Energy-efficient speed profile optimization of freight trains from onboard monitored data

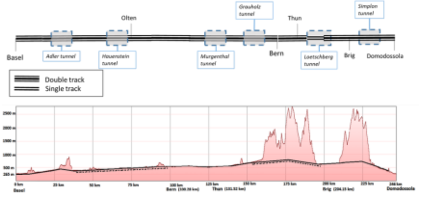
dr. Valerio De Martinis
Institut für Verkehrsplanung und Transportsysteme (IVT)
ETH Zürich
valerio.demartinis@ivt.baug.ethz.ch

Prof. Ulrich A. Weidmann
Institut für Verkehrsplanung und Transportsysteme (IVT)
ETH Zürich
weidmann@ivt.baug.ethz.ch

Introduction

While railway transport is already very energy efficient, there is still potential to reduce energy consumption thus reducing environmental impacts and operating costs. It is especially interesting to consider freight rail for energy efficient driving because it has higher operational flexibility than passenger transport and it suffers from lower performance and lower priorities during operation. Most of the literature refers to ideal operating conditions both in terms of starting condition and in terms of optimized solution. Real speed profiles show that there is much more variability in the sequence and in the number of motion phases, and moreover there is also variability in the percentage of performance used. The proposed methodology uses speed profile and energy consumption data collected from onboard monitoring equipment to provide detailed information on train motion phases. The reconstructed speed profiles created using this data enable better specification of the operating conditions in the model calibration process thereby helping improve the quality of optimized driving profiles. The proposed method uses a simulation-based approach both for model calibration and for generating energy optimal driving profiles.

Infrastructure data



On the left of the picture, the train route under analysis runs from Basel to Domodossola, via Bern. Main tunnels are shown in blue. On the left bottom, the height profile of the Basel – Domodossola route is depicted. The track position is shown in black. Dashed line identifies those sections equipped with ETCS level 2.

Rolling stock data

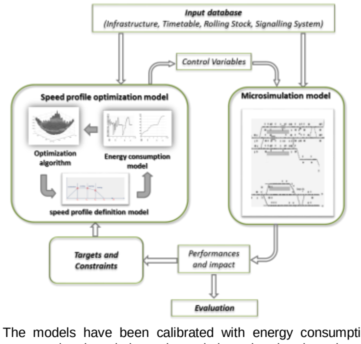
The locomotive used in the case study is a Bombardier TRAXX F140 AC unit, known as BLS Re485, which is configured for ETCS/ERTMS train control and safety systems.

BLS Re485	**Characteristics**
2002-2003	**Year**
84 tons	**Weight**
87 mph (140km/h)	**Max speed**
5.6 MW (7500 hp)	**Power class**
18.9 m	**Length**
300 kN	**Tractive effort**
240 kN	**Braking effort**

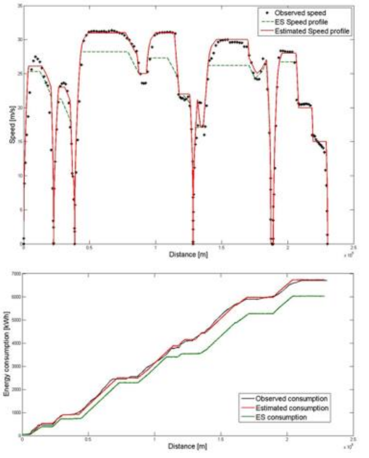
The rolling stock is composed by 15 wagon for a total weight of 1220 tons

Potential energy saving from speed profile optimization

In order to consider the complexity of a railway system, the possible energy savings from speed profiles have been evaluated though a simulation based approach (see figure below).



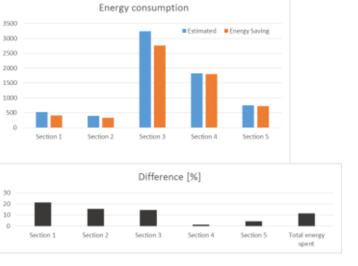
The models have been calibrated with energy consumption data measured onboard the train and the related train trajectory. The figure on the right presents an example of model application and potential energy reduction by comparing the "Observed" data (onboard monitored data* - timestep 1 min.), the "Estimated" data (data from the calibrated models) and the "ES" (Energy Saving) data (from the optimization procedure).



*** Onboard monitoring data of a BLS train traveling from Basel to Domodossola, via Bern. The specific train made 5 stops including the final one.**

Results

The energy saving speed profile shown in the figure can allow potential savings up to 11.5% of energy. For this example, simulations consider, as hypothesis, the full respect of DAS instruction and the drivers' constant attitude. Moreover, stops during journey have been included in the ES simulation for a better comparison between data



The energy savings in the single sections is mainly affected by the combination of the section lengths and gradients.
In particular, sections 4 and 5 do not provide the good conditions for energy saving driving because they have the highest variation of gradients due to the presences of tunnels; here engines must operate with nearly full performance in ascending sections of track, and needs speed control through braking in the decent

Conclusions and further developments

The use of onboard monitored data of energy consumption for model calibration is an innovative approach proposed by the authors: it improves the quality of calibration results, which otherwise are affected from additional assumptions on the tractive effort diagram. The results show that, the speed profile with the calibrated model accurately reflects the time spent and distance covered, and produces results with only a very small difference between the final energy consumed and its observed value (<1%).
Rail traffic is an important issue to consider. Unfortunately data on rail traffic were not available at the time of data collection, so some hypotheses on the possible causes of stops and speed changes have been made. The inclusion of rail traffic data for the speed profiles analysis will be a further step of this work.
Referring to freight trains, it is hard to replicate the same journey conditions between different trains (e.g., rail traffic, brake category), wagons composition (which affects air resistances), "planned" stops (which are known just before the departure time) and so to estimate correctly the variation of energy consumption during journey. Nevertheless, it is possible to collect a database of monitored data and to cluster the data with similar features. An ongoing research on this topic will be the base of a further development of this work.

Ongoing publications for reference

De Martinis, Weidmann. "Definition of energy-efficient speed profiles within rail traffic by means of supply design models". Research in Transportation Economics, Elsevier (publication within the year).

De Martinis, Weidmann, Nash. "An evaluation of freight train energy saving potential using onboard monitoring data". Submitted to Transportation Research Board, Washington D.C., 2016.

Schedule of the project

This work is part of the IVT-Wd project "Energy savings in rail freight by traffic flow optimization".

	Year	2014		2015				2016	
WP	trimester	3rd	4th	1st	2nd	3rd	4th	1st	2nd
WP1 State of the Art									
WP2 Definition of the framework									
WP3 Definition of a tool for energy efficient operation of freight trains									
WP4 "Proof of concept"									
WP 5 Cost-Effectiveness Evaluation model with KPI									
Final Report									