

# SIMULATION ASSESSMENT OF THE HEADWAY UNDER THE ETCS L3

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**ABSTRACT.** This paper deals with a simulation assessment of the impact of the introduction of ETCS L2 and L3 on the capacity of railway lines. The simulation itself is carried out in the OpenTrack simulation software, especially in the tool headway calculator. For this research, an infrastructure model has been built, which represents a typical layout of lines and stations in the Czech Republic. By successive modifications of the model, the significance of the impact of the implementation of ATP systems on the capacity of lines can be simulated. In the paper, the influence of the implementation of different application levels of ATP systems on the capacity of railway lines is evaluated.

**KEYWORDS:** Capacity, headway, ETCS, simulation.

## 1. INTRODUCTION

The gradual development of the railway network equipped with the ETCS system is moving to the foreground a question about the influence of this system on the throughput of a railway line [1, 2]. In addition to the traditional division of the ETCS system into its three basic levels (L1 to L3), based on foreign experience, other implementations of this system are beginning to appear, e.g., with shorter block sections that are about 400 meters long and are largely virtual with stop signs. German research has even found that the effectiveness of these L2 level adjustments can reach nearly the effects of the L3 level. Given the considerable technical complexity and uncertainty, this adds to the fact that the L3 level is not used for conventional rail [3–5].

In the conditions of the Czech infrastructure, some research [2, 5–7] and has so far been carried out by comparing the methodology of the Správa železnic, s.o. and the simulation software OpenTrack, which showed that the calculation of the subsequent interval using OpenTrack is possible, and its results are relevant about the methodology used on the Czech railways. Further research could therefore focus on the application of ETCS L2 to this model to determine the performance parameters of the infrastructure under the new conditions. The implementation of ETCS L2 with shorter block sections (approx. 400 meters) was chosen as the first logical step [8, 9]. The simulation model and its results for the ETCS L3 are the content of this article.

## 2. METHODS

A model from literature [2] was used for this research. Here, the authors demonstrated the possibility of using the model in the OpenTrack software to simulate the calculation of the headway, which is given by Czech

regulations. In the next paper, which is currently being prepared, the authors focused on the application of shorter block sections and verification of the impact of the introduction of ETCS L2 with shorter block sections on track capacity.

For this paper, the simulation model was subsequently modified to test the function of the moving block at the ETCS L3 level. In addition to the braking characteristics of the individual trainsets, it was also necessary to set safety limits (safety distance), which will cause the second train to be able to stop safely if the first train loses the connection or stops. There is currently no strict regulation on the size of these safety distances, but the size of this path must depend on:

- Train speed of the first train,
- Train speed of the second train,
- Braking parameters of the first train,
- Braking parameters of the second train,
- Slope and radius of curves.

However, standard trainsets for high-speed, conventional, and freight trains were used for this research. The slope and the radius of the curves were set to 0.

For the simulation of the influence of the ATP system on the track capacity, the OpenTrack software was chosen [10]. It is a specialized software that allows a broader assessment of the railway infrastructure from many points of view. For example, it can be used in the areas of assessment of rail vehicle dynamics, energy consumption, line and station operating intervals, line capacity, transport planning and assessing the effect of changes to rail infrastructure and rolling stock. Defining the objective of the model is always crucial for correct model building. Microscopic modelling guarantees the most accurate results, but at

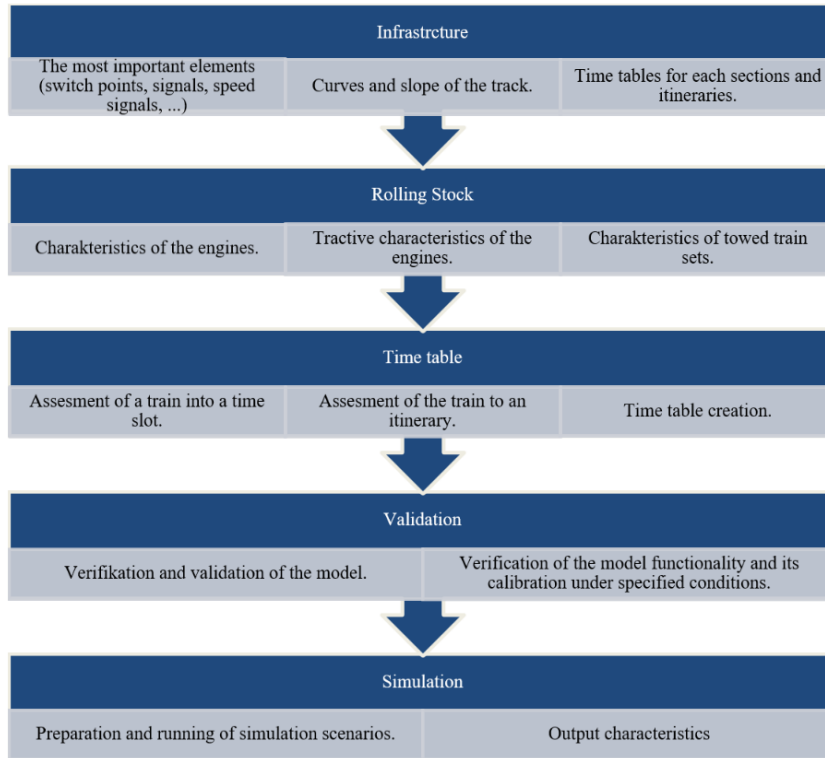


FIGURE 1. Scheme of the model preparation.

Train category	Engine	$V_{max}$	Length [m]	Weight [t]
Nex	TRAXX F 140 MS	120 km h <sup>-1</sup>	600	1 000
Pn	ČDC 363.5	80 km h <sup>-1</sup>	600	1 800
Os	ČD 471	140 km h <sup>-1</sup>	80	155
R	ČD 661	160 km h <sup>-1</sup>	132	170
Ex	ČD 680	200 km h <sup>-1</sup>	185	385

TABLE 1. Parameters of used train sets.

the same time requires very careful model processing [4]. Figure 1 shows the different stages of model preparation.

The infrastructure is represented in the simulation model by a network graph. The vertices of the graph are represented by ordered double points that show the kilometric position of each point. In that double point, some characteristics of the track (slope, curve, speed, ...) are changing. The edges connecting them represent the structural and technical characteristics of each part of the track or station area. The parameters of all possible routes need to be inserted into the network and thus prepared. The routes are in the station areas defined according to the table of control, signalling route or situation diagram. From those “Routes” are then designed “Paths” which are leading from one station to another station. The last step is connecting “Paths” to “Itineraries” which are leading from the origin station of each train to the terminal station.

For this model, a fictitious line with a total length of 18.35 km with three intermediate stations and three

stops was designed. The model track forms an infinite loop. The modelled stations are four-track with variant header and header parameters. Switches are used on the headers with a variable speed range in the branch direction from 40 to 80 km h<sup>-1</sup>. The length of each header has a variance of 300–800 metres.

An equally important feature of the simulation model in OpenTrack SW is the characteristics of each Engine and trainset. The main features are traction characteristics and vehicle resistance. The basic parameters of each train set are in Table 1.

It is also necessary to insert a timetable to simulate the considered operational concepts. Each train is assigned by a number, category, track occupancy method, timetable, and itinerary with their preferential order in this step. If there isn’t available a constructed timetable, it must be created. This is possible by running the simulation and determining the required journey times and process times.

To verify the functionality of the model, the actual verification, validation, and calibration of the model are further performed to prove the functionality of

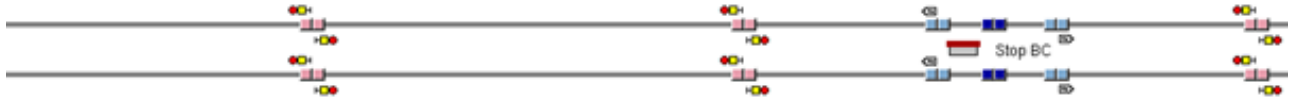


FIGURE 2. Model of the track for conventional operation with automatic train control.

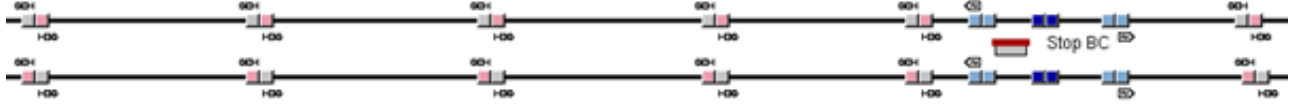


FIGURE 3. Model of the track equipped by ETCS L2.



FIGURE 4. Model of the track equipped by ETCS L3.

the model for the intended use. The simulation of individual simulation scenarios can then proceed.

### 3. SIMULATION SCENARIOS

To be able to correctly assess the impact of the different application levels of ETCS, individual operational scenarios were prepared for each application level of the system separately. For these reasons, modifying the original simulation model for each application level was necessary.

#### 3.1. CONVENTIONAL OPERATION WITH NATIONAL TRAIN PROTECTION SYSTEM

The first simulation scenario was a simulation of conventional operation. In this variant, all stations are equipped with an electronic station interlocking system. The line is protected by a two-way three-character automatic block. The distance of the block signals is standardised at 1 000 metres. Figure 2 shows a model for conventional operation with automatic train protection.

#### 3.2. OPERATION UNDER THE ETCS L2

The station interlocking system remains the same as in the first scenario. All main signals in the stations are also retained. The modification is that the point defining the beginning of the speed restriction area given by the signal the main signal is no longer the position of this signal but the position of the limiting infrastructure element. Typically, this is the first speed-restricted switch point. The block sections are no longer divided by block signals. They are divided by fictitious signals of ETCS (balise groups). These ETCS blocks are approximately 400–430 metres long. Figure 3 shows the modification of the model for the ETCS L2 application level.

#### 3.3. OPERATION UNDER THE ETCS L3

This application level enables the operation of so-called moving blocks. So that the length of each block depends only on variables from Equation (1). This application level isn't in regular use on any railway line yet. Therefore, the authors needed to find the safe security distance between two trains (the upper index in the formula means which train it is) by Equation (1):

$$S_{bezp} = l_{eb}^1 - l_{sb}^2 + l_{inn}^1 + l_{inn}^2, \quad (1)$$

where:

- $S_{bezp}$  – safe security distance [m],
- $l_{eb}$  – emergency brake distance [m],
- $l_{sb}$  – service brake distance [m],
- $l_{inn}$  – inaccuracy of the position of a train [m].

In this case, all the station and track interlocking systems relate to the radio block center (RBC). So, all movement authorities are controlled by the RBC. Figure 4 shows the model's modification for the application level ETCS L3.

## 4. RESULTS AND DISCUSSION

The authors decided to compare the effect of each application level's implementation by determining the headway values. The headway for the section is determined as a maximum of the sub-headways for each block in the section. The value of the headway is very important for the calculation of the line capacity and for the construction of a stable timetable. The software OpenTrack includes the tool Headway calculator which was used also in this research. Using multiple simulation methods, this tool determines the minimum value of the headway for any pair of trains by the interval halving method. The rules for the simulation are based on Směrnice SŽDC SM 104 –

Section B-C											
		Nex		Pn		First train		R		Ex	
		arr.	dep.	arr.	dep.	arr.	dep.	arr.	dep.	arr.	dep.
Second train	Nex	84	73	205	106	155	126	85	80	38	38
	Pn	73	73	106	106	105	76	80	80	38	38
	Os	73	73	<b>128</b>	<b>113</b>	135	136	80	80	38	38
	R	141	73	219	175	192	154	80	149	38	38
	Ex	200	73	278	153	251	148	172	127	62	38

TABLE 2. Results of the headway calculator for one of the sections.

Section	Comparison of Automatic train control system and ETCS L2		Comparison of Automatic train control system and ETCS L3	
	[s]	[%]	[s]	[%]
A-B	-15.76	11.39	-18.92	26.18
B-A	-20.96	25.44	-22.03	18.15
B-C	-22.24	21.86	-22.31	22.70
C-B	-26.00	22.97	-26.50	30.00
C-A	-20.52	15.82	-21.52	27.91
A-C	-13.96	11.19	-14.06	17.54
<b>Total</b>	<b>-19.91</b>	<b>18.11</b>	<b>-20.89</b>	<b>23.75</b>

TABLE 3. Comparison of headways.

Provozní intervaly a následná mezidobí [11] and Směrnice SŽDC SM 124 – Zjišťování kapacity dráhy [12] and regulation SŽ D1 part one [13].

The simulation is then run in the prepared model to determine the values of the headway in all sections. Each pair of trains was simulated separately in all sections. The output for each of the three simulation variants is six tables showing the headway values in seconds. The resulting headway value is then a maximum from each pair of values (one is on the arrival; one is on the departure). An example is bold in Table 2.

Then, the individual simulated variants were compared with each other to determine the effect of the implementation of different ETCS application levels. Table 3 shows the overall results.

## 5. CONCLUSION

The simulation model carried out by the authors for this paper is loosely related to their previous research in the Automatic Train Protection system simulation. The results obtained confirm the benefits of implementing ETCS L2 with benefits. Furthermore, the consideration of further track capacity increase using the Moving Block in the ETCS L3 application level was confirmed. The results obtained are of course valid for the proposed research infrastructure model and have no general validity. The simulation results show that the headway of the ETCS L2 application level is 19.1% lower than in the present interlocking system. The headway value for ETCS L3 is 23.75%

lower than in the present interlocking system. So that the benefit of the ETCS L3 is approximately 4 or 5%. Maybe this is not the way, how to improve the capacity of the Czech railway infrastructure.

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