filter level 1	38	525.2	7.2
Filter level 2	39	528.0	5.8

3.2 Break-behaviour

No significant difference between filters on time distance to the permitted braking (P) curve was revealed. In general, drivers left sufficient margins to the P-curve. In the beginning of the braking phase the average time was 4.9 s, and in the end 1.9 s.

3.3 Energy consumption

A significant effect of speed filters on energy consumption was found, such that compared to filter level 2, consumption was higher for an unfiltered profile (9 %) and for level 1 (7 %), according to Table 2.

Table 2. Descriptive statistics for energy consumption for the three filter levels.

Filter type	N	Mean [kWh]	SD [kWh]
Unfiltered	40	104.5	1.4
Filter level 1	40	102.6	0.9
Filter level 2	39	96.0	1.5

3.4 Driver Workload

The driving task was easy, as shown by low workload ratings in all conditions. On average, the RAW-TLX ratings were never higher than 33.3 on the scale from 0 (low effort) to 100 (high effort). However, a main effect of filter on experienced performance was revealed, such that performance was rated significantly higher when driving with the most filtered speed profile. There was also a significant interaction effect, such that higher age was connected to a larger increase in experienced performance with the most filtered speed profile.

4 Conclusions and Contributions

Conducting driveability studies and comparing various speed filters with a train driving simulator is a feasible method to increase the knowledge of speed filtering effects in the ERTMS environment. By applying speed filters and suppress a certain amount of speed signaling information to the train driver, the prerequisite for driveability is changed. When applying a time filter, suggested by the Swedish

Transport Administration, the filter time effects running time, energy consumption and driver workload.

A 60 s filter is required to get significant differences in running time, but the differences are small (<1%). The 30 s filter is too short to generate an effect as long as the restrictive ETCS braking curves are applied. A relative short time gain results in a 7-9% higher energy consumption. There was no effect of the speed filtering on brake behavior. However, the result from brake distance measurements showed a braking behavior close to the indication curve in the beginning of the braking phase.

Objective driving behavior measures correspond to participants subjective ratings. Speed filtering had a positive effect on workload, such that with a certain level of speed filtering, the train drivers reported increased performance. Accordingly, a certain filter level is required to get capacity, energy, and workload effects. However, a less filtered speed profile can be motivated to remove irrelevant speed increases without losing capacity, which could be useful not least in the transition towards ATO.

References

[1] Rosberg, T., Cavalcanti, T., Thorslund, B., Prytz, E., & Moertl, P. (2021). Driveability analysis of the european rail transport management system (ERTMS) : A systematic literature review. *Journal of Rail Transport Planning & Management, 18*.

[2] Trafikverket. (2020). Optimering av lutnings- och hastighetsprofil. Trafikverket.

[3] Olsson, N., Lidestam, B., & Thorslund, B. (2021). The practical part of train driver education : experience, expectations, and possibilities. *European Transport Research Review, 13*(1).

[4] Thorslund, B., Rosberg, T., Lindström, A., & Peters, B. (2019). User-centered development of train driver simulator for education and training. *8th International Conference on Railway Operations Modelling and Analysis (ICROMA 2019).* Norrköping, Sweden, June 17-20, 2019.

[5] Nordlöf, E., Hägglund, C., & Kecklund, L. (2014). Underlag till riktlinjer för E2 signalprojektering - För att skapa körbarhet ur ett förarperspektiv [Basis for E2 signal design guidelines -To create driveability from a driver´s perspective].Trafikverket.

[6] Trafikverket. (2020). Ådalsbanan. Signalerad hastighetstabell. Trafikverket.