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LOCALISATION WORKING GROUP (LWG)

Railways Localisation System
Localisation Performance Requirements
from use cases

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Modification history

Version	Date	Modification / Description	Editor
0A	12/06/2019	Internal review of TLG	LWG
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1f	31/07/2019	Including remarks after EUG meeting of 31/7/2019	GR
2	02/08/2019	Delivery for discussion with X2R2 WP3	LWG

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1 List of References and Acronyms

References

HLR	18E112 Railways Localisation System High Level Users' Requirements
RCA	RCA Architecture V0.5
Stanford Diagram	Navipedia page on Integrity
SS023	ERTMS/ETCS Subset-023 Glossary of Terms and Abbreviations
SS026	ERTMS/ETCS Subset-026 System Requirements Specification
SS041	ERTMS/ETCS Subset-041 Performance Requirements for Interoperability
EN50155	EN50155 2007 Railways applications – Electronic equipment used on rolling stock

Acronyms

ATO	Automatic Train Operation
MCI	Mission Confidence Interval
EoA	End of Authority
HHPLOC	High Safety High Impact on Operations and Precise Location
HHSD	High Safety High Impact on Operations and Speed Dependent
HL	High Safety Low Impact on Operations
LH	Low Safety High Impact on Operations
LL	Low Safety Low Impact on Operations
LLPLOC	Low Safety Low Impact on Operations and Precise Location
LHPLOC	Low Safety High Impact on Operations and Precise Location
MP	Mission Profile
PP	Performance Profile
RCA	Reference CCS Architecture
RP	Reference Point
SD	Standard Deviation
SoM	Start of Mission
VL	Vehicle Locator
MOT	Mobile Object Transactor
APS OA	Advanced Protection System Object Aggregator

2 Glossary and definitions

2.1 Localisation principles according to current ERTMS standards

2.1.1.1 Figure 1 describes the localisation principles used by ERTMS according to chapter 3 of [SS026].

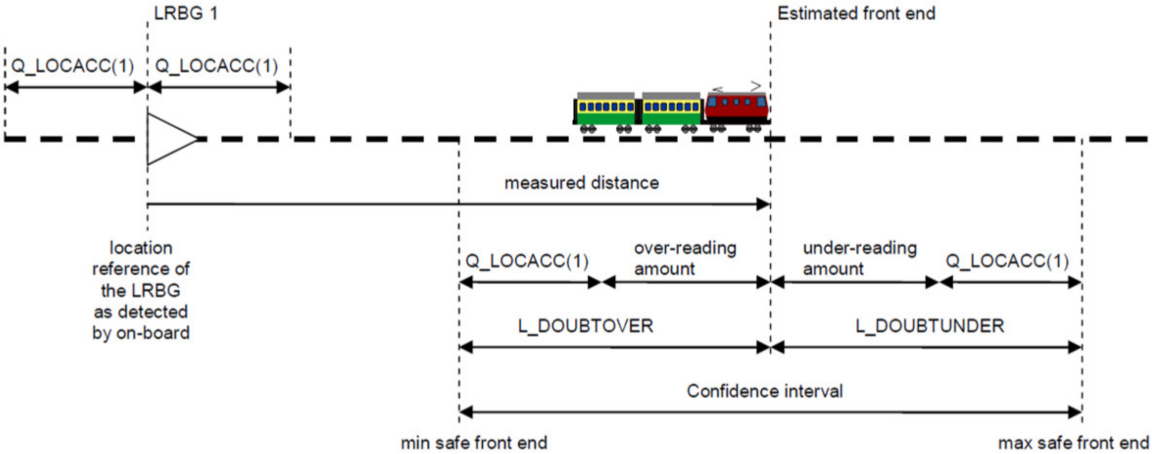

Figure 1: Train Localisation based on ERTMS Subset 026

2.1.1.2 Figure 2 describes the evolution in time of the confidence interval according to the localisation principles used by ERTMS.

2.1.1.3 Note: according to some current and future need (e.g. high density applications), the fulfilment of the accuracy target of distances measured on-board (see [SS041]) does not always ensure a satisfactory operational behavior.

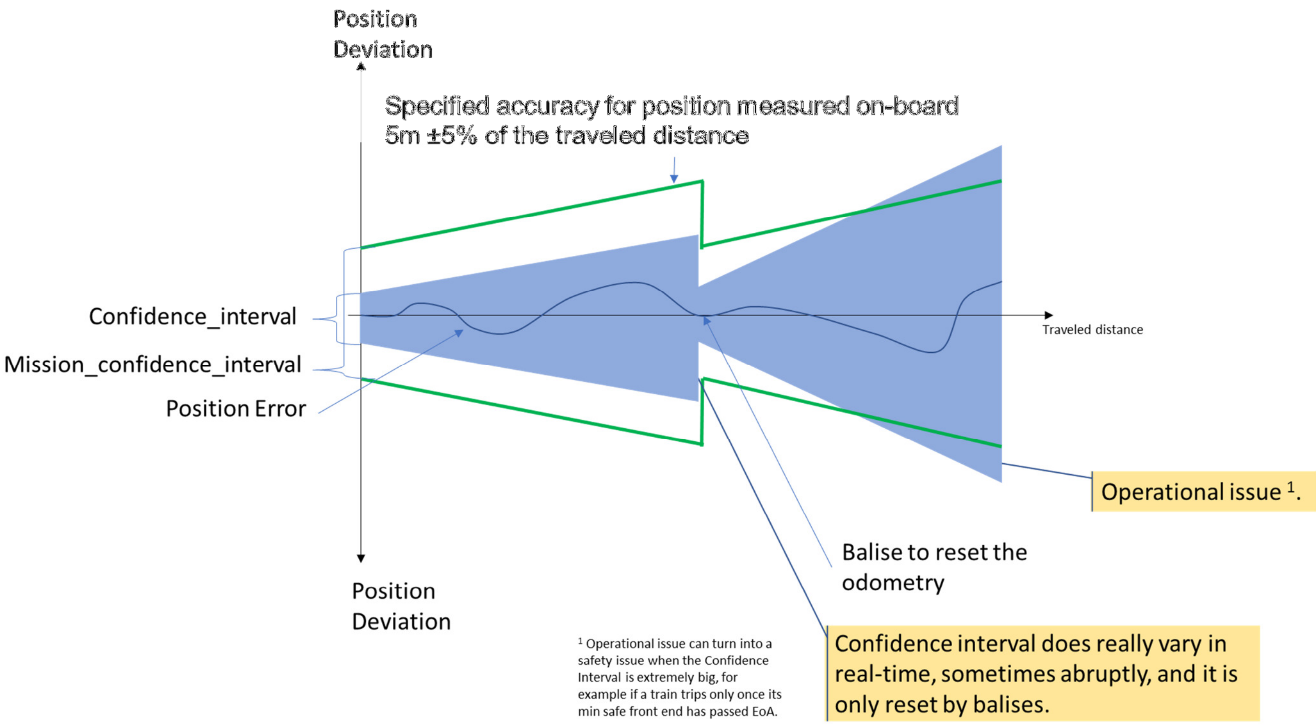

Figure 2: Confidence interval evolution

2.1.1.4 With reference to Figure 1 and Figure 2, the relevant terminology is defined in [SS026] and [SS023].

2.2 Localisation principles used in this document

2.2.1.1 Figure 3 describes the localisation principles used in this document and derived from the ERTMS ones.

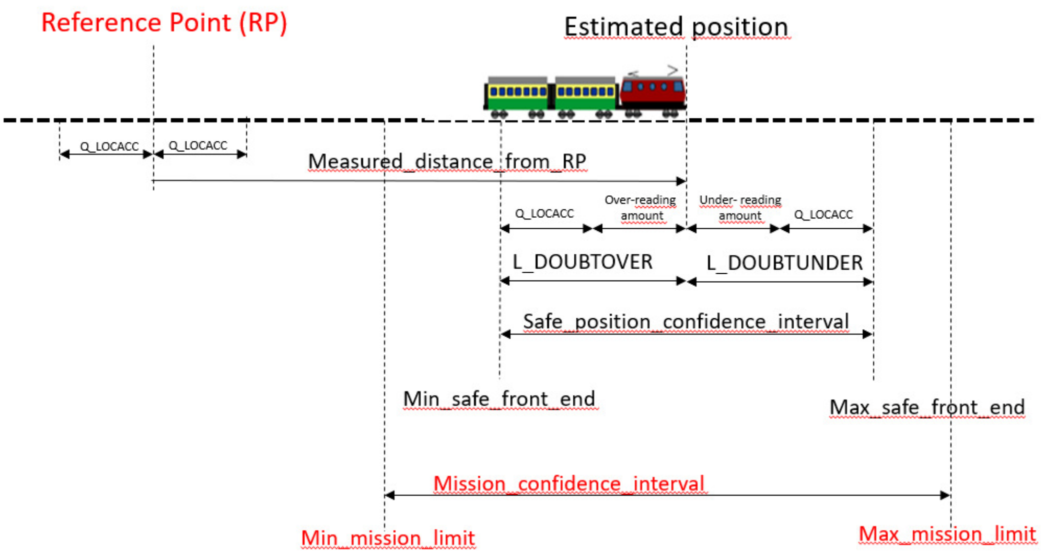

Figure 3: Confidence interval evolution

2.2.1.2 Figure 4 describes the evolution in time of the mission confidence interval according to the localisation principles used in this document.

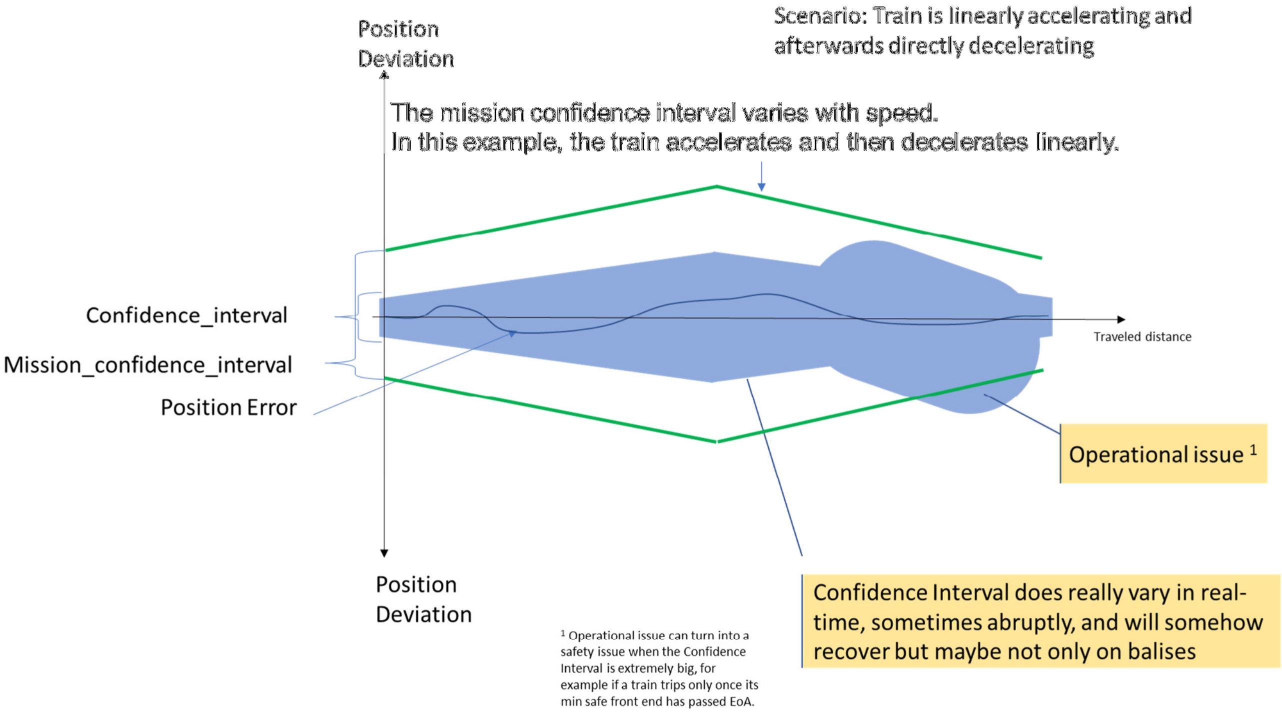

Figure 4: Mission confidence interval evolution

2.2.1.3 With reference to Figure 3 and Figure 4, the same terms used by ERTMS (e.g. confidence interval, Max/Min_safe_front_end) do not change their meaning.

2.2.1.4 The <u>max_mission_limit</u> and <u>min_mission_limit</u> are defined to bound the accuracy requirement able to fulfil operational needs.

2.2.1.5 The interval bounded by max_mission_limit and min_mission_limit is called <u>mission_confidence_interval (MCI)</u>.

2.2.1.6 Mission confident interval is defined with reference to a generic - technology independent - reference point (RP) which can either be physical (a balise group - LRBG) or virtual by a definition of a position.

2.2.1.7 When the confidence_interval is exceeding the mission_confidence_interval, the punctuality of operation is not guaranteed anymore.

2.2.1.8 The ratio of time when the confidence_interval is not exceeding the mission_confidence_interval to the mission time is called the <u>operational availability</u>.

2.2.1.9 The term "Mission critical" is related to the operational availability and it indicates how vastly the mission of the train and the capacity/operation of the network, or part of it, is affected in terms of delays in case the Train Localisation system is not able to fulfil the performance requirements.

2.2.1.10 The term “Safety critical” indicates that providing the Train Localisation system a wrong train location[1], without being detected, has a direct impact on trains safe operation.

2.2.1.11 In the performance profiles (see § 4 for the definition) described in § 6, different indicators are used to express accuracy requirements:

- for safety critical profiles, during operations, the confidence interval will be used to trigger safety reactions possibly impacting operations. Thus, the behaviour of the confidence interval is specified using MCI.
- for non-safety critical profiles, during operations, the estimated position will possibly be used without considering the confidence interval. Thus, it is sufficient and more flexible to specify the behaviour of the estimated position in a statistical manner using the standard deviation[2] (SD) of the error between the estimated value (e.g location) and the real value (i.e the ground truth).

2.2.1.12 For any additional definition found in this document, § 1 and [SS023] makes reference.

3 Scope of the document

3.1.1.1 The <u>Rail</u> Localisation system is the set of functional blocks able to provide “objects” (e.g. trains, coaches, maintenance rolling stock, workers) positioning information along the track.

3.1.1.2 Within the Rail Localisation system, the <u>Train</u> Localisation system is the subset of functional blocks able to provide “trains” positioning information along the track.

3.1.1.3 With reference to [RCA], the Train Localisation system includes the onboard functional block VL and trackside functional blocks MOT and APS OA (aggregating information also coming from possible trackside occupancy detection devices).

3.1.1.4 The purpose of the document is to identify the localisation performance requirements of the Train Localisation system starting from current and future needs derived from use cases (railways operational scenarios).

3.1.1.5 Localisation performance requirements deal with accuracy, availability and safety; the impact on safety and on operation has been evaluated in a qualitative way.

3.1.1.6 The evaluation of the impact of failures preventing the system from fulfilling the identified performance requirement and the definition of relevant quantitative RAMS requirements of the train localisation system are out of the scope of this document. This will be done in a future step.

3.1.1.7 The allocation of the identified requirements to the onboard and/or trackside functional block of the Train Localisation system is out of scope of this document.

3.1.1.8 The onboard VL shall not necessary fulfil all (nor the most stringent) identified requirements however the allocation of localisation requirements to the onboard VL

[1] With reference to ERTMS specification it is the case where real train position is outside the train confidence interval calculated by the onboard.

[2] Standard deviation: let X be a random variable with mean value μ, the standard deviation σ (sigma) is the square root of the variance of X; i.e., it is the square root of the average value of $(X – μ)^2$.

(minimum predictable performances under defined circumstances) is necessary to ensure interoperability and allow IM to put in place possible additional measures to achieve the expected performances requirements in case the VL is not able to achieve them by itself. Allocation of requirements to the onboard VL will be made after feasibility study of possible technological solutions and the technical and economical evaluation coming from research projects (proof of concepts).

3.1.1.9 The localisation of “objects” along the track different from trains is not in the scope of this document.

3.1.1.10 According to top-down approach, the current document intends to specify in detail the high level performance requirements provided by the High Level Users’ Requirements document [HLR] is an input of the current document.

4 Methodology

4.1.1.1 The first step consisted in identifying different use cases in which the localisation of the train is necessary or desired. For this purpose, operational units in different administrations were consulted, deriving different operational scenarios.

4.1.1.2 Specific use cases were provided by different experts. These use cases targeted the rail current and future operational scenarios in which localisation is needed. The list of use cases was shared and discussed.

4.1.1.3 These use cases were analysed and specific localisation requirements were allocated to each of them. Performance requirements for each of the use cases were assigned by different experts and recorded in a spreadsheet.

4.1.1.4 When the same use case had different performance requirements in different organisations, the most restrictive target was selected.

4.1.1.5 The analysis of use cases included the safety and operational criticality impact evaluation from a qualitative point of view.

4.1.1.6 To express localisation performance requirements, the definitions recorded in § 2 are used.

4.1.1.7 Uses cases were clustered in different performance profiles (PP) targeting similar performance localisation requirements and similar safety/operational criticalities. The figures associated to each PP were taken from use cases addressing common necessities in terms of performance.

4.1.1.8 Note: the following example is provided to make the methodology clearer. For train running on a high-speed line some administrations set target figures based on the distance travelled within a unit of time, others based it on absolute distance depending on speed intervals. These values are used when calculating the capacity of the line. After discussions, it was agreed that the necessity of the absolute distance is more important at low speeds. Then an agreement on the use case performance target was reached. This use case was also commonly catalogued as mission and safety critical. The use case was then clustered with other similar use cases to create the performance profile 1.

4.1.1.9 The resulting PP are shown and explained § 0.

5 Assumptions and constraints

5.1.1.1 The identified performance requirements shall be met on every European rail physical environment including (the list does not have to be considered exhaustive) tunnels, forests, mountains, underground stations, presence of metal masses around rail.

5.1.1.2 The identified performance requirements shall be met on every European rail meteorological environment including (the list does not have to be considered exhaustive) high rail temperature and low adherence conditions such as the presence of ice, snow, leaves; for what it concerns, EN50155 applies.

5.1.1.3 The identified performance requirements shall be met considering, as nominal, the operating condition of the different kind of loco traction systems (e.g. there are train normally running under “slipping condition”).

5.1.1.4 Track selectivity is mandatory for all performance profiles, understanding track selectivity as the Train Localisation system ability to discern in which track the train is located.

5.1.1.5 The localisation performance requirements are independent of any technical solution used. Combinations of different measurement technologies is expected to reach them.

6 Train Localisation Performance requirements associated to performance profiles

6.1.1 HHSD

6.1.1.1 Front

HHSD Front	
Description	Provide train front position and train speed (including direction) for track occupancy notification and for speed supervision.
Safety Critical	Yes
Mission critical	Yes
½ MCI	10m up to 40km/h, distance run in 1s at higher speed
Speed ½ MCI	2 km/h for speed lower than 30 km/h, then increasing linearly up to 12 km/h at 500 km/h.
Operational Examples	Train control while running, speed supervision, train control in ATO.

6.1.1.2 Rear

HHSD Rear	
Description	Provide train rear position for track occupancy notification.
Safety Critical	Yes
Mission critical	Yes
½ MCI	10m up to 40km/h, distance run in 1s at higher speed
Operational Examples	Track occupancy notification in L3

6.1.1.3 Note: profile 6.1.1.1 serves for speed supervision in L1 and L2. Supporting profile 6.1.1.2 enables running L3 high density applications.

6.1.1.4 Note: the HHSD performance profile covers most of the operational situations, they can be considered as fundamental.

6.1.1.5 Note: profile 6.1.1.1 also covers non-mission critical use cases where train front position and speed are necessary for external warning systems aiming to warn from incoming trains (e.g. devices to alert workers along the track).

6.1.1.6 Justification: accuracy expectations reflect capacity planning in dense traffic areas where releasing points within seconds is required. The specification of speed-dependent performance profiles is an attempt to avoid over-specifying at high speeds.

6.1.1.7 Justification, SoM in profile 6.1.1.1: minimise the travelled distance without supervision (Movement Authority).

6.1.1.8 Note: the expectations stated in 6.1.1.2 are notoriously challenging for freight trains. The considerations of 3.1.1.8 apply. The accuracy target may be relaxed according to feasibility and cost benefit analysis.

6.1.1.9 Note: no hint is made as to the method used to fulfill 6.1.1.2. Using safe length and integrity information is a possibility.

6.1.2 HHPLOC

6.1.2.1 Front

HHPLOC Front	
Description	Provide train front position and train speed (including direction) for track occupancy notification and for speed supervision in specific places or during specific scenarios.
Safety Critical	Yes
Mission critical	Yes
Front Position ½ MCI	1m
Speed ½ MCI	2 km/h for speed lower than 30 km/h
Operational Examples	Train control in parking areas, stopping, coupling, shunting operations.

6.1.2.2 Rear

HHPLOC Rear	
Description	Provide train rear position for track occupancy notification.
Safety Critical	Yes
Mission critical	Yes
Rear Position ½ MCI	1m
Operational Examples	Train control in parking areas, stopping, coupling, shunting operations.

6.1.2.3 Note: the expectations stated in 6.1.2.1 and in 6.1.2.2 are clearly challenging. The considerations of 3.1.1.8 apply. The opportunity of using track-side or onboard localisation techniques shall depend on feasibility and cost benefit analysis.

6.1.2.4 Note: concerning standstill detection, the possible interactions between Localisation and Roll Away Protection, Reverse Movement Protection and Standstill Supervision have not been investigated yet (anyway this document does not intend to relax requirements of [SS026] on D_NVROLL).

6.1.2.5 Justification, parking: on short parking tracks, train buffers may lie within a few meters of danger points. Moreover, if several trains are parked on the same track, it is often necessary to park them very close together.

6.1.2.6 Justification, coupling: minimise the distance without full supervision. Speed constraints can be required.

6.1.2.7 Justification, stopping: covers cases ranging from virtualisation of stopping indicators to precise EoA in tight places.

6.1.3 LHPLOC

6.1.3.1 Front

LHPLOC Front	
Description	Provide train front position, train speed (including direction), train acceleration for ATO and train control functions while the train is stopping.
Safety Critical	No
Mission critical	Yes
Front Position SD	0.5 m
Speed SD	2 km/h
Acceleration SD	To be defined
Operational Examples	parking, stopping in ATO, Guidance and control of the ATO

6.1.3.2 Rear

LHPLOC Rear	
Description	Provide train rear position for ATO and train control functions while the train is stopping.
Safety Critical	No
Mission critical	Yes
Rear Position SD	Under analysis, TBD
Operational Examples	parking, stopping in ATO

6.1.3.3 Note: profile 6.1.3.1 also covers non-mission critical use cases where train front position and speed is necessary for monitoring or civil engineering purposes (e.g. track monitoring/surveying, spraying trains monitoring).

6.1.3.4 Justification for 6.1.3.1: accurate regulation of speed and acceleration and stopping at platforms under ATO.

6.1.3.5 Justification for 6.1.3.2: the control loop of the ATO for freight train could need information from rear to adapt the traction power during the starting phase. A freight train is like a chain. Before providing full power, the driver shall add tension to this chain, wagon by wagon. Today it is up to the driver to adjust power traction accordingly. For an automatic system, it could be useful to know when the tension of this chain is optimal.

6.1.4 Intentionally deleted

6.1.5 LH

6.1.5.1 Front

LH Front	
Description	Provide train front position, and train speed (including direction) for TMS, passenger information and location-based services
Safety Critical	No
Mission critical	Yes
Front Position SD	10m up to 40km/h, distance run in 1s at higher speed
Speed SD	2 km/h for speed lower than 30 km/h, then increasing linearly up to ± 12 km/h at 500 km/h.
Operational Examples	Location for passenger information system, input for the train management system, information for fleet management

6.1.5.2 Rear

LH Rear	
Description	Provide train end position for TMS, passenger information and location-based services.
Safety Critical	No
Mission critical	Yes
Rear Position SD	10m up to 40km/h, distance run in 1s at higher speed
Operational Examples	Location for passenger information system, input for the train management system, information for fleet management

6.1.5.3 Note: these performance profiles are automatically fulfilled if HHSD performance requirements (see 6.1.1) are. Though, in case a safe localisation information cannot be delivered, an unsafe localisation information is still useful for TMS and passenger information.

6.1.5.4 Justification: feed the customer information and TMS trackside databases to inform customers and take the decision for the operation officer. Speed will be used to predict the future position of the train to avoid conflict at the cross section (e.g. switch) or to detect automatically a potential problem.

6.1.5.5 Justification: this information could be used for onboard passenger information as well.

6.1.5.6 Note: the size of the train or the rear position is mandatory to optimise TMS performances since the train is not a point but a segment (e.g. it is important to manage traffic in degraded situations with permissive blocking system).

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6.1.7 Intentionally deleted

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