ADDITIONAL METHODS TO DETECT TRAIN INTEGRITY UNDER ETCS LEVEL 3 AND THE EFFECTS ON CAPACITY AND CONTROL OF MOVEMENT

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ETCS Level 3 – today the highest level of ETCS – relies on train-side detection of train-integrity. This paper elaborates on newly designed alternatives for detection of train-integrity. The fundamental safety targets of German train protection systems served as a basis for the presented alternatives. We compare these alternatives to the effects on capacity at lines and different kinds of stations. Furthermore we show the positive effect to control of shunting movements and parked vehicles. In addition the effects to the start-up and sign-in process of traction vehicles and the use as a fall-back level are shown.

1. Motivation

To resolve numerous constraints in cross-border rail traffic ([1] & [2]) the implementation of and research on the European Rail Traffic Management System (ERTMS) is under way. One mayor activity is the specification and implementation of the European Train Control System (ETCS). ETCS Level 3 – today the highest level of ETCS – relies on train-side detection of train-integrity [3]. This, in combination with other components of ETCS, enables to consider driving in moving block. Positive effects on capacity are anticipated but at most a more cost efficient infrastructure without components for track-side detection of train-integrity is hoped-for.

Until today the sole implementation of ETCS Level 3 is the West Dalarna Line in Sweden. The implemented derivate of ETCS Level 3 is known as “ERTMS Regional” [4]. The experiences gained in this project are crucial for the further – not yet finished ([5] & [6]) – specification process of ETCS Level 3. This on-going process is one reason for European infrastructure managers to hold back an ETCS Level 3 implementation ([7] & [8]), despite the anticipated positive effects.

The presented research aims for a concept to integrate alternative methods to detect train-integrity into ETCS Level 3. Of course the finalized concept should allow safe train operations but in addition the concept should allow an increased number of train operations at lines and at different kinds of stations. The aim of the research was therefore to allow an increase of capacity and to improve the control of shunting movements and parked vehicles.

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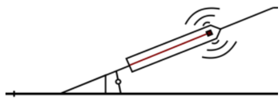
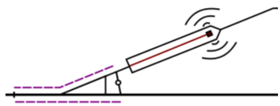
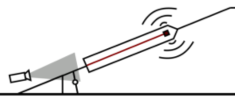
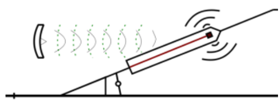
2. Methodology

Our research started with a comparison of the most common used German train protection systems (PZB & LZB) and ETCS Level 3. Basic requirements and safety targets, which are inherent in the national train protection systems, are identified:

- Information for the train driver
- Warning of the train driver
- Control of the alertness of the train driver
- Triggering the emergency brake
- Carrying out the emergency brake to the stop of the train
- Preventing the unauthorized movement of a train

The last three identified safety targets served as a basis for the creation of three alternative concepts to detect train-integrity. These concepts are compared to ETCS Level 3 with focus on the effects on capacity and the additional costs for different kind of stations. The alternatives that were further analysed are shown in the table below:

Tab. 1 Alternative concepts

concept	example
Pure ETCS Level 3	
ETCS Level 3 & conventional track-side detection of train-integrity at selected switches	
ETCS Level 3 & track-side checkpoints for end-of-train-detection (i.e. automated video-based detection)	
ETCS Level 3 & radar detection at stations	

These alternatives rely on additional track-side components, a renunciation from pure ETCS Level 3. The additional track-side components for end-of-train-detection or continuous detection of train movements can be placed at selected locations of the track field of stations. These components should allow for accelerated train movements (including shunting movements). In order to compare these alternatives the obstruction of subsequent trains through reduced speeds when entering into siding was evaluated.

3. Capacity for regular operation

To evaluate these obstructions at first the capacity was evaluated. A double-track line with two stations served as a basis. Both stations feature a siding. The selected timetable reflects typical a typical operation program and is destined to unveil conflicts at the switching zone of station B.

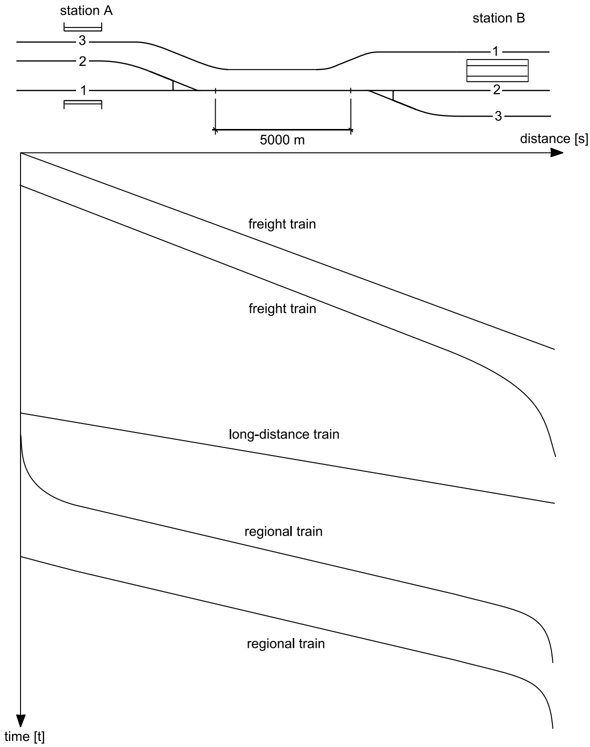


Fig. 1: Track layout and timetable

UIC Code 406 offers a method for capacity evaluations of lines with fixed blocks based on route occupancy but offers no recommendations for capacity evaluations of lines with moving blocks. The principles of blocking time stairways cannot be used for these lines. Consequently the UIC Code 406 cannot be used without further adjustments.

The calculation of journey time is not affected. However the calculation the speed-depending braking operation is of particular interest, because the minimum headway time is calculated from the speed-depending braking distance and a safety distance. The algorithm described in UIC Code 544-1 offers an accurate method.

Our model calls for a minimum clearance at any given time in front of the train composed of the current braking distance and a proportionate safety distance. The proportionate safety distance is selected to 20 % of the current braking distance. Switches have to have safely reached their final position before a movement authority can be issued beyond the position of the switch. The evaluation of capacity is based on the assumption that switches reach their final position, are locked and that this state is safely communicated via the Radio Block Centre to the train in total within 0.2 min. A future technical solution with or without a signal box shall not be discussed in this paper.

The timing of the vacancy notification of track elements is dependent on the chosen time interval of the position reports of the train [9]. ETCS Level 3 stipulates a fixed interval. With the aid of the presented additional track-side components for end-of-train-detection or continuous detection of train movements selected track elements can be notified as vacant prior to the next position report of the train. An acceleration of the operation would be expected.

Only the first switch of station B was equipped with additional track-side components of capacity demonstrates in the evaluation. However, the above-mentioned positive effect can be demonstrated. But, the effect is small. Compared to pure ETCS Level 3, the occupancy rate differs in a margin of 0.5 percentage points for the presented alternatives. The maximum achievable value is larger, but can only be achieved with trains of the same speed.

The effects on the occupancy rate of decelerating trains on the track between stations A and B and the time of the position report of stopping trains in station B were far greater. For example the position report of a stopping train may be delayed by several seconds because of the fixed interval for position reports. An additional unscheduled position report at the actual time of stopping is not intended in ETCS Level 3. But such a measure would have positive effects on capacity.

4. Costs and benefits for regular operation

To further compare the presented alternatives the additional costs were determined. For three different kinds of stations with different functions in the rail-network – a station with one siding, a terminal station and a junction station – the count of additional track-side components has been identified. The exact amount of money needed could not be determined, because some of the presented technologies have never been used for the intended purpose.

For the model station with a single siding the track plan of the station “Mörfelden” served as a basis. A simple layout with one checkpoint for end-of-train-detection suits the intended purpose. Because of the ideal-typical track plan of this station the insights gained about the positive effect can be easily transferred to other stations in the rail-network.

For the model terminal station the track plan of the Wiesbaden main station served as a basis. With the help of a single radome the multiple conflicts between entering and leaving trains can easily be monitored in a terminal station. The crucial switches are concentrated in a confined space. Therefore vacant track elements can be detected quickly and are disposal for upcoming trains. In addition the continuous surveillance of parked vehicles and shunting movements in storage sidings is possible. The loss of conventional track-side components for detection of train-integrity, and maybe even the abandonment of protection switches and derailers can be compensated with this alternative concept. Movements that are not permitted can quickly be detected and a possible emergency stop order can be triggered.

For the model junction station the track plan of the Darmstadt main station served as a basis. Because of the great amount of additional track-side components needed to equip all important switches the study concentrated on others subjects. The effects on shunting movements in confined spaces of the station that is necessary for the reinforcement of trains during peak times and the effects on directly afterwards departing trains are of particular interest. The execution of these time-critical shunting movements can be supported with the continuous detection of movements via radar technology. Additionally, parked vehicles can be monitored after the shunting movement. The abandonment of protection switches and derailers is a possibility for storage sidings in a confined space that can be monitored via radar technology. In summary, it can be stated that the surveillance of movements with the help of radar technology offers great advantages and several application scenarios are possible.

5. Use as fall-back level

Through the use of various technologies of the developed alternatives a complementary redundancy to train-side detection of train-integrity is achievable. A small number of checkpoints for end-of-train-detection could be provided alongside lines. Unlike pure ETCS Level 3 a greater capacity is maintained when the train-side means for detection of train-integrity fail or a non-equipped train is traveling on an ETCS Level 3 line. Especially the last-mentioned possibility is interesting, as the migration period will be rather long and non-equipped trains may travel on new lines that are only equipped with ETCS Level 3 [10].

6. Conclusions

- Further research on the functional and operational use of the presented alternative concepts is needed
  - The positive effects on capacity shown in this paper are small
  - However a much greater effect in networks with similar trains (i.e. Metro-systems) is expected
  - Another capacity study should be conducted
- The control of Shunting Movements and parked vehicles is possible
  - Radar technology offers the greatest advantages
  - Further research on the implementation of radar technology in stations and the detection of full trains compiled from different wagons is needed

- Components of the presented alternative concepts can be used to safely detect the position of traction vehicles during the start-up and sign-in process

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