



EEIG ERTMS Users Group

123-133 Rue Froissart, 1040 Brussels, Belgium

Tel: +32 (0)2 673.99.33 - TVA BE0455.935.830

Website: www.ertms.be E-mail: info@ertms.be

ERTMS USERS GROUP – ENGINEERING GUIDELINE

**64. Handling of level crossings with
Baseline 3**

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1. Introduction

1.1 Foreword

- 1.1.1.1 The procedure for level crossing supervision is defined technically in chapter 5 of the SRS (see SUBSET-026 [2]) and operationally the harmonised ERTMS rules apply (see TSI OPE [1], Appendix A) in addition to national rules. In Baseline 2 (B2) of the SRS, the level crossing functionality is an open point since there is no agreed solution. In Baseline 3 Maintenance Release 1 (B3MR1) of the SRS the support for level crossing supervision has been introduced (as specified within CR413). This guideline mainly applies for B3MR1, but a solution with B2 is provided as well.
- 1.1.1.2 The aim of this document is to provide a series of tools or solutions for handling level crossings in ERTMS, for the benefit of future ERTMS projects. Depending on the national safety rules and on the type of level crossing some solutions could be appropriate and some of them not. The objective is to support an efficient and safe implementation of ERTMS, both from a technical and operational point, simplifying and harmonising future system implementations taking advantage of the experience obtained from projects already in operation. A common goal with the solutions is to minimise the road closure time and to achieve a constant closure time of the level crossing.
- 1.1.1.3 This guideline is part of a bundle of guidelines with the Overall ETCS guideline [7] being the main guideline which will redirect the reader to the relevant guidelines. Be aware that the Overall ETCS guideline may also include recommendations which are related to the topics addressed in this guideline.

1.2 Scope and Field of Application

- 1.2.1.1 This document is applicable for level crossings in areas only equipped with ETCS level 2/3 based on ERTMS/ETCS Baseline 3. An alternative solution for Baseline 2 is however described in clause 5.2.4.3.
- 1.2.1.2 It is strongly recommended that any entity using ERTMS/ETCS follows the recommendations defined in this document.
- 1.2.1.3 This guideline is based on the requirements of SUBSET-040 [4] as far as relevant for trackside engineering.
- 1.2.1.4 Level crossings can be categorised into four different types:
- 1) Monitored – a crossing where the movement authority requires the crossing to be proven as operating.
 - 2) Autonomous – a crossing which functions independently of the interlocking, failure alarms may be provided to a supervisory point.
 - 3) Train driver operated or supervised – a crossing where the driver is responsible for checking the protection is in place before proceeding.
 - 4) Unsupervised – a crossing with no signalling equipment.

- 1.2.1.5 This guideline only covers the first type of level crossing since this type is the only one controlled and monitored by the ERTMS system. The usage of the other types of level crossings is project specific.
- 1.2.1.6 This guideline is intended for a trackside where the System Version is 2.Y, but some of the solutions described can also be used with a trackside where the System Version is 1.Y.
- 1.2.1.7 This guideline takes into consideration on-board systems where the active System Version is either 1.Y or 2.Y.
- 1.2.1.8 This guideline considers the ERA/OPI/2020-2 [5] error correction document. The following CRs contained in the document have been identified to have an impact on this guideline: CR887, CR940, CR1251 and CR1324.

1.3 Document structure

- 1.3.1.1 Chapter 1 introduces the document and defines the scope.
- 1.3.1.2 Chapter 2 provides the references, terms and abbreviations used in this document.
- 1.3.1.3 Chapter 2.3 provides the general functional steps for passing a level crossing.
- 1.3.1.4 Chapter 4 provides the criteria assessed for the recommendations.
- 1.3.1.5 Chapter 5 provides the recommendations (solution A) for each functional step.
- 1.3.1.6 Chapter 6 provides the recommendations (solution B) for each functional step.
- 1.3.1.7 Appendix A provides some detailed description of solution B.

2. References and Abbreviations

2.1 Definitions

2.1.1.1 The following table includes terms and definitions which are used in the current document:

Terminology	Definition
LX activation trigger	The event detected by the interlocking or RBC which initiates the level crossing protection sequence.
LX announcement time	The minimum value of the LX warning time that is defined for a specific LX. The LX announcement time is dependent on the characteristics of the LX (number of tracks, etc.).
LX approach area	The area in rear of the LX in which the RBC has to make the calculation to determine the right moment to activate the LX. The actual size of the area is depending on local circumstances. It has to be large enough to enable the RBC to make the calculation in time, to fulfil the local requirements on the LX announcement time.
LX start location	The location in rear of the level crossing where the train should stop in case of non-protected LX
LX triggering area	The area in rear of the level crossing where the level crossing is triggered to close to fulfil the project specific requirements for waiting time
LX speed restriction	A speed restriction related to a level crossing. The restriction is active when the LX is Not Protected.
LX warning time	Time interval between the activation of the LX (e.g. red lights start flashing, bells start ringing) and the moment when the front of the train passes the LX. The LX shall be designed in such a way that the actual LX warning time is as short as possible.
On-sight route	A locked route which is not unambiguously detected as free
Pre-warning time	The time from start of warning signalling until the level crossing has reached a protected state.
Virtual Marker board	A geographical point acting as EOA in rear of an LX. It may or may not be represented by a physical marker board depending on operational requirements. It is used to set the appropriate time

	values for OBU to request an MA based on T_MAR. Virtual Marker Board will not be necessary if LX function defined in SUBSET-026 [2], by sending packet 88, is used.
Waiting time	The time the road traffic will have to wait for the train to pass, from start of warning signalling.
Warning signalling	The optical and/or audible warning towards road traffic as long as the level crossing is closed for passage by road traffic.

2.2 Abbreviations

2.2.1.1 The following table includes acronyms and abbreviations which are used in the current document:

Abbreviation	Description
ATP	Automatic Train Protection (national systems)
BG	Balise Group
DMI	Driver Machine Interface
EOA	End of Authority
FE	Front End
FS	Full Supervision (ETCS mode)
IL	Interlocking
LRBG	Last Relevant Balise Group
L2	ERTMS/ETCS Level 2
L3	ERTMS/ETCS Level 3
LX	Level crossing
M	Message; e.g. M3 is ERTMS message 3
MA	Movement Authority
MRDT	Most Restrictive Displayed Target
MRSP_RBC	The most restrictive part of the on-board and trackside related speed restrictions, calculated by the RBC.
OS	On-sight (ETCS mode)
P	Packet, e.g. P41 is ETCS packet 41

RBC	Radio Block Centre
SoM	Start-of-Mission; procedure for start-up of an ERTMS/ETCS train
SSP	Static Speed Profile
TIMS	Train Integrity Monitoring System
TLX	The time needed in the track side equipment to achieve the state protected
TSR	Temporary Speed Restriction
VM	Virtual Marker board

2.3 References

2.3.1.1 The following documents and versions apply:

Ref. N°	Document Reference	Title	Version
[1]	TSI OPE	Commission Decision 2012/757/EU, dated 2012-11-14, amended by Commission Decision 2015/995/EU, dated 2015-06-08, TSI OPE	4
[2]	SUBSET-026	ERTMS/ETCS Class 1 System Requirements Specification	3.4.0
[3]	SUBSET-041	Performance Requirements for Interoperability	3.1.0
[4]	SUBSET-040	Dimensioning and Engineering rules	3.3.0
[5]	ERA/OPI/2020-2	Opinion of the European Union Agency for Railways to the European Commission regarding error corrections of current ERTMS baselines	2020-05-05
[6]	SUBSET-039	FIS for the RBC/RBC Handover	3.1.0
[7]	22E087	Overall ETCS	1-

3. Passing a level crossing

3.1 Introduction

3.1.1.1 This chapter intends to give a general overview of how to pass a level crossing and can be used as a reference for the issues discussed in chapter 4. The track layout and sequence diagram presented here are further detailed in chapter 5 (solution A) and 6 (solution B), e.g. with alternative solutions as applicable for each functional step.

3.2 Functional Steps

3.2.1.1 In order to facilitate the recommendations detailed in chapter 5 and 6, the passage of a level crossing is divided into the following functional steps:

- 1) Triggering the level crossing to close
- 2) Supervision of the level crossing
- 3) Opening the level crossing

3.3 Generic Track Layout

3.3.1.1 Figure 1 shows the generic and relevant track design and balise groups needed to perform the different functional steps of passing a level crossing listed in paragraph 3.2.1.1. There are intentionally no signals shown in the figure as they are not relevant for passing the level crossing as such from a technical point of view.

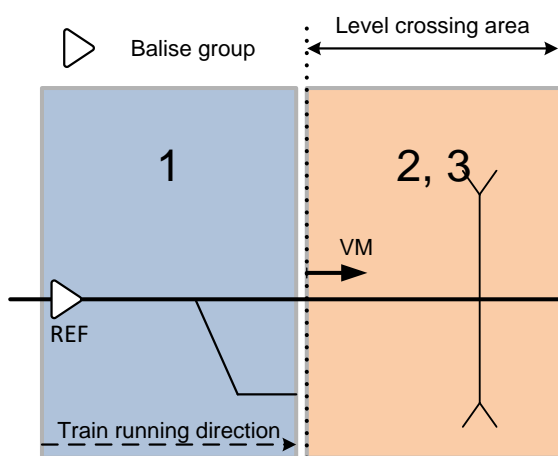


Figure 1: Generic track layout for passing a level crossing

3.3.1.2 Table 1 below represents the balise groups and information (in ETCS packets) needed for each functional step to succeed with a passage of a level crossing. Additional balise groups and packets will be suggested in chapter 5 and 6.

BG	BG DESCRIPTION	BG INFORMATION (ETCS PACKETS)
REF	Last Reference BG	No packet relevant for the level crossing

Table 1: Balise groups for passing a level crossing

3.3.1.3 The information in the balise groups in the figures is only valid in the indicated train running direction, unless defined otherwise.

- 3.3.1.4 The specific national trackside equipment requirements are project specific and not part of this guideline.
- 3.3.1.5 Balise group REF provides the reference for the level 2 MA related to the level crossing.
- 3.3.1.5.1 Note: Any balise group marked as linked (and included in the linking information sent by RBC) in the route passing the level crossing can fulfil the function of the reference balise group REF.
- 3.3.1.6 The Virtual Marker board (VM) is an RBC internal reference for EOA, i.e. not necessarily represented by a physical track-side marker board. The Virtual Marker board is not known by the interlocking and cannot act as a route setting point.

3.4 General Sequence Diagram

3.4.1.1 The sequence diagram in Figure 2 shows the relevant information that is exchanged between the main actors when performing the three functional steps listed in 3.2.1.1 above.

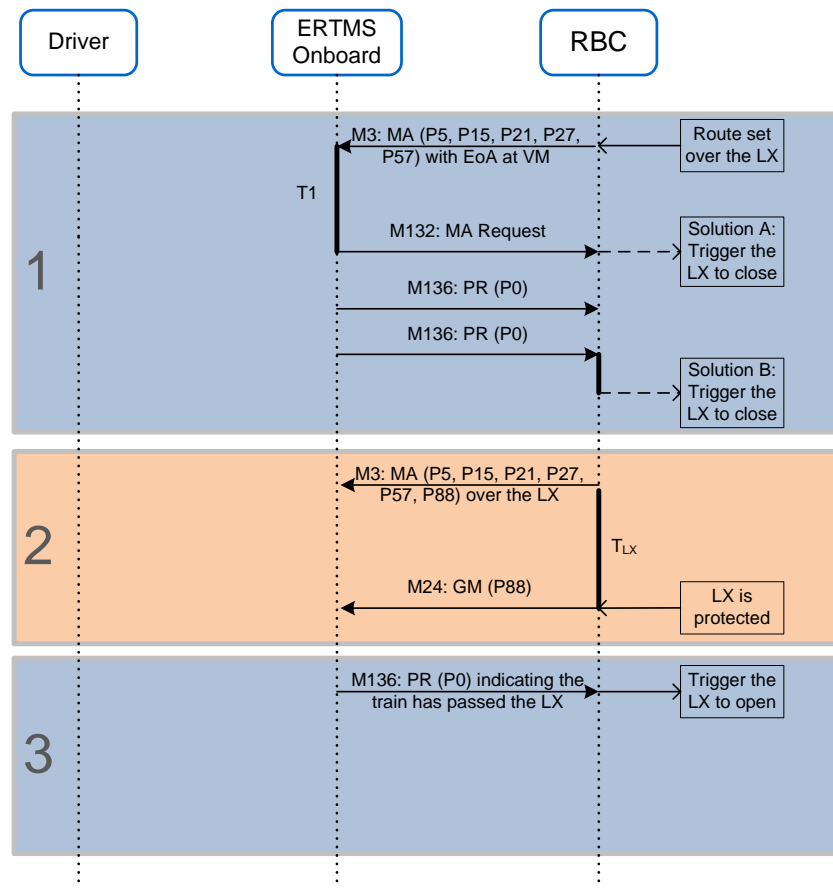


Figure 2: General sequence diagram for passing a level crossing under normal conditions

3.4.1.2 The information exchange and the time required for that are further detailed for each functional step in chapter 5 and 6.

- 3.4.1.3 The diagram in Figure 2 does not represent all the mandatory information exchanged by the relevant actors but defines in general the different functional steps that are considered in this document for the recommendations given in chapter 5 and 6.
- 3.4.1.4 The movement authorisation is issued by the RBC when the route is set and other conditions to deliver the level 2 MA are fulfilled. The specific conditions are project specific.
- 3.4.1.5 Step 1 ends and step 2 starts when MA request is received by RBC or train position is calculated to be in the triggering area of the LX.
- 3.4.1.6 During the period T_{LX} a movement authority is issued over the level crossing which is protected by a Packet 88 control. The speed setting and optional requirement to stop before the crossing is project specific.

4. Criteria and risks to be addressed

4.1 Introduction

4.1.1.1 This chapter lists the criteria and risks that need to be considered for passage of a level crossing. Some are further detailed in the recommendations given in chapter 5 and 6. The criteria that are not part of the recommendations are mentioned here because projects could need to consider them.

4.2 Issues

4.2.1 Loss of level crossing protection

4.2.1.1 After cancellation of the LX protection, project specific requirements may require a safe reaction in case of failure of one or more conditions supervised to protect the level crossing; e.g. due to broken barriers or broken signals.

4.2.1.2 The RBC can then try to stop the train, e.g. by sending an LX restriction or an Emergency Stop Message.

4.2.2 Allow level crossing passage at line speed

4.2.2.1 Trains approaching the level crossing should not face speed restrictions caused by the level crossing under normal operating conditions.

4.2.2.2 To achieve this goal the level crossing must have entered a protected state before the train faces a speed restriction because of the applied LX restriction, i.e. the LX restriction must be cancelled before the train enters the braking curve.

4.2.2.2.1 Note: This will generate a waiting time greater than the braking time to standstill for the train plus the required pre-warning time (project specific).

4.2.3 Manual cancellation of the route over the level crossing

4.2.3.1 In case the route over the level crossing is cancelled manually for operational purposes (e.g. for preferred vehicle movements, change of departure sequence, etc.), the authorisation to pass the level crossing must be revoked. This can be achieved by issuing a request to shorten the MA. The closure command to the LX should then also be revoked.

4.2.3.2 To avoid that the train is supervised by a previously sent LX restriction while not passing the level crossing, the LX restriction shall be cancelled if the authorisation to pass the level crossing is cancelled (see 5.2.3.8 and 6.2.3.2).

4.2.4 Start of mission in rear of a level crossing

4.2.4.1 ERTMS/ETCS trains always have the possibility to perform start-of-mission in the LX triggering area, but since the recommended solution for triggering the level crossing is based on an MA request or train position with MA information and that the train has received an MA up to the VM/LX start location, an unambiguous position of the train is required (else the RBC cannot send an MA). To position the train in rear of the LX during SoM, an additional balise group may be needed in the LX triggering area.

4.2.4.2 To avoid tripping a train in SR (by sending an MA up to the VM without release speed) when the position of the train becomes valid and unambiguously close to the LX, the RBC should instead send the MA over the LX immediately in this situation (i.e. without setting the EOA at the VM). The sending of the MA over the LX will then trigger the LX to close.

4.2.4.3 If no MA can be issued over the level crossing, the train has to pass the LX in SR mode. To avoid trains in SR passing a non-protected level crossing, an additional method for triggering the level crossing is needed. See the recommendations in clause 5.1.3.8 and 6.1.3.7.

4.2.4.4 The operational use of the “override EOA” function to pass a level crossing shall be according to national rules.

4.2.5 Decrease of static speed profile in rear of the level crossing

4.2.5.1 The on-board calculation for generating an MA request, which is based on MRSP rather than actual train speed, will take into consideration heavily reduced SSP in rear of the level crossing. This will generate a LX activation trigger much earlier than needed, thus increasing the waiting time. See recommendations in chapter 5.1.3.9.

4.2.5.1.1 Note: The level crossing unprotected status and speed/stop requirements are only displayed when they are the Most Restricted Display Target – this may « mask » the level crossing information. See SUBSET-026 [2] chapter 5.16.1.4.

4.2.6 Avoid driver intervention when approaching a LX under activation

4.2.6.1 The time T_MAR, for configuring the MA request, may have to be extended to include a sufficient margin to avoid that the driver starts to brake based on the information provided in the planning area, showing a rather short distance to EOA, because of non-extended MA over the level crossing. This is particularly an issue at higher speeds. See clause 5.1.3.2.

4.2.6.2 The RBC will then have to delay the triggering of the level crossing, but not to risk exceeding the maximum waiting time (project specific), in case an early extension of the MA is needed for operational reasons.

4.2.7 Level crossings with short maximum waiting time

4.2.7.1 For some types of level crossing installations, the required maximum waiting time could be too short to allow the train to stop in rear of a level crossing that is non-protected (e.g. in case of a malfunctioning level crossing). An alternative solution for supervising these kinds of level crossing is needed to avoid that the train faces a speed restriction, due to an LX speed restriction, under normal operating conditions.

4.2.7.1.1 Note: The recommended solution, described in section 5.2, based on applying a LX restriction until the level crossing is protected, will always generate a braking intervention for the train if the maximum required waiting time is shorter than the required pre-warning time plus the braking time to zero.

4.2.7.2 The triggering of such level crossing must be delayed from reception of the LX activation trigger in order to facilitate a short waiting time. For this type of level crossing a safe closure of the level crossing is assumed once commanded. The moment to order the level crossing to be closed requires a safe predication of time of arrival of the train at the level crossing minus the time to safely close the level crossing. The moment to order the level crossing to close is calculated before the MA is extended. The calculation of the train arrival time at the level crossing is based on received position reports and shall take margins in speed, location and system delays into account. This is detailed in section 5.1.4.

4.2.7.2.1 Note: Besides the short waiting time, a constant waiting time is also regarded as an important factor in level crossing safety. Using train dependent speed information allows for achieving a more constant waiting time.

4.2.8 Planned train stop in rear of a level crossing

4.2.8.1 In case a planned train stop in rear of the level crossing the triggering of the closing of the level crossing and the extension of the MA can be delayed until the departure time of the train (minus the level crossing closing time). This to avoid a long waiting time for stopping trains compared to a train passing through. This delay can be realized with timers based on the train stop, triggers controlled by the conductor or with route setting command from the traffic management system.

4.2.9 Planned train stop in advance of a level crossing

4.2.9.1 In case of a planned train stop in advance of the level crossing an alternative solution of triggering the closing of the level crossing could take into account the trains' reduced speed due to the braking for the stop if the safe deceleration information is available.

4.2.10 Failure that prevents the level crossing to be protected

4.2.10.1 In FS/LS/OS/SR considerations must be made whether the train should be allowed to pass a non-protected level crossing or not. The TSI OPE [1] requires that Rule 7 of Appendix B2 shall be applied. This rule is managed by IM/RU.

4.2.10.2 In FS/OS the use of packet 88 enables the dedicated LX icon on the DMI to be displayed when supervising a non-protected level crossing. When using packet 88 it is also possible to force a stop before passing the level crossing and to restrict a train's speed while traversing the level crossing.

4.2.10.2.1 Note: If a train has already stopped within the stopping area indicated by a packet 88, the reception of another (identical) packet 88 that contains a demand to stop will force the train to stop again.

4.2.10.3 In SR packet 76 may be used to alert the driver on the approach of a non-protected level crossing. Fixed text message with variable Q_TEXT = 0 ("LX not protected") can be used to warn the driver about the unprotected state of the level crossing.

4.2.10.4 In SH mode the text message function is inactive. National and non-harmonised rules and procedures should be put in place in order to allow the driver to pass a non-protected level crossing.

4.2.11 Reducing the closure time after train passage

4.2.11.1 To optimise the closure time after a train has passed, a robust and safe method is to use external track-side equipment such as track circuits or axle counters to register the train's passage.

4.2.11.2 For a safe and fast opening of the LX by only relying on position reports, the min safe rear end of the train should be used (a TIMS is then needed on the train). If the rear end of the train is not considered safe (no TIMS available), min safe front end should be used together with a defined maximum train length for all trains running on the line. The odometry inaccuracies should be considered and therefore will delay the opening. The position report parameters force the train to report its location only based on max safe front end when min safe rear end is not available by the use of Q_LGTLOC. Therefore, this location shall be either train specific or one value (max length) for all trains.

4.2.11.3 If the train is equipped with TIMs, and there is no train integrity information or train integrity is lost, the LX opening cannot rely on the train rear end, because the train length is entered by the driver and thus not safe. In this case the LX cannot be reopened until safe train rear end has been proven to be out of the LX area. The use of external equipment such as axle counters or track circuits is a robust and safe method to reopen the LX.

4.2.12 Exceeding maximum waiting time

4.2.12.1 If a LX is closed for too long, there is an increased risk of 'unauthorised passing'. For this situation, an alarm can be raised, possibly resulting in a LX speed restriction.

4.2.13 Train not in contact with RBC

4.2.13.1 In case of a train operating in SR or not in contact with the RBC, the crossing will not be triggered or protected. Alternative controls may be required to initiate the crossing, see clause 5.1.3.8.

4.2.14 Level crossings located close after each other

4.2.14.1 The closure times for level crossings located close to each other must not be unnecessarily extended due to this fact. Considerations must be made whether the level crossings should be triggered individually or combined into one control object, depending on the distance between the level crossings.

4.2.14.2 The driver must be able to distinguish the level crossings from each other or be aware that one LX restriction concerns several level crossings. Considerations must be made whether the level crossings should be individually supervised or combined into one supervised object, depending on the length of the LX restriction and the distance between the level crossings.

4.2.15 NID_LX assignment

- 4.2.15.1 When sending Level Crossing information by Packet 88 to the on-board, the Level Crossing information shall have a unique LX identity using NID_LX, so that all Level Crossing information is independent of each other (see SUBSET-026 [2] 3.12.5.2).
- 4.2.15.2 There are limited LX identities available. For example, 129 NID_LX values are reserved for RBC transmission. If there are more Level Crossings in an RBC area, it is not possible to assign a unique identity to each level crossing. Another solution is to only provide unique identities to each train, taking into account the memorized identities on-board. The number of Level crossing information in 1 message and memorized on-board is limited to 10 (see SUBSET-040 [4] 4.3.2.1).
- 4.2.15.3 When connecting one RBC area to another RBC area, the management of unique identities shall be managed offline (see SUBSET-039 [6] 4.7.1.1). In the RRI request on the NRBC interface only the amount of remaining LX packets (N_REMAINLX = max 10) are sent to the ACC RBC, not which NID_LX values are already sent to the train.

5. Recommended solutions A

5.1 Triggering the closing of the level crossing

5.1.1 Basic considerations

5.1.1.1 Functional step 1 is about the process to trigger the closing of the level crossing.

5.1.1.2 The following issues from chapter 4.2 must be considered in this functional step:

- Allow level crossing passage at line speed (4.2.2)
- Start of mission in rear of a level crossing (see 4.2.4)
- Decrease of static speed profile in rear of the level crossing (see 4.2.5)
- Avoid driver intervention when approaching an LX under activation 4.2.6)
- Level crossings with short maximum waiting time (see 4.2.7)
- Planned stop in rear of a level crossing (see 4.2.8)
- Planned stop in advance of a level crossing (see 4.2.9)
- Exceeding maximum waiting time (see 4.2.12)
- Level crossings located close after each other (see 4.2.14)

5.1.1.3 The recommendation for solution A is to use the on-board functionality for generating an MA request for triggering of the level crossing. This has the following benefits:

- The waiting time will be optimised since the properties of each individual train is taken into consideration
- Each individual train will be able to stop in rear of the level crossing in case of malfunctioning level crossing
- There is no issue of accelerating trains within the LX triggering area since the MRSP is used as reference. I.e. MA request (by T_MAR) is not based on current train speed.

5.1.2 Track layout

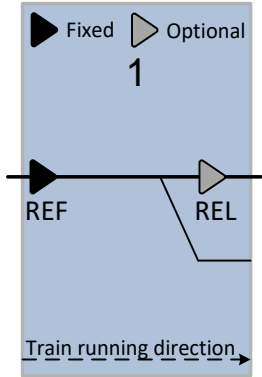
TRACK LAYOUT	BG	DESCRIPTION	PACKET INFORMATION
	REF	Last Reference BG	No packet relevant for the level crossing
	REL	Relocation Balise (optional)	No packet relevant for the level crossing

Table 2: Balise groups used for functional step 1

5.1.2.1 Balise group REF is the reference balise group for the movement authorisation issued by the RBC (see also chapter 3.3.1.5).

5.1.2.2 Balise group REL is optional and can be used to position the train in rear of the level crossing on places where SoM with unknown position is expected to occur.

5.1.3 Sequence diagram

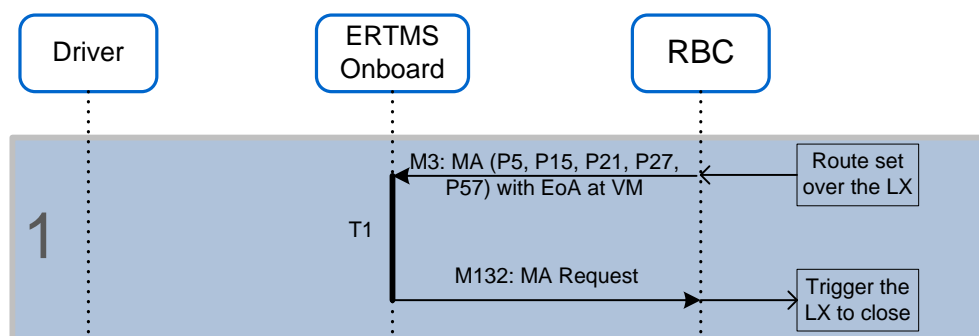


Figure 3: Sequence diagram for step 1

5.1.3.1 When there is a route set over the level crossing and the conditions to send the level 2 MA are fulfilled, the RBC sends the level 2 MA to the Virtual Marker or over the level crossing together with MA request parameters configured for the specific level crossing.

5.1.3.2 In order for the RBC to know when to trigger the level crossing to close, the on-board functionality for requesting a new MA a defined time before the train reaches the pre-indication location (see SUBSET-026 [2] 3.8.2.3.a) is used. This time is sent from RBC in variable T_MAR.

5.1.3.2.1 Note: The definition of T_MAR has been changed between Baseline 2 (based on the indication limit) and Baseline 3 (based on the pre-indication limit).

5.1.3.3 The value of T_MAR shall be configured for each level crossing and consider the time required from the start of the warning signalling until the level crossing is considered as protected, including sufficient margins for internal system delays and communication delays. The conditions for considering the level crossing as protected are project specific.

5.1.3.3.1 Note: Project specific requirements could imply a reduction of T_MAR to support a partially protected level crossing (i.e. improved from not protected, but not fully protected).

5.1.3.4 T1 is the time from when on-board receives an MA with EOA at VM/LX start location until it is located T_MAR seconds from the pre-indication curve, i.e. the on-board then sends a MA request to RBC.

5.1.3.5 The RBC orders the interlocking to close the level crossing when the MA request is received in order to achieve a protected state of the level crossing before the train enters the pre-indication curve.

5.1.3.5.1 Note: An issue was discovered in a project where multiple MA requests from an on-board unit would also trigger a level crossing on the line. This issue was solved by not extending the MA to the second level crossing until the first level crossing

was detected to be protected. An MA up to – or beyond – a level crossing is a condition for activating the level crossing.

- 5.1.3.6 In case the level crossing is in a protected state when an MA request is received, e.g. due to a preceding train, the level crossing shall be kept closed until passage of the second train.
- 5.1.3.7 A prerequisite for using an MA request as trigger for closing the level crossing is that the conditions to send a Level 2 MA are fulfilled. One of these conditions is that the position of the train is unambiguous, which is not the case if SoM with unknown position is performed in rear of the level crossing. To position the train after a SoM an additional balise group may be needed in certain places (see 5.1.2.2) where SoM is likely to occur.
- 5.1.3.8 To trigger the level crossing for a train not running in FS/OS mode an alternative method is needed, e.g. by a special command from the signaller, by using track circuits or other external equipment. This is project specific.
- 5.1.3.9 Heavily reduced SSP in rear of the level crossing could cause the on-board to request a new MA too early because of the indication location being at the start point of the reduced SSP. Special measures may be needed to discard this undue MA request, e.g. to define an expectation window within the LX triggering area.

5.1.4 Alternative solutions

- 5.1.4.1 Chapter 6 describes an alternative LX activation through position reports.
- 5.1.4.2 The triggering of the level crossing can also be based on external equipment, such as track circuits, axle counters or loops in the track.

5.1.5 Degraded situations

- 5.1.5.1 This functional step has the following degraded situations:
 - 1) Failure to read the REF balise group
 - 2) Failure to read the REL balise group
 - 3) Loss of radio contact or delayed messages
- 5.1.5.2 The consequence of degraded situation 1) is that the level 2 MA to the Virtual Marker board and over the level crossing may not be sent (since the BG REF (or any linked balise group) is acting as LRBG for the MA over the LX). In situation 1 another BG will react as the LRBG (according to 3.6.2.2.2, SUBSET-026 [2]). Then it should be considered that the location accuracy will decrease. This influences the activation moment.
- 5.1.5.3 The consequence of degraded situation 2) is for the recommended solution that the level crossing will not be triggered to close after a SoM with unknown position in rear of the level crossing. See chapter 5.1.3.8 for methods to mitigate this risk.
- 5.1.5.4 The consequence of degraded situation 3) is that the triggering of the level crossing will be delayed, so the train will supervise its EOA at the Virtual Marker board/LX start location. If packet 88 is used, the train will be supervised according

to LX speed restriction. National rules for passing level crossing that is not secured will apply.

5.1.5.5 For the alternative solution based on position reports, the consequence of degraded situation 3) is that the triggering of the level crossing will not be optimized by the delayed messages.

5.2 Supervision of the level crossing

5.2.1 Basic considerations

5.2.1.1 Functional step 2 is about supervising the level crossing. The following issues from chapter 4.2 must be considered in this functional step:

- Loss of level crossing protection (see 4.2.1)
- Allow level crossing passage at line speed (see 4.2.2)
- Manual cancellation of the route over the level crossing (see 4.2.3)
- Level crossings with short maximum waiting time (see 4.2.7)
- Level crossings located close after each other (see 4.2.14)

5.2.1.2 The recommendation is to issue a LX restriction before the level crossing is protected. This has the following benefits:

- All trains will manage to stop in rear of a malfunctioning level crossing (project specific if stop is required or not)
- It will be possible to pass a malfunctioning level crossing with the permitted speed within the LX speed restriction.
- The driver will get a clear indication of the reason to the speed restriction in case of a malfunctioning level crossing

5.2.2 Track layout

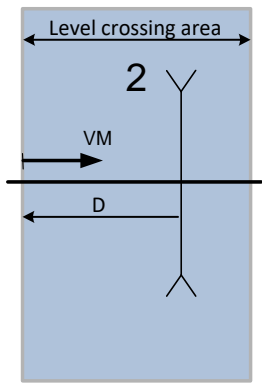
TRACK LAYOUT	DISTANCE	DESCRIPTION	PACKET INFORMATION
	D	LX start location	The defined stopping area in rear of the level crossing where the braking curve to zero ends

Table 3: Track layout for functional step 2

5.2.2.1 The distance D defines the point where the braking curve to zero ends when the level crossing is not protected.

5.2.2.2 The distance D must include necessary safety margins to guarantee the train will be stopped before the level crossing.

5.2.3 Sequence diagram

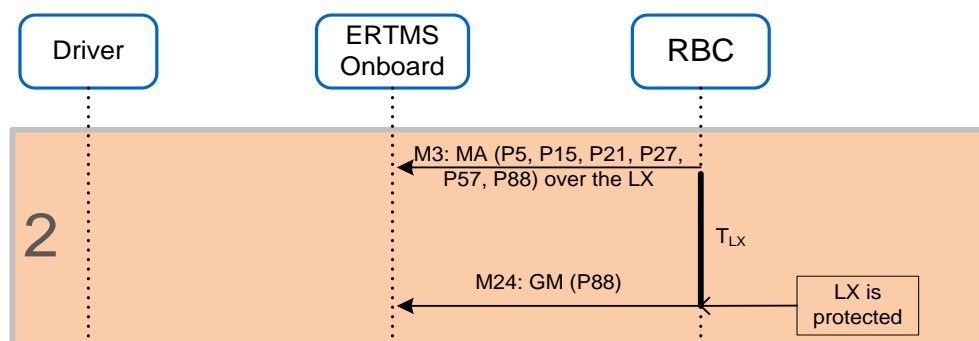


Figure 4: Sequence diagram for step 2

- 5.2.3.1 The extended MA over the level crossing includes information about the level crossing status. When extending the MA the level crossing is not protected, this will apply an LX restriction.
- 5.2.3.2 The LX restriction will not be displayed in the planning area of the DMI. But a dedicated LX icon will be displayed on DMI when supervising a non-protected level crossing.
- 5.2.3.2.1 Note: In case the stopping position or the speed restriction is not the MRDT the LX icon will not be displayed.
- 5.2.3.3 When the track side equipment considers the level crossing as protected (after time T_{LX}), the active LX restriction is cancelled by sending status protected to on-board. The time T_{LX} is the time needed in the track side equipment to achieve the state protected, the conditions for considering the level crossing as protected are project specific.
- 5.2.3.4 Project specific requirements could imply a level crossing to be partially protected (i.e. improved from not protected, but still not fully protected). This could be handled by resending the P88 with a higher LX speed when the protection becomes improved.
- 5.2.3.5 Depending on national rules the driver may be required to stop in rear of a non-protected level crossing before passing the level crossing. Whether it is required to supervise the train to standstill or not before passing a non-protected level crossing is defined by variable Q_STOPLX .
- 5.2.3.6 After the LX restriction has been cancelled (because of protected state reached), there must be a method to warn the train and/or trying to stop the train in case the protection is lost again. The recommendation is to reapply the LX restriction.
- 5.2.3.6.1 Note: By reapplying the LX restriction in case of loss of protection, the train will be tripped if the train cannot stop before the LX start location.
- 5.2.3.7 The trackside should not repeat the unprotected LX information when the train has already passed an unprotected LX start location with its min safe front end (see problematic scenario described in CR1324 ERA/OPI/2020-2 [5]).

5.2.3.8 In situations where the route over the level crossing is manually cancelled, leading to a shortened MA, the issued LX restriction will be kept on-board until it has been cancelled. To avoid speed restrictions when not passing a level crossing the LX restriction must be cancelled.

5.2.3.9 In order to limit the speed for trains passing the level crossing in SR a balise group in rear of the LX containing a TSR could be used. To make it applicable only in SR the balise group should be marked as linked but not included in the linking information (Baseline 2), or to ignore the specific NID_TSR by RBC (Baseline 3).

5.2.4 Alternative solution

5.2.4.1 Level crossings with a short-required waiting time cannot use the recommended solution A since the trains will always face speed restrictions under normal operating conditions. If this type of level crossing needs to be supervised, an alternative solution can be to apply the LX restriction first after a defined time of non-protected status, or to define a validity time of the section of the MA (i.e. T_SECTIONTIMER) covering the level crossing that is cancelled when the level crossing becomes protected.

5.2.4.1.1 Note: By applying the LX restriction or section time out for trains located near the level crossing, the train will be tripped.

5.2.4.2 Packet 88 may be sent from Balise instead of RBC.

5.2.4.3 Instead of using packet 88, which is a Baseline 3 function, the TSR function could be used to supervise level crossings with Baseline 2.

5.2.4.4 To force the train to stop in rear of a non-protected level crossing when using the TSR solution, the initial TSR could be set to 0km/h. This TSR is then substituted by another TSR when the train has reported standstill to provide a possibility to pass the level crossing with a reduced speed.

5.2.4.5 Another approach to supervise level crossings is to let the MA be conditioned by the level crossing status, so that no MA is extended over the level crossing until the level of protection has reached partially protected or fully protected.

5.2.4.5.1 Note: Passing an unprotected level crossing then has to be performed in SR according to national operational rules.

5.2.4.5.2 Note: Where operational rules allow OS over the unprotected/partially protected LX then a physical marker and “standard” EOA could be used with special forward route to authorise the OS mode.

5.2.5 Degraded situations

5.2.5.1 This functional step has the following degraded situations:

- 1) Loss of radio contact or delayed messages
- 2) Malfunctioning level crossing equipment

5.2.5.2 The consequence of degraded situation 1) is that the MA cannot be extended over the level crossing which could lead to unacceptable waiting times. In addition, the LX restriction may not be removed with operation impact.

5.2.5.2.1 Note: It is assumed that radio contact is lost after the MA request has been received by the RBC and the updated MA has been issued.

5.2.5.3 For the alternative solution in clause 5.2.4.1, the consequence of degraded situation 1) is that the LX restriction will not be applied for a non-protected level crossing.

5.2.5.4 The consequence of degraded situation 2) is for the recommended solution that the train will be supervised according to the P88 LX protection functionality in rear of the level crossing.

5.2.5.5 For the alternative solution in clause 5.2.4.1 the consequence of degraded situation 2) is that the train will be tripped and may not be able to stop in rear of the level crossing.

5.3 Opening the level crossing

5.3.1 Basic considerations

5.3.1.1 Functional step 3 is about opening the level crossing. The following issues from chapter 4.2 must be considered in this functional step:

- Manual cancellation of the route over the level crossing (see 4.2.3)
- Reducing the closure time after train passage (see 4.2.11)

5.3.1.2 The recommendation is to use train detection equipment for registration of train passage to open the level crossing, but to use the alternative solution as a fall-back in case of failure in the train detection equipment. This has the following benefits:

- Minimised closure time after train passage
- Safe and robust method to open the level crossing
- The fall-back solution will open the level crossing in case of failure in the external equipment.

5.3.2 Track layout

TRACK LAYOUT	DISTANCE	DESCRIPTION	PACKET INFORMATION
	D2	Length of central track section	The distance between the geographical points in each direction where the train is considered having passed the LX

	<p>D3</p>	<p>Point where the reported train position has passed the LX</p>	<p>The distance in advance of the LX where a position report from the train could safely be used to open the level crossing</p>
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Table 4: Track layout for functional step 3

- 5.3.2.1 The distance D2 defines the geographical points where the train is considered as having passed the level crossing.
- 5.3.2.2 The distance D2 should be short in order to support a short closure time after train passage.
- 5.3.2.3 The distance D3 defines the geographical point where the min safe front end of the train should be located to open the level crossing based on position report.
- 5.3.2.4 The distance D3 must consider the maximum train length operating the line in order to guarantee that the complete train has passed the level crossing. Since the train length is manually entered by the driver it cannot be considered as a safe value to be used to open the level crossing. In case a train is equipped with TIMs, a dynamic D3 distance can be used to optimise the instant when the train reports its location and its integrity status (see 4.2.11.2)
- 5.3.2.4.1 Note: Using the maximum train length does not mitigate the risk if a train is actually broken. This is independent if a train is reported as integrity lost or as integer.

5.3.3 Sequence diagram

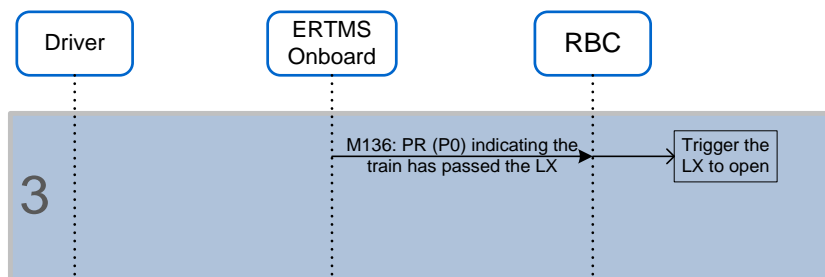


Figure 5: Sequence diagram for step 3

- 5.3.3.1 A position report from the train – indicating that its min safe front end has passed the distance D3 – is used as a trigger to open the level crossing in case the train detection equipment has failed to open the level crossing. The position report parameters including position D3 shall be sent. This will minimise the delay in retrieving the position report.

5.3.3.2 If the train is equipped with TIMs the distance D3 where the train will report its position including integrity status, can be optimised by calculating the point where the train has to report its position.

5.3.3.3 The LX must not be opened in front of another train approaching the same LX. If the second train has sent an MA Request while the LX is still protected, the opening based on the first train passage must be cancelled and await the passage of the second train.

5.3.4 Degraded situations

5.3.4.1 This functional step has the following degraded situations:

- 1) Loss of radio contact or delayed messages
- 2) Failure in the external track-side equipment
- 3) Malfunctioning level crossing equipment

5.3.4.2 The consequence of degraded situation 1) for the alternative solution is that the opening of the level crossing will be delayed or not opened at all, due to delayed or no position report at all received by RBC.

5.3.4.3 The consequence of degraded situation 2) is for the recommended solution that the level crossing will not be opened.

5.3.4.4 The consequence of degraded situation 3) is that the level crossing will not be opened.

6. Recommended solution B

6.1 Triggering the closing of the level crossing

6.1.1 Basic considerations

6.1.1.1 Functional step 1 is about the process to trigger the closing of the level crossing.

6.1.1.2 The following issues from chapter 4.2 must be considered in this functional step:

- Allow level crossing passage at line speed (see 4.2.2)
- Start of mission in rear of a level crossing (see 4.2.4)
- Decrease of static speed profile in rear of the level crossing (see 4.2.5)
- Avoid driver intervention when approaching an LX under activation (see 4.2.6)
- Level crossings with short maximum waiting time (see 4.2.7)
- Planned stop in rear of a level crossing (see 4.2.8)
- Planned stop in advance of a level crossing (see 4.2.9)
- Exceeding maximum waiting time (see 4.2.12)
- Level crossings located close after each other (see 4.2.14)

6.1.1.3 The recommendation is to use the on-board functionality for generating position reports for triggering of the level crossing.

6.1.1.4 This requires that the speed and distance to the level crossing is used for dynamically calculating when to trigger the level crossing. Also time/clock synchronisation between the on-board and RBC must be taken into account, resulting in a corrected time stamp to be used in the RBC for generating the correct LX activation trigger.

6.1.1.5 Annex A describes this LX activation through position reports in more detail.

6.1.1.6 If position reports are used to trigger the level crossing there is no need for the Virtual Marker board. The MA, including P88, can be sent over the level crossing without need to end at a Virtual Marker board.

6.1.1.7 This has the following benefits:

- The waiting time will be optimised since the properties (actual position, speed) of each individual train is taken into consideration
- The discovered issue described in clause 5.1.3.5.1 is avoided as the trigger is based only on train position and not on a specific message from the on-board.

6.1.2 Track layout

TRACK LAYOUT	BG	DESCRIPTION	PACKET INFORMATION
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	REF	Reference BG	No packet relevant for the level crossing
	REL	Relocation Balise (optional)	No packet relevant for the level crossing

Table 5: Balise groups used for functional step 1

- 6.1.2.1 Balise group REF is the reference balise group for the movement authorisation issued by the RBC (see also chapter 3.3.1.5).
- 6.1.2.2 Balise group REL is optional and can be used to position the train in rear of the level crossing on places where SoM with unknown position is expected to occur.
- 6.1.2.2.1 Note: The interval between position reports is important for achieving an optimised and accurate waiting time. This can be achieved by strategic balise positioning and/or to request position reports at certain occasions by RBC (i.e. by using M_LOC).

6.1.3 Sequence diagram

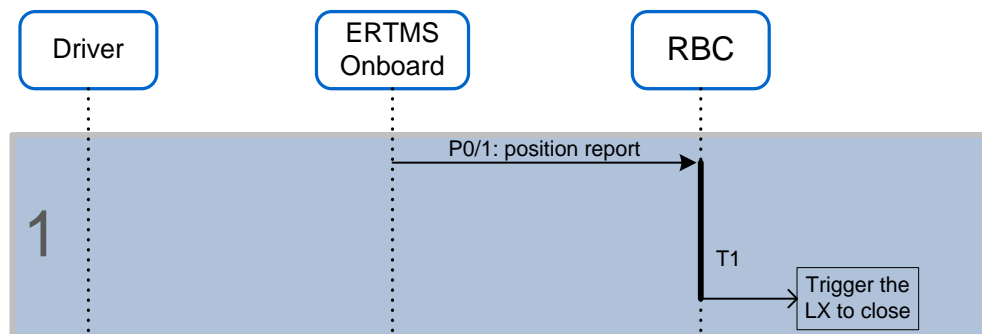


Figure 6: Sequence diagram for step 1

- 6.1.3.1 Before speed and distance information within the position report could be used the on-board timestamp needs to be compared to the RBC clock. This mechanism is described in A.2.4.
- 6.1.3.2 In order for the RBC to know when to trigger the level crossing to close, the speed and position information provided regular by the on-board is used. Together with the information from the train (maximum train speed and position reports), the trackside speed profiles (SSP, TSR) and the fixed LX announcement time, the RBC calculates the moment on which the trigger to activate the LX shall be given. This calculation is repeated at every position report received.
- 6.1.3.3 As soon as the calculated moment is reached, the RBC orders the activation of the LX.

- 6.1.3.4 T1 is the time between moment the RBC received the position report from the on-board and the calculated moment to trigger the activation of the LX.
- 6.1.3.5 In case the level crossing is already activated, e.g. due to a preceding train, the level crossing shall be kept activated or closed until passage of the second train.
- 6.1.3.6 A prerequisite for using speed and position information together with trackside speed profiles is that the conditions to send a Level 2 MA are fulfilled. One of these conditions is that the position of the train is unambiguous, which is not the case if SoM with unknown position is performed in rear of the level crossing. To position the train after a SoM an additional balise group may be needed in certain places (see 5.1.2.2) where SoM is likely to occur.
- 6.1.3.7 To trigger the level crossing for a train not running in FS/OS mode an alternative method is needed, e.g. by a special command from the signaller, by using track circuits or other external equipment. This is project specific.

6.1.4 Alternative solutions

- 6.1.4.1 Chapter 5 describes an alternative LX activation triggered by MA request.
- 6.1.4.2 The triggering of the level crossing can also be based on external equipment, such as track circuits, axle counters or loops in the track.

6.1.5 Degraded situations

- 6.1.5.1 This functional step has the following degraded situations:
- 1) Failure to read the REF balise group
 - 2) Failure to read the REL balise group
 - 3) Loss of radio contact or delayed messages
- 6.1.5.2 The consequence of degraded situation 1) is that the level 2 MA over the level crossing may not be sent (since the BG REF (or any linked balise group) is acting as an LRBG for the MA over the LX). In situation 1 another BG will react as an LRBG (according to 3.6.2.2.2, SUBSET-026 [2]). Then it should be considered that the location accuracy will decrease. This influences the activation moment.
- 6.1.5.3 The consequence of degraded situation 2) is for the recommended solution B that the level crossing will not be triggered to close after a SoM with unknown position in rear of the level crossing. See chapter 6.1.3.7 for methods to mitigate this risk.
- 6.1.5.4 The consequence of degraded situation 3) is that the triggering of the level crossing will not be optimised by the delayed messages.

6.2 Supervision of the level crossing

6.2.1 Basic considerations

- 6.2.1.1 Functional step 2 is about supervising the level crossing. The following issues from chapter 4.2 must be considered in this functional step:
- Loss of level crossing protection (see 4.2.1)
 - Allow level crossing passage at line speed (see 4.2.2)

- Manual cancellation of the route over the level crossing (see 4.2.3)
- Level crossings with short maximum waiting time (see 4.2.7)
- Level crossings located close after each other (see 4.2.14)

6.2.1.2 The recommendation is to use a failsafe level crossing, which is statistically guaranteed closed after activation. If the level crossing could not be activated in the normal way an alternative method is needed, e.g. by a special command from the signaller, by using track circuits or other external equipment. This has the following benefits:

- The level crossing will always be closed before train is passing.

6.2.2 Track layout

TRACK LAYOUT	DISTANCE	DESCRIPTION	PACKET INFORMATION
	N/A	N/A	N/A

Table 6: Track layout for functional step 2

6.2.2.1 There are no specific track layout items.

6.2.3 Sequence diagram

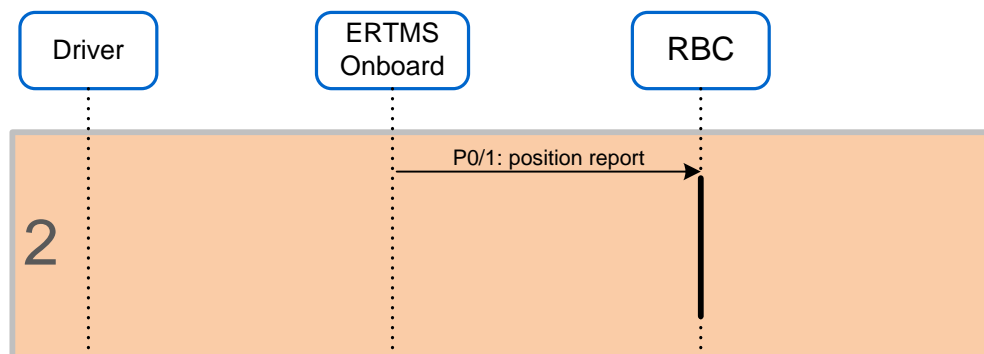


Figure 7: Sequence diagram for step 2

6.2.3.1 Once the LX activation is triggered the failsafe level crossing will be statistically guaranteed closed.

6.2.3.2 In situations where the route over the level crossing is manually cancelled, leading to a shortened MA, the LX activation will be cancelled if assured the train will not pass the level crossing anymore.

6.2.3.3 In order to limit the speed for trains passing the level crossing in SR a balise group in rear of the LX containing a TSR could be used. To make it applicable only in SR the balise group should be marked as linked but not included in the linking information (Baseline 2), or to ignore the specific NID_TSR by RBC (Baseline 3).

6.2.4 Degraded situations

6.2.4.1 This functional step has the following degraded situations:

- 1) Loss of radio contact or delayed messages
- 2) Malfunctioning level crossing equipment

6.2.4.2 The consequence of degraded situation 1) is that the MA cannot be extended which could lead to unacceptable waiting times if the rear end of the train has not yet passed the level crossing.

6.2.4.3 The consequence of degraded situation 2) is that the level crossing is already closed independent of the activation which could lead to unacceptable waiting times.

6.3 Opening the level crossing

6.3.1.1 The same functional step 3 as recommended solution A is used.

Appendix A LX Activation by position reports

A.1 Scope

A.1.1.1 This annex describes the way the LX announcement functionality achieved with ERTMS position reports.

A.1.1.2 The scope is limited to the announcement of the LX.

A.1.1.2.1 Note: The principles described in this annex are equally valid in Baseline 2 and Baseline 3.

A.2 Principle mechanism

A.2.1 Principles

A.2.1.1 The mechanism to trigger the ERTMS based announcement of the LX on ERTMS level 2/3 lines is based on the following principles:

- The ETCS on-board provides speed and position information to the RBC at regular intervals.
- Based on the information from the train (maximum train speed and position reports), the trackside speed profiles (SSP, TSR) and the fixed LX announcement time, the RBC calculates the moment on which the trigger to activate the LX shall be given. This calculation is repeated at every position report received.
- As soon as the calculated moment is reached, the RBC orders the activation of the LX.

A.2.1.2 The start of this LX approach process shall be defined in the RBC early enough to activate of the LX with the related minimum announcement time.

A.2.1.2.1 Note: The start of the LX approach process can be before or after an MA to pass the LX is sent to the train, depending on the local circumstances.

A.2.2 Train Speed

A.2.2.1 The speed profile in the LX approach area (MRSP_RBC) shall be determined by the RBC as the most restrictive parts of V_MAXTRAIN and all (train category specific) trackside speed restrictions (SSP, TSR, etc.). For the purpose of the LX announcement the actual value of the speed profile is taken into account.

A.2.2.2 Compensation for overspeed up to the intervention limit is assumed to be not required. This is a project specific decision.

A.2.2.3 Optional: The actual train speed is reported by the on-board to the RBC in the position report. According to SUBSET-041 [3] this reported train speed has an inaccuracy of about 2%. An error of 2% in the warning time of the LX is acceptable.

A.2.2.3.1 Note: Compensation of this error is assumed not to be required. This is a project specific decision.

A.2.3 Train position

A.2.3.1 The train position is reported by the on-board to the RBC in the position report. According to [2] this reported train position has an inaccuracy of about 5%+5m from the last LRBG. To use this information for a safe announcement of the LX, the inaccuracy of the train position shall be taken into account. For the LX announcement, the max safe front end of the train shall therefore be used, i.e. $D_LRBG + L_DOUBTUNDER$.

A.2.4 Time Stamp

A.2.4.1 In order to use speed and distance information within the position report for LX announcement, the RBC needs to know the time when the position report was sent.

A.2.4.2 The on-board time stamp in the received message is a simple wrap around counter which is not synchronised to the RBC clock. This means that the RBC needs to make an evaluation of the on-board time stamp in the received message compared to the RBC clock.

A.2.4.3 For the use in the LX announcement this needs to be a safe evaluation. Safe means in this context that the evaluated RBC time corresponding to the on-board time stamp shall be earlier than, or equal to, the real time corresponding to the on-board time stamp. The following mechanism, which is illustrated in Figure 8, provides such a safe evaluation:

- The RBC shall send at regular intervals general empty messages (message 24 without any packets) which have to be acknowledged by the on-board ($M_ACK=1$). Note that for the LX functionality it is not an absolute requirement that the message is empty, but the shorter the message, the better the RBC can estimate the time delay related to the communication on-board \leftrightarrow RBC.
- For every acknowledged message 24, the RBC shall determine the offset between the on-board time stamp in the corresponding acknowledgement (message 146) and the internal RBC clock.

$$RBC_offset_ref = TS146_ref - T24_RBC_ref - t_min$$

- Where:
 - RBC_offset_ref is the offset between the on-board clock (used for time stamping) and the internal RBC clock.
 - $T24_RBC_ref$ is the time according to the internal RBC clock at which the message 24 was sent.
 - $TS146_ref$ is the time stamp in the corresponding message 146.
 - t_min is the theoretical minimum delay for the transmission of message 24 to the on-board. For a safe evaluation, this value can be set to 0s (normally it will be in the range 0.5s to 1.0s).
- In principle, the RBC can use this offset to determine the RBC time which corresponds to the time stamp in a position report and subsequently determine the moment to activate the LX. However, due to the drift of the

on-board clock an increase of the offset over time has to be taken into account. To keep the offset as small as possible

- a new offset is calculated for every new message 24/146 combination.

$$\text{RBC_offset_new} = \text{TS146_new} - \text{T24_RBC_new} - t_min$$

- If $\text{RBC_offset_new} < (\text{RBC_offset_ref} + t_drift)$ then RBC_offset_ref shall be set to the value of RBC_offset_new and TS146_ref shall be set to the value of TS146_new , where:

$$t_drift = 0.001 * (\text{TS146_new} - \text{TS146_ref})$$

- The factor 0.001 is the drift of the on-board clock (0.1%) according to SUBSET-041 [3].

A.2.4.3.1 Note: The on-board clock is a counter with a wraparound time of 497 days (see SUBSET-026 [2]). In the exceptional case where $\text{TS146_new} < \text{TS146_ref}$ and the RBC detects that this is due to a wrap around, the wrap around shall be compensated by adding the maximum value of T_TRAIN (excluding the special value, see SUBSET-026 [2]) to TS146_new before making the subtraction of TS146_new and TS146_ref .

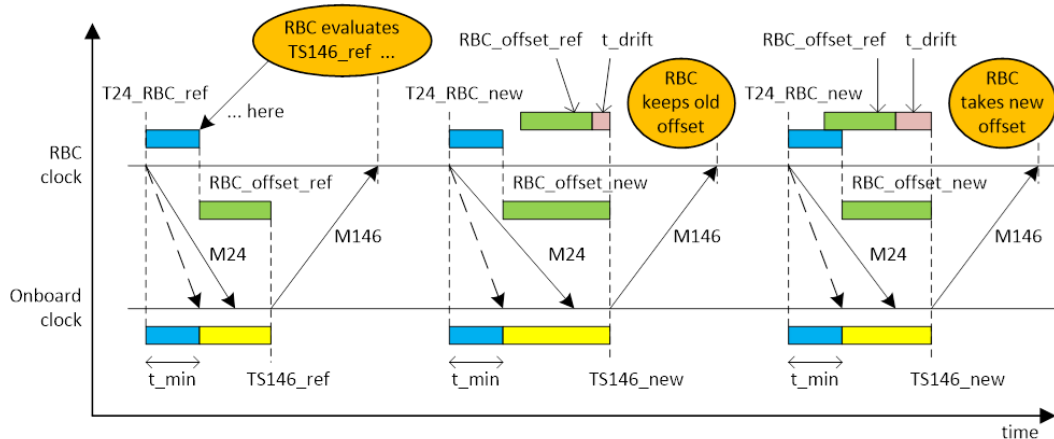


Figure 8: Clock synchronisation

A.2.4.4 With the help of the offset between the RBC clock and the on-board clock, the RBC can determine the RBC time of a position report (message 136).

A.2.4.4.1 Note: There may be various events to trigger a message 136 in the on-board. The exact cause of the position report is not relevant for the LX calculation, but it is assumed that in the LX approach area position reports are sent at regular intervals.

A.2.4.5 The calculation is made as follows, see also Figure 9.

$$\text{TS136_RBC} = \text{TS136} - (\text{RBC_offset_ref} + 0.001 * (\text{TS136} - \text{TS146_ref}))$$

Where:

- TS136_RBC is the evaluated RBC time which corresponds to the on-board time stamp in message 136.
- TS136 is the time stamp in the corresponding message 136.
- TS146_ref is the time stamp in the corresponding message 146.

A.2.4.6 The RBC has now determined the equivalent RBC time which corresponds to the on-board time stamp of the position report.

A.2.4.7 One additional aspect still has to be considered. The moment when the on-board estimates the position of the train front is less than 1s before the position report is sent to the RBC (see SUBSET-041 [3]). This means that the evaluated RBC time, which corresponds to the reported position of the train front, has to be corrected with 1s.

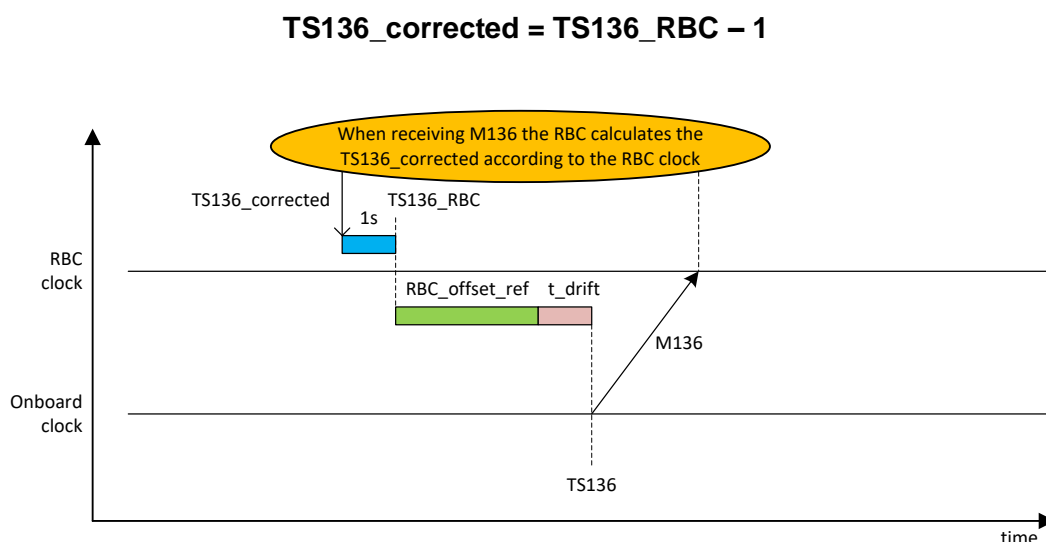


Figure 9: Evaluated RBC time of Position Report

A.2.5 LX announcement

A.2.5.1 The corrected time stamp (TS136_corrected) of the position report shall be used by the RBC as a reference to determine the moment when the activation order has to be sent to the LX.

A.2.5.2 The following calculation, which is illustrated in Figure 10, shall be made.

A.2.5.3 The shortest time t_{travel} in which the max safe front end of the train can cover the distance from the position in the position report to the LX shall be calculated. In a first step a simple calculation is used. The actual train speed is considered to be equal to the speed profile MRSP_RBC in the LX approach area. In other words, the train is assumed to have infinite acceleration and deceleration. This basic calculation is sufficient for standard LX on the open line. For specific situations, optimised calculations may be used. With t_{travel} known, the moment for the order to activate the LX can then be calculated:

$$t_{travel} = (D_{LX} - (D_{LRBG} + L_{DOUBTUNDER})) / MRSP_{RBC}$$

$$T_{order} = TS136_{corrected} + t_{travel} - t_{announcement} - t_{delay}$$

Where:

- t_{travel} is the minimum time interval for the train to reach the LX from the location in the position report.
- MRSP_RBC is the most restrictive part of all relevant trackside speed restrictions and the maximum train speed ($V_{MAXTRAIN}$). Note that for the description of the principle it is assumed that there are no speed steps in the MRSP_RBC.
- T_{order} is the moment when the RBC orders the activation of the LX.
- $t_{announcement}$ is the LX announcement time. This is a fixed time, configured in the RBC, which is dependent on the specific LX.
- t_{delay} is the maximum delay time between the transmission of the activation order by the RBC and the moment the LX receives this order. This is a fixed time, configured in the RBC, which is dependent on the transmission channel between RBC and LX.

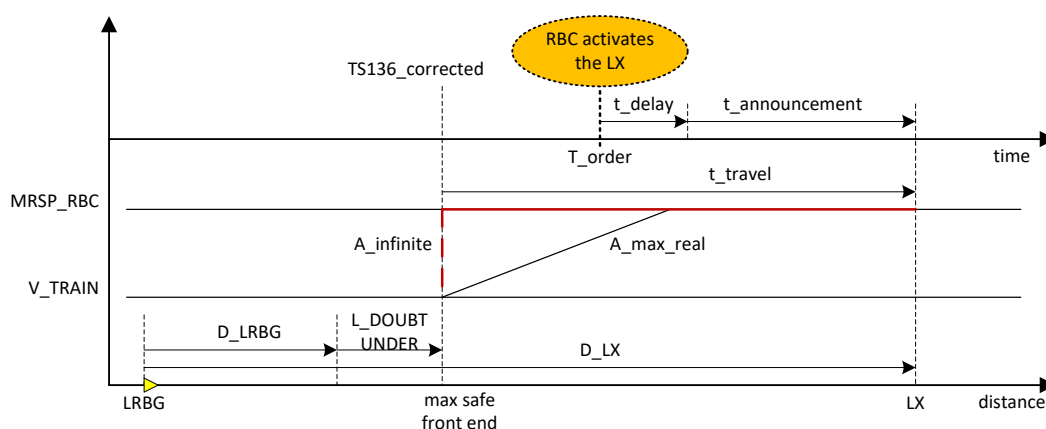


Figure 10: LX activation order

A.2.6 Margin (calculation example)

A.2.6.1 The principle mechanism to calculate the moment that the RBC orders the LX to activate has to take certain inaccuracies and time delays into account. This means that in practice the LX warning time will be longer than the theoretically achievable minimum, even if the train runs at MRSP_RBC. In order to get an impression of the margin between the actual and theoretical LX warning time, an example is given here. This example is illustrated in Figure 11 and is based on the following assumptions:

- $t_{announcement}$ is 20s (absolute minimum requirement for the LX announcement time in the theoretical LX warning time).
- The distance between two balise groups in the LX approach area is not more than 500m.
- $V_{TRAIN} = MRSP_RBC = 140\text{km/h}$.
- The actual front end of the train is assumed to be at the min front end position of the position report (worst case).
- t_{min} can vary in theory between 0 and 1s and in practice between 0.5 and 1s. For the calculation of TS136_RBC it is assumed to be 0s while for the calculation of the margin it is assumed to be 1s (worst case).

- The contribution of t_{drift} is ignored. In principle, this value should be added to the worst-case value of t_{min} . Because t_{min} can vary in practice between 0.5 and 1s (a range of 0.5s) t_{drift} can never become more than 0.5s before RBC_offset_new is taken into account and t_{drift} is reset to zero. The LX warning time is evaluated only in whole seconds, therefore t_{drift} can be ignored.
- t_{delay} can vary between 0 and 1s. For the calculation of T_{order} it is assumed to be 1s, while for the calculation of the margin it is assumed to be 0s which would result in 1s extra for time interval during which the LX is activated (worst case).

A.2.6.2 The worst-case margin between the theoretical LX warning time and the realistic announcement in this example is calculated as follows:

$$\begin{aligned}
 t_{\text{margin}} &= (\text{L_DOUBTUNDER} + \text{L_DOUBTOVER}) / (\text{V_TRAIN} / 3.6) + t_{\text{min}} \\
 &\quad (\text{worst case}) + t_{\text{delay}} (\text{worst case}) = 2 \cdot (5\text{m} + 0.05 \cdot 500\text{m} + 2\text{m}) / \\
 &\quad (140 / 3.6) + 1 + 1 = 1.65 + 1 + 1 \\
 &= 3.65\text{s}
 \end{aligned}$$

A.2.6.3 Figure 11 shows the probability of the realistic announcement time.

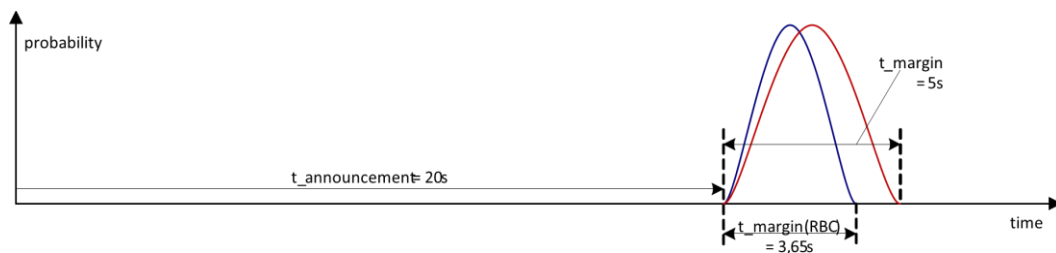


Figure 11: Realistic announcement time probability