

SPEED OF FREIGHT TRAINS IN TRACK JUNCTIONS

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Abstract

This article forms part of a broader thesis focused on train speeds within railway stations, with a new emphasis placed on the inclusion of freight trains. It presents the results of direct speed measurements conducted at the exit of the Břeclav-přednádraží yard and outlines several challenges encountered during the measurement process.

Keywords

Speed, Acceleration, Marshalling yard, Receiving yard, Neutral section

1 INTRODUCTION

The article follows on from previous measurements of passenger train speeds [1]. However, in contrast to this measurement, it is necessary to resolve several problematic factors that are not as evident in the measurements of passenger trains. In particular, it considers the significant variability in the weight of freight train consists, which plays an important role in train performance during acceleration. Additional attention is devoted to the methodology of the measurement process itself, including the selection of appropriate measurement locations. The article is currently in its preliminary phase; the primary objective is to outline the key assumptions and conditions under which the data collection is being conducted.

The infrastructure manager's effort is to insert switches with the highest possible speed on the branch line into the station heads [2]. However, the practical applicability of such speeds during regular operations remains a matter of debate. On the one hand, train acceleration and braking may be constrained by infrastructure limitations, potentially reducing the throughput capacity of station heads and, by extension, the entire line. On the other hand, implementing high-speed turnouts that cannot be fully utilised may lead to increased costs for track components and unnecessarily extend the physical length of the station head without any corresponding increase in the effective length of the tracks. A key consideration in this context is the role of signalling and interlocking systems. Under the legacy approach, a uniform speed was required throughout the entire switch zone adjacent to the main signal [3]. However, with the implementation of the European Train Control System (ETCS), a progressive speed profile through station heads may now be feasible.

Objectives of the Study

The primary objective of this article is to develop acceleration and braking curves for freight trains. This objective is pursued through a dual approach: first, by conducting *in situ* measurements, and subsequently by simulating train performance using the OpenTrack software. The *in situ* measurements are initially carried out using a handheld radar device to capture train speed data; in later stages of the research, this method will be complemented or replaced by more advanced techniques, such as fixed-speed monitoring systems. A comparative analysis between the simulation results and empirical measurements of train acceleration will be conducted in a subsequent phase of the study.

The resulting speed profiles are intended to inform the optimal design of station heads, with particular emphasis on track groups within marshalling yards. High entry and exit speeds have the potential to reduce the occupation time of station heads, thereby increasing overall line and node capacity.

2 METHODOLOGY

Signalling system and ETCS

Since the latter half of the 1960s, a speed-based signalling system has been employed on both national and regional railway lines within the Czech Republic. This system was developed under the auspices of the Organisation for Cooperation of Railways (OSŽD) and is largely standardised among its member states, including infrastructure managers operating within the OSŽD framework [4], [5], [6], [7]. The fundamental principle of this system is the signalling of permissible speed within a specific track circuit, with the indicated speed remaining valid until the next main signal. Unlike German or Austrian signalling practices, both speed increases and decreases are explicitly indicated [6], [8]. The signalling system utilises a series of discrete speed values: 40, 60, 80, and 100 km.h⁻¹ which are harmonised across OSŽD members and correspond to standard turnout designs. As switch technology has evolved, additional signalling speeds have been introduced (e.g., 50 km.h⁻¹ and 120 km.h⁻¹), and the current system allows for the indication of any speed in tens of kilometres per hour.

Another significant difference between the Czech signalling system and the German one is the absence of an overlap and a release speed. The overlap is the distance between the end of authority [9] (i.e. currently the main signal) and the fouling point (e.g. a clearing point). The release speed is the maximum speed allowed for a train approaching a signal, that may approach a signal at danger, as shown in Fig. 1. The release speed can refer to a point before the end of authority [9], at a distance x from the main signal; if it refers directly to the end of authority [9], then the distance x is zero.

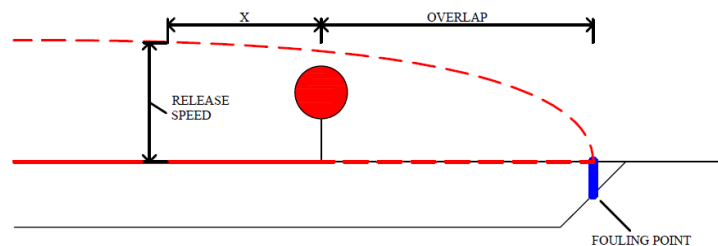


Fig. 1 Overlap and release speed.

The higher the release speed, the longer the corresponding overlap, which consequently increases the total length of the station heads. In tight conditions, the overlap can be allowed to extend beyond the fouling point, excluding collision railway paths, as shown in Fig. 2, which is a solution applied in Poland [5]. Alternatively, the overlap length can be reduced by lowering the release speed, as shown in Fig. 3, which is common practice in Austria [8].

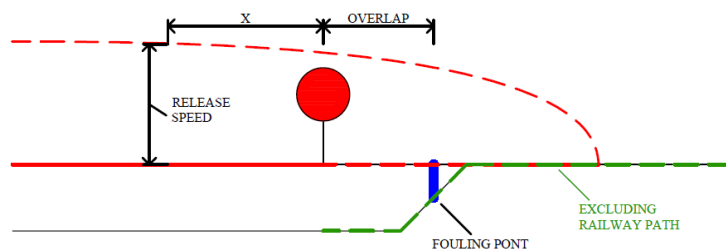


Fig. 2 Overlap while excluding collision paths.

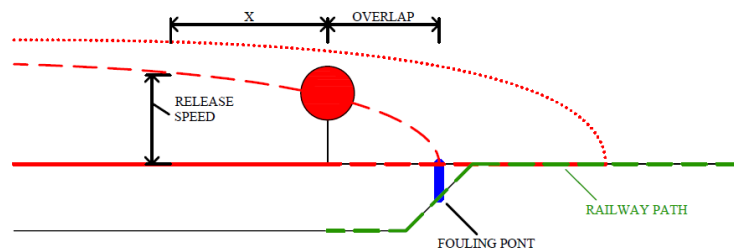


Fig. 3 Shortening the overlap by reducing the release speed.

The current Czech signalling and interlocking system does not incorporate these elements; however, the implementation of ETCS Level 2 [10], [11] assumes their inclusion. The integration of such features may result in a significant extension of station heads without a corresponding increase in the effective length of the tracks, or alternatively, a notable reduction in line capacity when using the procedure according to Fig. 2 and Fig. 3. When the release speed is reduced, the train approaches the end of authority [9] and runs at a lower speed and blocks the block section for a longer time; in the case of excluded train paths, on the other hand, it may not be possible to establish a route for an overtaking train, which would then be required to stop in the preceding block section and wait until the occupied section is cleared.

Braking

Another aspect under investigation is the braking behaviour of trains. As braking typically occurs over relatively short distances, it may be a critical factor in evaluating the overall speed profile. The braking distances within which a train must be able to come to a complete stop under the most adverse conditions are specified in [3]. Regulatory requirements and conditions for vehicle braking performance are outlined, for example, in national legislation applicable in the Czech Republic [12].

Direct measurement

The default method is to measure speed with a handheld radar. Although in later phases it is planned to install stable meters, it is necessary to choose the optimal place for their installation, and this is precisely done by measuring with a handheld radar [1].

A Bushnell Speed Radar Gun, model 101911, serial number 001000250755–0000, is used for the measurement. According to the manufacturer, it is capable of measuring speed values in the interval of 17 – 322 km/h at a maximum distance of 457 m. Tab. 1 provides a summary of the measurement distance. The temperature range is from 0 to 40 °C. The measurement error stated by the manufacturer is ± 2 km/h.

The distance of the measuring points at each site varies according to several parameters:

- the location of the measuring sites itself (station head, plain line),
- choice of measuring points (fixed pillars, parts of switches),
- visibility to individual measuring points.

Tab. 1 Comparison of distances and speeds of measuring points.

	Shortest measured distance (m)	Longest measured distance (m)	Lowest measured speed (km·h ⁻¹)	Highest measured speed (km·h ⁻¹)
Site no. 1	20	160	16	100
Site no. 2	93	294	20	75
Site no. 3	27	137	40	74

Traction characteristics

A key factor influencing a train's acceleration is the tractive performance of the powered vehicle, which is described by the traction characteristic, i.e. the relationship between the tractive force applied at the wheel circumference and the corresponding speed under constant power. This relationship is constrained by physical limitations, most notably the adhesion limit, beyond which the available adhesion force is insufficient to transmit the required tractive effort, resulting in wheel slip. This dependence shows Fig. 4.

We distinguish between step-by-step power regulation [10], where each driving step has its own dependence and these steps are switched between by a jump, which is typical for old vehicles, and continuous power regulation, where the traction characteristic curve forms an envelope of possible traction characteristics [13].

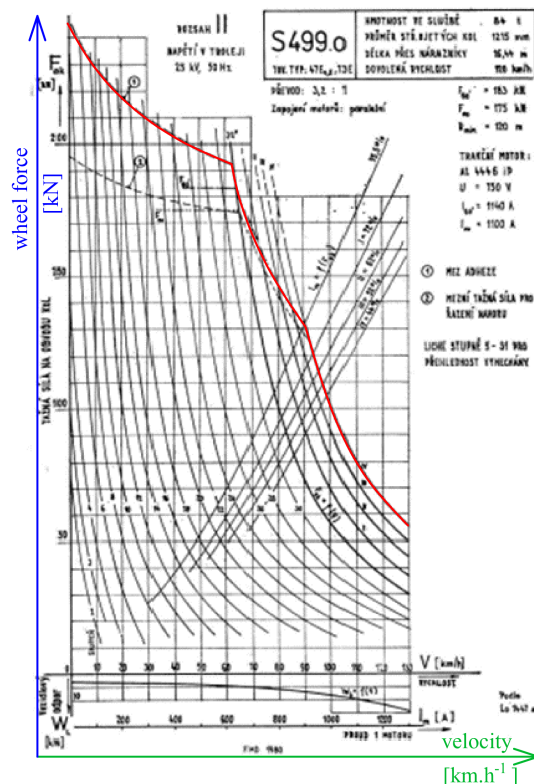


Fig. 4 Traction characteristics of the 240 series locomotives with step-by-step power regulation. The curves of the particular driving stages are clearly visible (only every second one is plotted), the characteristic is limited on the right side by the maximal speed and on the top by the adhesion limit [14].

Weight and length of trains

A previous article focused on measuring the speed of passenger trains, where train compositions are fixed and publicly available. This information enables at least a rough estimation of train weight, although a fully accurate assessment would also need to account for the weight of passengers, based on average occupancy levels. In contrast, such data are not typically accessible for freight trains. However, train weight is a critical parameter affecting acceleration, while train length significantly influences the occupation time of the station head. For the purposes of this article, it was possible to arrange for the communication of train weight and length data through coordination with the dispatcher at the Central Dispatching Office in Přerov (CDP Přerov).

The lightest recorded train had a total mass of approximately 192 tonnes and was operated by an electric locomotive of class 363 with empty cars. In contrast, the heaviest train measured weighed 2,224 tonnes was operated by an electric locomotive of class 193; it was a through freight service transporting metallurgical products. The majority of trains observed were through freight services with train weights ranging from 1,000 to 2,000 tonnes. Tab. 2 presents all locomotive types captured during the measurements.

Tab. 2 The powered vehicles of measured trains.

	Locomotive marking
Electric locomotives with AC asynchronous traction	1216; 193; ET43
Electric locomotives with DC traction	363; 230
Diesel-electric locomotive	742.7

Selection of the location

Another critical factor in the implementation of the measurement campaign was the selection of a suitable location. In line with the objectives of this article, the preferred setting was marshalling yards (or, in the case of passenger trains, branch stations), with the following criteria taken into account:

- Trains should commence movement from a standstill; therefore, it was essential to select a station where a significant proportion of trains undergo shunting or other operational procedures (e.g., powered vehicle exchange or engine driver changes), which excluded the initially considered location of Přerov.
- The station heads serving the marshalling yards should permit high departure speeds, ensuring that freight train movements are not restricted by infrastructure limitations. This condition was not satisfied at the ultimately selected site, where the current station head design allows a maximum speed of only 40 km/h. Other locations considered included Česká Třebová station, where connections to the marshalling yard are constructed using flat turnouts permitting speeds of 60 km/h and 80 km/h in diverging directions. However, these connections are situated in the Zádulka and Parník junctions, which are considerably distant from the station head itself—again designed for only 40 km/h.
- The measurement site should be located on a line with substantial freight traffic. As the current method relies on hand-held radar measurement, the presence of an operator on site is required. It is therefore advantageous to select a location with high train frequency to maximise the efficiency of data collection. The selected site lies on the Czech Republic's Second Transit Corridor, which experiences heavy freight traffic, particularly from block trains operating along the (Poland –) Ostrava – Austria route.

Based on the above considerations, the station Břeclav-přednádraží was selected for the study, specifically the Hrušky station head. Three measuring sites were designated at this location, with five individual measuring points established within each site.

Measuring sites

It was necessary to select a suitable measuring site for direct measurements, as shown in Fig. 5.



Fig. 5 Layout of measurement of standing surface [16].

In the first phase of measurement, a site was selected directly at the station head of the groups, as shown in Fig. 6.



Fig. 6 Site no. 1.

This site enabled the measurement of both arriving and departing trains from the directions of Hrušky and Podivín. However, train speeds were limited by the low permitted speed through the switch zone, frequently falling below the lower threshold of the operational range of the hand-held radar device.

The total number of trains measured at each measuring site is summarised in Tab. 3.

Tab. 3 Volume of Data of direct measurement.

	Entry to Břeclav (pcs)	Exit from Břeclav (pcs)
Site no. 1	15	15
Site no. 2	6	4
Site no. 3	3	6

As a result, it became necessary to conduct measurements at multiple locations. The final acceleration curve was subsequently composed of data aggregated from several measurements. Trains were categorised based on similar weight and length characteristics, as well as identical types of powered vehicles. The resulting representative curve was then constructed from the averaged data within each category.

The second site was located at km 86.4, as shown in Fig. 7.



Fig. 7 Site no. 2.

A complicating factor at this measurement site is the presence of a neutral section in the overhead contact line. As a result, trains led by electric locomotives must coast through this section without drawing traction power, which is consequently reflected in the recorded speed profiles.

The third site is located at km 86.6, as shown in Fig. 8, i.e. behind the section affected by the neutral field.



Fig. 8 Site no. 3.

Unfortunately, during the measurement campaign, an emergency event related to a system shutdown occurred, which prevented the completion of the planned data collection.

The measurements were conducted across six sessions on the following dates: 05/04/2024; 08/04/2024; 24/07/2024; 14/08/2024; 07/04/2025; 28/04/2025.

Other influences

Another factor affecting the measurements is the prevailing weather conditions. Thus far, measurements have been conducted under sunny conditions, with ambient temperatures ranging from 25 °C to 32 °C and low relative humidity. However, it is anticipated that the acceleration curve will become noticeably flatter under conditions of increased humidity due to the associated reduction in the coefficient of adhesion, particularly when combined with leaf fall during the autumn months.

3 RESULTS

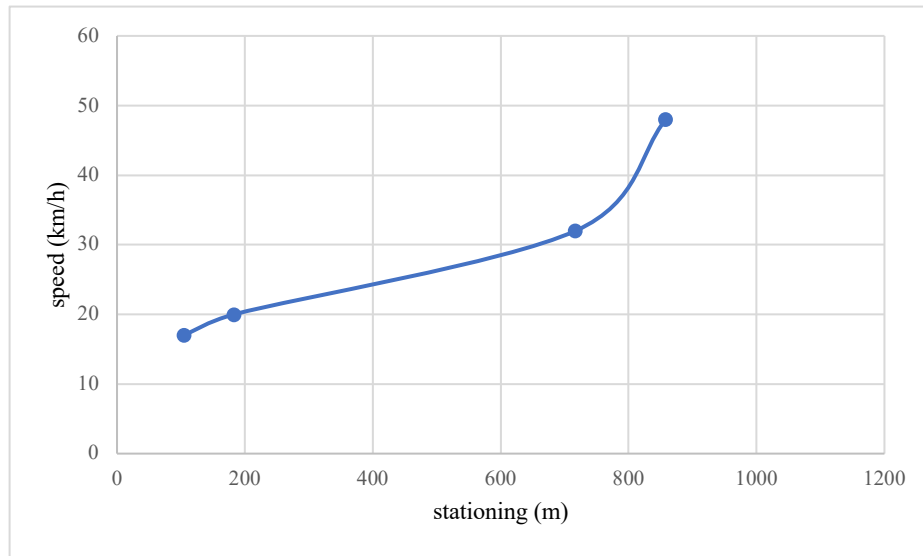


Fig. 9 Starting curve of a train with locomotive class 193, 570 m long, 1435 t in weight.

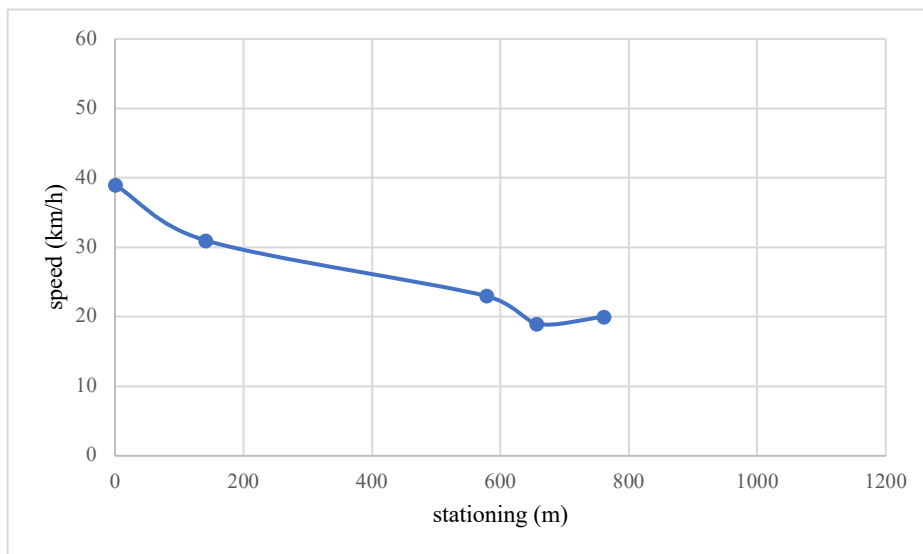


Fig. 10 Braking curve of a train with locomotive class 193, 473 m long, 1825 t in weight.

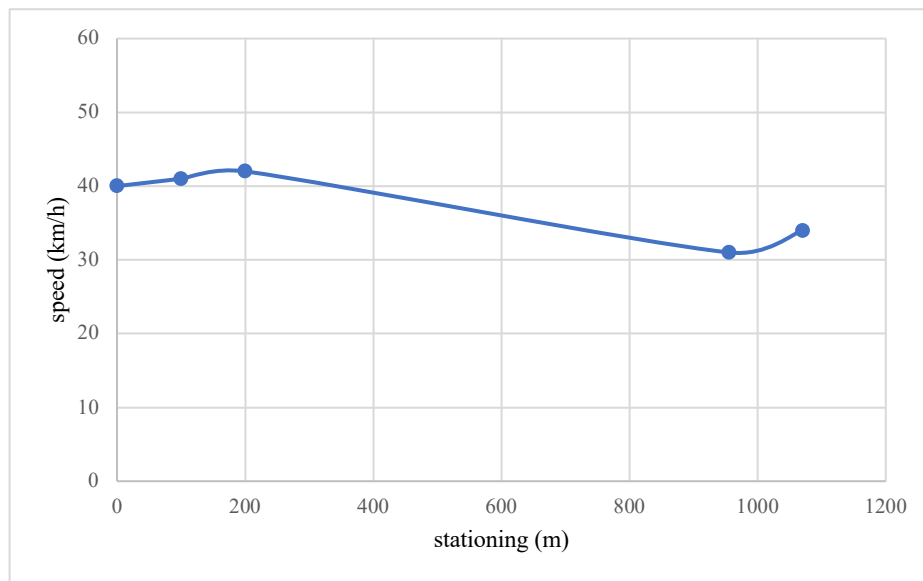


Fig. 11 Starting curve of a train with locomotive class 363 in a neutral section, 563 m long, 1217 t in weight.

4 DISCUSSION

In the subsequent phase of the research, a simulation was conducted using the OpenTrack software. However, due to time constraints, this phase has not yet been fully developed, and therefore only preliminary results are presented here. A comparative analysis between the simulation outputs and empirical measurements is planned for the next stage of the research.

As the measurement campaign is still in its initial phase, the results are indicative only, the result of this phase of measurement shows Fig. 9, Fig. 10 and Fig. 11. Nevertheless, they provide a valuable basis for decisions concerning the further organisation of the measurement process, such as the placement of fixed measuring devices.

Looking ahead, the inclusion of additional measurement sites within the Břeclav-přednádraží location is being considered—specifically, to capture train entries and exits on the line towards Podivín, as freight traffic on the line towards Hrušky experienced a notable decline during the monitoring period.

A revision of the measurement methodology is also under consideration. Options include the installation of fixed-speed measuring devices or a complete reorganisation of the measurement approach. Alternative methods being explored involve the analysis of analogue speedometer records or their digital equivalents.

Another topic for discussion is the change of location, we considered the Bohumín-Vrbice marshalling yard, or Ostrava – Kunčice; other locations were excluded (Přerov, Česká Třebová, see chapter *Selection of the location*). An additional alternative is to conduct speed measurements outside of marshalling yards, for instance at intermediate stations where freight trains are overtaken (e.g., Podivín), or at stations where the load is transferred to the siding (e.g., Řečany nad Labem), or at junctions adjacent to marshalling yards (e.g., Parník junction).

5 CONCLUSION

This article presents the initial phase of research focused on the acceleration and braking characteristics of freight trains, with the aim of informing the more efficient design of marshalling yard station heads. While previous studies concentrated on passenger trains, the specific operational and technical conditions associated with freight traffic, such as variable train weights, differing traction capabilities, and infrastructure constraints necessitate a distinct methodological approach.

Preliminary measurements were carried out using a handheld radar, with the test site located at the Břeclav-přednádraží station, specifically at the Hrušky station head. Although the presence of a neutral section and the low permitted speeds in the switch zone posed certain limitations, useful indicative results were obtained.

These results have laid the groundwork for future improvements in both measurement methodology and site selection. The categorisation of trains by traction unit, mass, and length enabled the construction of representative acceleration curves, although these remain provisional.

The presence of a neutral section affects the shape of the acceleration curves and must be accounted for in further analyses.

A systematic comparison of simulated and empirical data is planned for the next phase of the project, alongside consideration of alternative data acquisition methods, such as the installation of fixed measuring devices or analysis of vehicle speed logs.

Future research will also explore alternative measurement locations, including other marshalling yards or stations with high freight throughput and operational relevance. The goal remains to establish reliable acceleration and braking profiles for freight trains, which may ultimately support more precise infrastructure planning and optimisation of the design of station heads.

Acknowledgements

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