No barriers for level crossings with ERTMS

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SUMMARY

The best level crossing is no level crossing. Although the goal is to eliminate the level crossings this may not always feasible or affordable. This paper addresses a method where ERTMS allows to innovate the level crossing protection to take away some barriers.

Currently, trains are announced with trackside train detection when approaching a level crossing. This can cause considerable variations in closure times (i.e. the train speeds vary) and issues with temporally loss of shunt. With the train position and speed information obtained by ERTMS, a more constant warning time (CWT) can be achieved without the use of track side train detection. The possibility of updating the movement authority allows to reduce long the closing times, e.g. in case of unpredictable delays in dwelling. The specific ERTMS LX DMI function to instruct the driver to cautiously approach the level crossing improves operation degraded situations. These functions allow to take away barriers to improve the performance, safety, reliability and to reduce the costs for level crossings with ERTMS.

1 INTRODUCTION

In the conventional signalling systems, trackside train detection is used to close the level crossing, if the train arrives in the depicted announcement zone. When analyzing the ERTMS Hybrid Level 3 concept [4] it became clear that the reduction in trackside train detection equipment will be limited with the current number of level crossings for specific lines. As the ERTMS onboard system in the train frequently reports it position and speed, it seemed a logical approach to use this information. However, can we rely on this information to provide a safe protection of the level crossings? I.e. how to deal with communication delays, lost messages, position inaccuracies, etc.? After a detailed study on the ERTMS reported position, speed, time and communication delay, a safe method was found [1]. This method addresses how, with a simple calculation based on the received train information, a reliable prediction on the earliest time the train can reach the level crossing can be achieved. This calculation is the basis for an alternative level crossing announcement.

As discussed in an earlier published article [2], the type of level crossing protection concepts varies. In the Netherlands the announcement time can be relatively short. This because the closure of the level crossing is considered to be fail-safe. This deviates from some countries where the barriers must be reported as closed before the train is authorized across the level crossing. Both approaches for level crossing announcements are described in detail in the ERTMS level crossing announcement engineering guideline [3]. This paper addresses the activation method for protected level crossing in the Netherlands.

2 PRINCIPLE MECHANISM

2.1 Principles for level crossing activation with ERTMS

The mechanism to trigger the ERTMS based announcement of the level crossing (LX) on ERTMS level 2/3 lines is based on the following principle depicted in Figure 1. This mechanism consists out of the following steps and starts before authorizing a train across the level crossing:

1. Calculate the earliest possible arrival time of the train on reported position and speed (T_acc+T_SSP).
2. Set level crossing closing time (T_Order_LX) based on the required announcement time (T_LX).
3. Repeat this calculation on new (train position) information.

Ad 2) When the required LX announcement time is not fulfilled, the movement authority is delayed until this condition is fulfilled. This only occurs when the train is already close to the level crossing when the route is set.

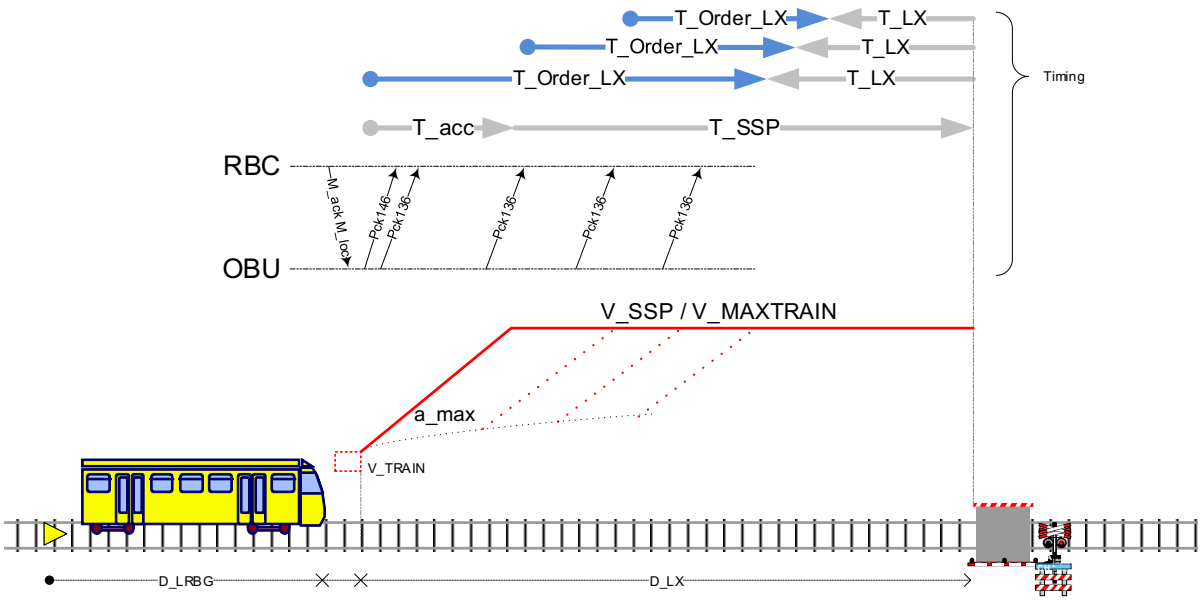

Figure 1: LX ERTMS announcement principle

2.2 Speed profile

The speed profile in the LX approach area is determined by the maximum allowed train speed and all train specific trackside speed restrictions. Compensation for overspeed up to the intervention limit is possible but not done in the current situation for level crossings in the Netherlands [6].

2.3 Train position

The train position is reported by the ERTMS onboard to the trackside safety system (the RBC) in the position report. To use this information for a safe announcement of the level crossing, the inaccuracy of the train position shall be considered. For the LX announcement calculation, a safe assumption on the possible error in the reported position is taken into account (i.e. the maximum safe front end of the train).

2.4 Time stamp

To be able to use the speed and distance information in the position report for the LX announcement, the trackside system needs to know the time at which the position report was sent. The onboard time stamp in the received message is a simple wrap around counter (T_TRAIN) which is not synchronized to the trackside clock. To have a safe evaluation, the trackside sends a message on regular intervals to be acknowledged by the onboard. This allows the trackside to use a safe evaluation of the onboard time stamp. This mechanism is detailed in the ERTMS LX guideline [3].

2.5 Actual train speed and acceleration

The actual train speed is reported in the position report. If a maximum acceleration can be determined, this speed can be used to optimize the calculation of LX activation timer. For the Netherlands, the maximum allowed acceleration is specified in existing Dutch level crossing engineering rules [6]. If no maximum acceleration can be determined, the maximum allowed speed according to the speed profile (2.2) is used. Note the possible acceleration can also be restricted by temporally limiting the speed towards the level crossing.

According to the ERTMS performance specification [5], this reported train speed has an inaccuracy of about 2%. Compensation of this error can be requested by an ERTMS national value. This is not required in the Netherlands.

The requirements of the age of the train speed information as reported in the position report was originally not specified, but is set to a maximum of 1 second in the recent ERTMS specification [5].

2.6 Safety margin

The calculation for the level crossing protection must take inaccuracies and time delays into account. As the method considers a safe position as well as communication delays, the LX warning time will be longer than the theoretically achievable minimum. To get an impression of the margin between the actual and theoretical LX warning time, an example is given. This example is illustrated in Figure 2 and is based on the following assumptions.

- The minimum requirement for the LX announcement time in the Netherlands [6] i.e. 20 seconds.
- Allowed speed = 140 km/h (normal line speed in the Netherlands).
- The distance between two balise groups in the LX approach area is not more than 500 meters.
- The maximum error of the reported position (see 2.3 and [5]). I.e. 2 * (5 m + 5%*500 m) = 60 meters.
- The maximum age of the position report is 1 second (see [5]).
- The mechanism regarding communication and synchronizing trackside and onboard clocks, as detailed in [3], limits this inaccuracy to 1 second.

The possible margin in the LX announcement in this example is calculated as follows: 60 m / 140 km/h + 1 second + 1 second = 3,6 seconds. According to [6], the currently allowed margin for level crossing announcement based on trackside train detection in the Netherlands is 5s. It shows that the activation of the level crossing by ERTMS is at least as good as the activation by trackside train detection.

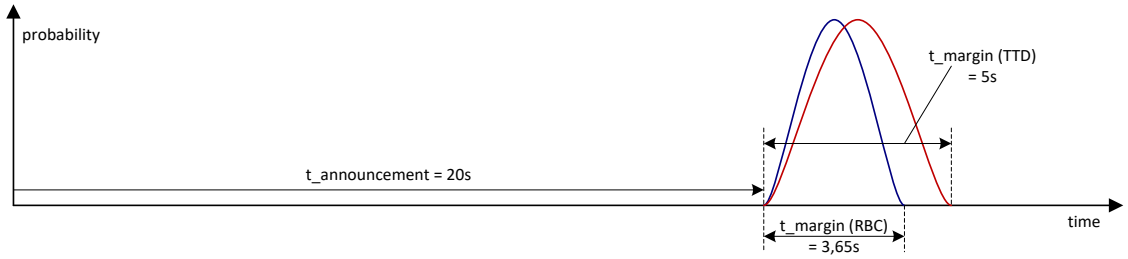

Figure 2: Realistic announcement time probability

3 LEVEL CROSSING SCENARIO'S

3.1 Advantages of the LX announcement by ERTMS

The described LX announcement principle for ERTMS can be used for different situations. In this chapter the following situations will be discussed:

1. Level crossings on the open track
2. Level crossings beyond a platform where the train stops

3.2 Level crossing at the open line

The simplest situation is a level crossing on the open track where trains normally approach the level crossing with line speed. For this situation, the LX announcement by ERTMS would not reduce the announcement time. But as ERTMS has additional train information, a more constant warning time can be realized if the maximum allowed train speed is lower than the line speed.

For example, see Figure 3, the line speed is 140 km/h and the maximum allowed speed of a cargo train is 80 kmh. For an announcement time of 25 second the fixed announcement distance would be (140 km/h * 25 seconds=) 972 meter (exclusive margins). For an 80 km/h train, when trackside train detection is used, the announcement time would be (972m / 80 km/h=) 44 seconds. This is an increase of approx. 19 seconds compared to the 25 seconds. This increase of the announcement time is avoided with the ERTMS LX announcement calculation where the actual maximum allowed train speed is used.

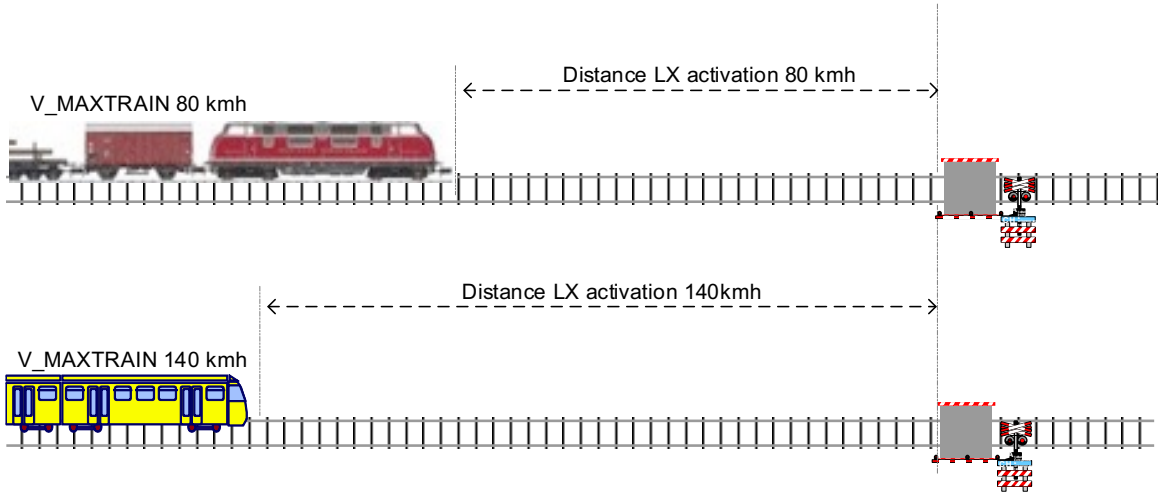

Figure 3: Speed depended LX announcement

As another example, a train running at a low speed is taken. In this case the ERTMS LX announcement calculation also provides a reduced waiting time. However, the possible gain is reduced, because an acceleration must be assumed. For example, for a train running at 40 km/h and a line speed of 140 km/h, the gain would be approx. 10 seconds for an assumed acceleration of 1 m/s^2. This gain would be reduced to 5 seconds if the assumed acceleration of 2 m/s^2 is considered. Alternatively, for situations where the train drives in degraded situations with a low speed the announcement time can be reduced considerably by limiting the allowed speed (i.e. SSP) for the train towards the level crossing. If for instance the train is only running at 40 km/h and the allowed speed for this situation is reduced up to the level crossing. The increase for the LX announcement time with a trackside side train detection up to 87 seconds is avoided with the ERTMS LX announcement calculation. But as this is not a nominal situation this is not considered for the Netherlands.

3.3 Level crossing in advance of a platform

When the level crossing is in advance of a platform, special precautions are considered to avoid that the level crossing is closed during the approach, stop, dwelling and departure of the train. This is referred in the Netherlands as the Stop/Door (Stop and Continue) functionality. In Figure 4 the two level crossing's (LX1, LX2) in advance of a platform and several scenario steps are depicted.

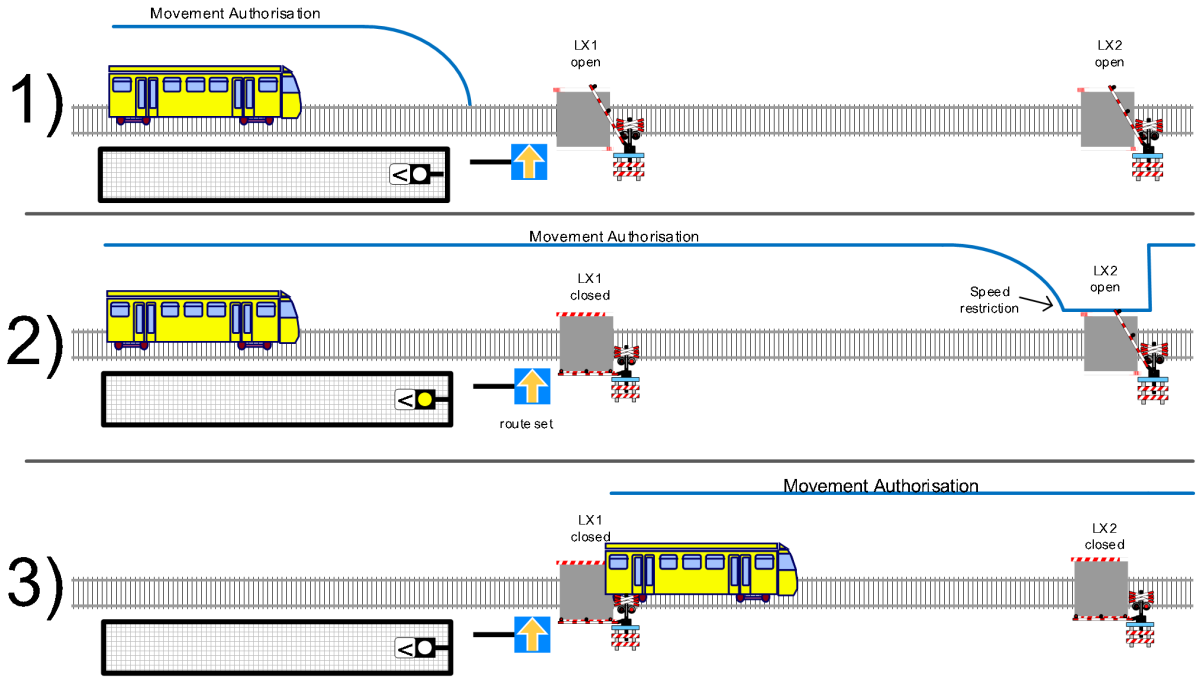

Figure 4: Level crossings in advance of a platform

The three scenario's steps depicted in Figure 4 are detailed below:

1) The train has a movement authority (MA) up to the marker board.
    a. The train stops at the platform. When the train is stopped, this is reported to the trackside.
    b. The trackside starts the dwelling timer. When the planned departure time and a minimal dwelling time is reached, the trackside sets the following route (across both LX's). LX1 is commanded to close and the trackside delays the MA until the LX1 is closed long enough (see ad 2 in chapter 2.1).
2) The train receives the MA across both level crossings, when the LX1 is safely protected (i.e. closed long enough).
    a. Note that the actual train position is taken into account in the calculation to assure that the LX1 is safely closed, e.g. delay in issuing the MA is shorter if the train is located further from the LX1.
    b. Depending on the departure procedure, the train can depart directly or the passenger departure process is started.
    c. Although the MA is issued and the LX2 can be relatively close (200-800 meter), the LX2 is still open. LX2 will be commanded to close when the first position report is received, which reports that the train has departed.
    d. As this position report can be delayed or lost, the MA has a (temporally) allowed speed of 10 km/h at LX2. LX2 will also be closed when multiple position reports are missed (i.e. two periodic position report cycles, 10 sec). This safe reaction assures that the train cannot reach the LX2 while not closed long enough. In nominal situations this speed restriction is lifted before the train is hindered.
    e. An alternative protection would be to issue the MA only up to the LX2 and not across the LX2. However, the drivers explained that they would not depart on a short MA and a dead lock could be created.
3) The train has departed and is approaching LX2.
    a. The calculation to check if LX2 will be closed long enough before the train can arrive at the LX2 (see chapter 2.1) is performed on every position report. If this condition is fulfilled, the lowered speed at the LX2 is removed and the train can continue its journey.
    b. The (temporally) lowered speed at the LX2 also prevents that a very fast accelerating train can arrive at the LX2 too soon, as this train would run into the brake curve of the lowered speed. For a normal departure this speed reduction is removed before the driver would run into the brake curve (i.e. would reach the indication curve). This allows to close the level crossing on detected departure for level crossing relatively close to the platform (i.e. 100m).

The additional information, when and where the train has stopped, allows a more accurate setting of the departure route and thus a minimization of the closing time for a level crossing directly in rear of the platform (LX1). The actual information on the depart, as used in LX2, prevents that level crossing will be closed too long when departure is delayed because of an extended dwelling process. For this enhanced function no additional hardware and/or train detection is required. The use of these enhanced LX announcements requires a data configuration in the trackside systems.

4 DEGRADED SITUATIONS

4.1 Level crossing reported in failure

In the Netherlands, if a level crossing is closed too long, i.e. typically more than 5 minutes, the level crossing is considered as insufficiently protected. This because the risk of people 'trespassing' increases. A special procedure is applicable in this situation for the driver in order to approach the level crossing cautiously. This procedure is triggered by the signaller and requires a vocal instruction for the driver. In a year this procedure is used more than 20.000 times. This procedure will be replaced by an ERTMS 'packet 88'. This results in a warning on the driver machine interface (DMI) with a special LX symbol and the speed of 10 km/h is enforced across the level crossing.

Figure 5: LX symbol

Because this LX symbol is only shown when the train is running with a movement authority (MA), the driver is instructed to always approach the level crossing cautiously when running without an MA (e.g. mode Staff Responsible). To close the level crossing when running without an MA, the middle section will be equipped with train detection. A special LX panel will be used in rear of the level crossing to indicate the start of the middle section of the level crossing. The middle section of the level crossing will also provide an optimal timing, to open the level crossing, when the train has left the level crossing.

4.2 Lost communication and route revocation

The LX announcement with ERTMS also allows to avoid that, if a train is stopped in the approach area, a level crossing will remain closed for a long time. For instance, when a train was reported to approach the level crossing but has come to a standstill in rear of the level crossing. In such a situation train reports that the movement authority will not be used (i.e. the desk is closed and the train performs an "end of mission"), it is assured that the train will not use the MA across the level crossing and the level crossing can be opened. This also applies when it can be assured by other means that the train cannot use the MA, e.g. when the MA is revoked and the train stop is confirmed or after a time-out after losing the connection with the trackside.

5 DIFFERENCE IN LX ANNOUNCEMENTS

As mentioned in the introduction, in chapter 1, the types of level crossing protection concepts vary. For the Netherlands, a safe closure of the level crossing is assumed, i.e. when not commanded to remain open, the level crossing will close (i.e. fail-safe operation). Together with the safe detection when a train is approaching the level crossing and an additional level crossing failure procedure, a short waiting time can be achieved. The ERTMS engineering guideline [3] also describes a method where the barriers must be closed before the train is authorized across the level crossing. The difference in distance for the LX announcement for both methods is illustrated in Figure 6. In the bottom situation the barriers must be closed before the train is authorized across the level crossing. The top situation illustrates the method used in the Netherlands, allowing much shorter waiting times.

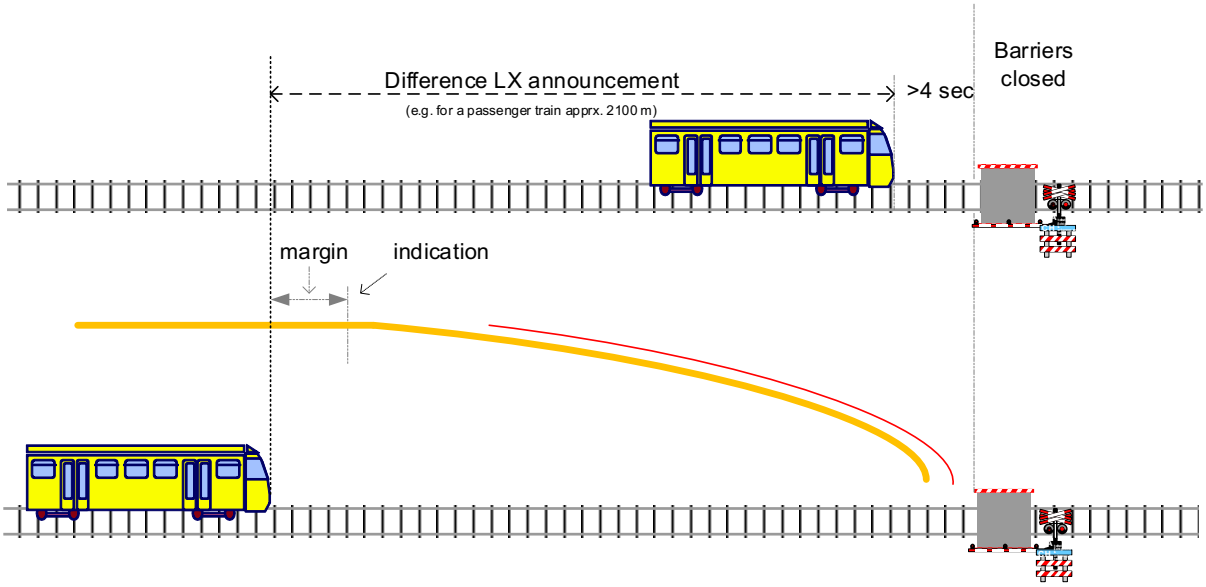

Figure 6: Different LX announcement concepts

6 CONCLUSION

The ERTMS train position and speed information provides a more constant warning time, by means of a simple algorithm. This of ERTMS train information allows for the reduction of the waiting time for the level crossing users. This combined with the possibility of continuing updating the movement authority provides for a further reduction of long closing times, e.g. in case of unpredictable delays in dwelling. The LX announcement with ERTMS requires no trackside train detection which results in an improved reliability and reduction of costs. The ERTMS LX function on the DMI, which instructs the driver to approach the level crossing cautiously, improves the operation in degraded situations. Hence, ERTMS takes away barriers to improve the performance, safety and reliability for protecting level crossings and reduces the cost for the required train side train detection equipment.

7 REFERENCES

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