RCA

Reference CCS Architecture

An initiative of the ERTMS users group and the EULYNX consortium

Position Paper Level Crossings

Document ID: RCA.Doc.79

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1 Preamble

1.1 Release Information

Basic document information:

RCA-Document Number: RCA.Doc.79

Document Name: Position Paper Level Crossings

Cenelec Phase: N/A

Version: 1.0

Approval date: 2022-09-30

1.2 Imprint

Publisher:

RCA (an initiative of the ERTMS Users Group and EULYNX Consortium)

Support and Feedback:

For feedback, or if you have trouble accessing the material, please contact rca@eulynx.eu.

1.3 Disclaimer

No disclaimer defined.

1.4 Purpose

See chapter 'Introduction'.

2 Version history

Version	Date	Author	Description
1.0	2022-09-30	Jonas Fiori, Philipp Nicolaus, Frank Schiffmann, Dr. Eric Schöne, Xu Zhang	First published version for RCA BL1 R0

3 Introduction

3.1 Type of document

This document is a position paper on potential handling of Level Crossing in RCA context. The position is focused on handling of Level Crossing by the Advanced Protection System (APS).

Disclaimer	A detailed coordination on handling of Level Crossing with further parts of RCA like the Plan Execution (PE) and interfaced Traffic Management System (TMS) does not take place yet.

3.2 References

Please refer to the references listed in /RCA.Doc.52/ APS Detailled concepts overview and /RCA.Doc.6/ RCA documentation plan.

3.3 Terms and abbreviations

Please refer to the abbreviations listed in /RCA.Doc.52/ *APS Detailled concepts overview* and /RCA.Doc.14/ *RCA terms and abstract concepts*.

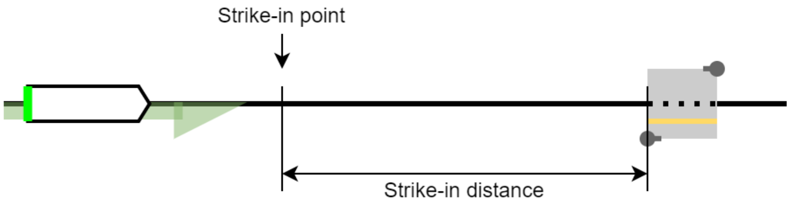
Specific terms and abbreviations for handling the Level Crossing topic within the context of this position paper are listed in the table below. They are strongly based on present applications from which considerations for the potential handling of APS were derived and shall therefore be treated as interim. It is expected that as new stepwise architectural, functional and technical solutions are incorporated by RCA, new terms will be introduced to avoid misinterpretation towards present applications.

Term	Definition
APS LX classes	Depending on the specific Level Crossing Protection Facility functionality, APS categorises the Level Crossing into the following APS LX classes based on the required Protection State of LX: • (a) the Protection State of LX is 'closed' or 'closed and no detected obstacle between the barriers' • (b) the Protection State of LX is 'activated' • (c) the Protection State of LX is 'activation is feasible'
Level Crossing	A Level Crossing is an intersection where a railway line crosses a path (e.g. a road) at the same level.
Level Crossing is 'protected'	This term is used to describe the view point from the signalling system. The Level Crossing is protected, if the required Protection State of LX suitable for the specific installation is reached.

Term	Definition
Level Crossing Protection Facility	The Level Crossing Protection Facility is present at Level Crossings not falling into the category of Open Level Crossing. The Level Crossing Protection Facility is the system that provides the required site-specific warning and protection for the level crossing users. It includes all the standing equipment used to protect both the railway and the level crossing users from a collision. A variety of solutions are currently applied combining, as required, the installation of (list non-exaustive): • barriers to fully or partially block the width of a road, • obstacle-detectors to assure the clearance of the crossing area, • road signals to give advance warning to approaching road traffic, • interfaced road traffic lights to regulate approaching traffic at crossroads. Note: The abbreviation LCPF is used in EULYNX documentation.
Level Crossing Users	This includes all potential users crossing the rail, like motorists, pedestrians, cyclists, wheelchair users etc.
Open Level Crossing	A Level Crossing without any Level Crossing Protection Facility is named Open Level Crossing. Priority of rail against road traffic can be shown by fixed road traffic signs.

Protection State of LX	The P rotection State of LX describes the different grades of securing from view point of the Level Crossing Protection Facility. Those are:
	• not protected (initial state);
	• Protection State, represented with the following states:
	  • activation is feasible;
	  • activated;
	  • closed;
	  • closed and no obstacle between the barriers.

Term	Definition
Protection State of LX 'not protected'	This term is used based on a technical focus for issuing unrestricted authorities for rail movements. A Level Crossing is in Protection State 'not protected', if • the activation has not started; • the activation has failed; • the Level Crossing Protection Facility must be treated as defective. *Note: This leads in terms of ETCS to the operation according TSI OPE Appendix B Rule 7. It is indicated by a symbol on the ETCS DMI or by a text message in old ETCS applications.*
Protection State of LX 'activation is feasible'	The Level Crossing Protection Facility has checked at run-time that all requirements are fulfilled for activation.
Protection State of LX 'activated'	The Level Crossing Protection Facility has checked, that the activation process is initiated and all mandatory tasks specified for the specific system are performed correctly e.g. switch on of Level Crossing user signals. Several task, e.g. lowering barriers can be taken on later stage.
Protection State of LX 'closed'	The Level Crossing Protection Facility is fully protected according to the specific equipment of the Level Crossing, e.g. barriers are lowered.
Protection State of LX 'closed and no obstacle between the barriers'	The conditions for Level Crossing in Protection State of LX 'closed' are fullfilled and additionally no obstacles are detected between the barriers. *Note: this applies only, if the obstacle detection is associated towards the Level Crossing Protection Facility. Independent solution for check outside of this functionality can be present in addition.*
Off-time	The Off-time (*LX Protection Facility operation time*) describes the time span while Level Crossing users are not allowed to cross the Level Crossing. The time consists of a warning time (e.g. the Level Crossing road signals shows a restricted aspect), the time for the barriers closure (if present) and the obstacle detection operation (if present), additional safety margins (if applicable), the time required for the train to pass clear of the Level Crossing up to the triggering of the level crossing deactivation, and the time needed for the opening of barriers (if present). *Note: pre-warning where Level Crossing user is allowed to pass, is not part of this time.*

Term	Definition
Securing time	The Securing time is the time span from the triggering of Level Crossing Protection Facility up to obtaining the required Protection State for the LX. This is level crossing type specific. The Securing time is part of the Off-time and only includes the time segments of the Level Crossing Protection Facility. It does not include the time segments of other parties which are involved into the activation process (e.g. functions of route protection). The securing time is part of the engineering data of the Level Crossing and must be known for optimised activation. *Note: this time can be fixed - based on the worst-case conditions - or it can be calculated on runtime, depending on current data of the operating state and the characteristics of the specific movement permission foreseen to pass the Level Crossing. Plan Execution (PE) must know this specific time per installation.*
Strike-in distance	The Strike-in distance is the distance between the Level Crossing and the latest point (Strike-in point) in which the Level Crossing Protection Facility must be activated not to restrict the foreseen railway operation movement. It is based on the Securing time for the specific LX or the specific movement. *Note: the location cannot be derived directly by the Securing time. Thus, it is first a theoretical Strike-in point forming the Strike-in distance. The method of activation and inaccuracies of the specific data must be considered. By consideration these facts, a specific window is present, where the activation shall be started. This related windows must consider, that the activation is not to early (to long Off-time) but also not to late (after the theorectival Strike-in point).* 
Strike-in time	The Strike-in time is based on the Strike-in distance and represents the running time on this specific distance. It can be mapped to the fastest possible movements on line speed, indicating the shortest possible Strike-in time or the specific Strike-in time for a certain movement considering all restrictions.

The following abbreviations are used:

Abbreviation	Term
LX	Level Crossing, abbreviation is used referring to functions and ETCS
OC	Object Controller as defined by EULYNX, interfacing switchable field elements towards a signalling system
ATO	Automatic Train Operation

Abbreviation	Term
GoA	Grade of Automation

3.4 Scope

The scope of this position paper is an initial overall consideration about how to integrate Level Crossings in RCA. The first conceptional ideas are written down and generic requirements on RCA are derived.

This document shall serve as a base for the coordination inside RCA and the system pillar, to progress with the integration of Level Crossings. Because the topic is large and complex, this **position paper** is used to explain the needs for further detailing of the requirements to be adopted by RCA development. It is a first initiative to incite stakeholders to provide feedback.

For enabling a stepwise detailing, the document covers the following:

- a description of embedding in RCA context
- a top-down breakdown of fields of investigation,
- the relationship to current applications,
- the definition of LX (supervision) types for better handling of the current LX solutions and the potential needs for APS on this matter,
- the mentioning of main operational situations and/or scenarios including a look over degraded operation,
- the elaboration and laying of possible and imaginable approaches down, based on the situations/scenarios including variants where assumed sensible for the current conceptional state,
- an intermediate check of the argumentation results based on the abstraction of switchable field elements by the use of Drive Protection Section (DPS) as named in /RCA.Doc.61/,
- a proposed solution approach.

This paper focuses on the handling of Level Crossings inside APS during normal operation. Further borders of consideration can be found in **delimitations**.

3.5 Embedding of Level Crossing in RCA context

3.5.1 Targets in RCA

For the core formulation of the existing Advanced Protection System (APS), Plan Execution (PE) and the Map Data Management (MAP) concepts, the main targets were derived as formulation of business strategy, targets and a problem definition (see /RCA.Doc.50/). A detailed view on specific objectives can be found in /RCA.Doc.53/.

Based on these, the RCA main targets for the handling of Level Crossing (LX) in RCA can be highlighted below:

- the implementing of LX interfaces within the APS
- the interfacing of Level Crossing Protection Facilities by usage of interface specifications developed, published and maintained by EULYNX
- a clear split between safety level and Railway Operation by implementation of LX - a break from the current mixture concepts in the interlocking world

- the reduction of trackside asset and costs also in terms of LX
- the harmonisation of operations by standardisation

3.5.2 Challenges of integrating LX in RCA

When dealing with multifaceted systems like Level Crossings, it is necessary to be aware of some important characteristics. Four major aspects are highlighted here for consideration:

- many legacy applications with different solutions: a high number of Level Crossing Protection Facilities including a wide variety of different types are present in the many networks of the European Rail system,
- the absence of an European-wide replacement plan of Level Crossing Protection Facilities by brigdes leads to the need of integration of many installations within the rollout of a new CCS system on existing lines,
- a mixture of operational and safety functions is present in the interlocking and as well in the Level Crossing Protection Facilities based on historical stepwise development: no clear functionally segregated architecture is today present in CCS,
- an alignment between stakeholders (both from road and rail) is always required to address technical and ergonomic concerns in order to achieve tolerable risk levels

3.5.3 Constraints for implementing LX in RCA Context

The following conditions - based on RCA target picture and on the current state of play of Level Crossing systems, must be taken into consideration when approaching the integration of level crossings into the RCA solution:

- RCA uses the current approach in EULYNX (see /RCA.Doc.50/ architectural environment) as base for integration of Level Crossing Protection Facilities;
- RCA must consider that the current approach in EULYNX does not cover the optimised handling of LX for lines with radio-based ETCS. A stepwise progression detailing this matter in EULYNX has just started and coordination is needed between these workstreams;
- RCA must, in addition, provide for radio-based ETCS handling level "R" with "moving block", which will require an additional need of coordination with further initiatives;
- RCA focuses on a target picture that enables highly automated operation up to GoA 4, thus different situations compared to driver-based operation must be considered by RCA and other initiatives, including considerations such as the impact on external stakeholders (e.g. Level Crossing users);
- RCA focuses on a centralised data handling with less data in specific installations, thus Engineering Data shall be converted towards a RCA compatible format and stored in MAP Data. MAP shall serve for further specific data locations of the specific application as central data base for APS and for PE;
- RCA involves abstraction principles and geometric properties that can be used to enable generic rule sets; these switchable field elements must be represented in topology data (see /RCA.Doc.51/ core principle 1);
- MAP data update nearly during 'runtime' must be possible for short interruption times to implement changes in data;

- APS uses a strong binding between MP and MA due to combination of route securing, signalling and train control;
- RCA must ensure the operation of a system with no loss of safety or operability. Furthermore, to be attractive, it shall strive to derive general improvements, e.g. optimised shorter off times could result in trespass risk reduction;
- APS shall enable an efficient tool-box for interfacing a variety of interface-compatible Level Crossing Protection Facilities, including new types of devices not yet present;
- RCA must allow the change of the current philosophies of protecting a specific LX by usage of the tool-box of APS and demonstrate integration methods including adapter solutions interfacing various types of installations;
- RCA must respect in system development the presence of different approaches concerning safety vs. short closing times in the various countries as a barrier for full standardisation. This implies the potential implementation of customer-specific and country-specific configurable business parameters.

3.6 Delimitations

Open Level Crossings are not considered in this position paper in detail. There is only a short lookout at the end.

This paper focus only on Level Crossings that can be integrated and supervised in a signalling system - i.e. those containing Level Crossing Protection Facilities and the needed interface. To the same extent therefore no independent Level Crossing Protection Facilities with own sensors, signals and train control system are in scope, also. Some information on Open Level Crossing are documented, too.

According to the /TSI OPE/ there are three major categories for operational modes:

- Normal operation
- Degraded operation
- Handling of emergency situations

This document focusses currently on normal operation with some statements on potential integration for degraded operation.

4 Problem description with current solution

4.1 Current solution

Concerning the protection, there are two types of Level Crossings.

- Open Level Crossing

  Open Level Crossings are often marked by road signs, especially the St. Andrew's crosses (in some cases, e. g. pedestrian crossings, there is no general need of road signs). A clear view between approaching trains and Level Crossing users must be ensured, so that the Level Crossing user can make the clear decision whether or not it will be safe to pass the Level Crossing. For the direction from train towards the Level Crossing user, there is in some cases no demand for having a clear view, by meaning that train drivers can react and stop in front of the level crossing in case the level crossings are not fully cleared. But a good view from the train driver towards the level crossing can reduce any risks of collision. In certain cases, trains must emit acoustic signals when approaching open crossings as a mitigation against the lack of optimum visibility or as an additional measure to sufficient visibilty to increase the safety at Open Level Crossing.

- Level Crossing with Level Crossing Protection Facilities

  These Level Crossings types have diverse technical solutions to mitigate a number of safety hazards. Installations include in most cases for example signals and barriers.

The Level Crossings with Level Crossing Protection Facilities may be activated and controlled in one of the following three ways:

- Activation by interlocking

  The activation is triggered by interlocking. Therefore the Level Crossing is integrated in or connected to the interlocking. The trigger can be for example the setting of a route. In this case, the Level Crossing is usually interlocked with protecting signals. The correct functional behaviour of the Level Crossing is checked by the interlocking at a certain point of time before authorising the movement, and/or on a regular basis, depending on the application.

- Activation by train

  The activation is triggered automatically by the train, as it passes trackside devices (e.g. rail contacts, track circuits) placed on the approach of the Level Crossing for activation. Same situation applies if activation is used by considering additional information from train number subscribing system or further train control systems like the RBC in terms of deriving the optimised activation location. This method can be used by stand-alone Level

Crossings, where the control is independent from the interlocking or by Level Crossing connected with an Interlocking.

- Activation by operator

  Level Crossing can be activated manually by a local Level Crossing operator or remotely by a operator in a control centre. The operator could be also the train driver, using devices like push-buttons or infrared transmitters.

The kind of activation and controlling are not the only variants a specific Level Crossing can be classified by. For supervision and signalling different possibilities are present and named as summary:

- Level Crossing supervised/signalled by main signals or shunting signals
- Level Crossing supervised/signalled by own supervision signals in braking distance
- Level Crossing supervised/signalled by train control equipment, specific case interfaces towards ETCS-radio based installation
- Level Crossing supervised by knowledge of correct health state, error disclosure or monitoring by operator (without any signalling)

Note: Concerning the handling of time spans, several additional time spans to the Off-time and securing time exists. These can be times between two cycles of activation or time needed for activation of specific road signals of a road signalling unit as a kind of pre-information towards the Level Crossing user. These are special issue to handle on a later stage on development and standardisation phase of RCA.

4.2 Problems with current solution

Large level crossing Off-time increases the probability that a level crossing user crosses a closed Level Crossing. Depending on national regulations, there might be a maximum Off-time defined. An issue of current solution and future applications is the conflict between efforts for ensuring small Off-times and the definition of an acceptable risk target for trespassing. This is not only a technical issue, but also an aspect with reference to human actors. Therefore, the optimisation of Off-times (through the optimal handling of strike-in times) combined with the reduction of equipment, have been the major work items for Level Crossings in the past and will continue to be in the future.

Current solutions involving protecting signals for rail traffic require the level crossings to be secured in time before trains reach the sighting distance of the least restricted aspect of these signals sequence, considerably hindering the operational capacity of the line. Furthermore, the current application does not offer a wide set of possibilities, for enabling degraded and emergency situations of a safe and, in the same instance, sufficient operational quality which hinders an efficient operation. In addition, most overlay ETCS installation does not optimise the present situation significantly.

Finally, a wide field of different installations with complex functions within interfaced interlocking exists. The consequences are high efforts for operation, maintenance and upgrades to be performed. In a stepwise evolution of the rail system, this hinders real optimisation and does not lead to real standard applications by in operation on acceptable cost level.

5 Handling of Level Crossings in RCA

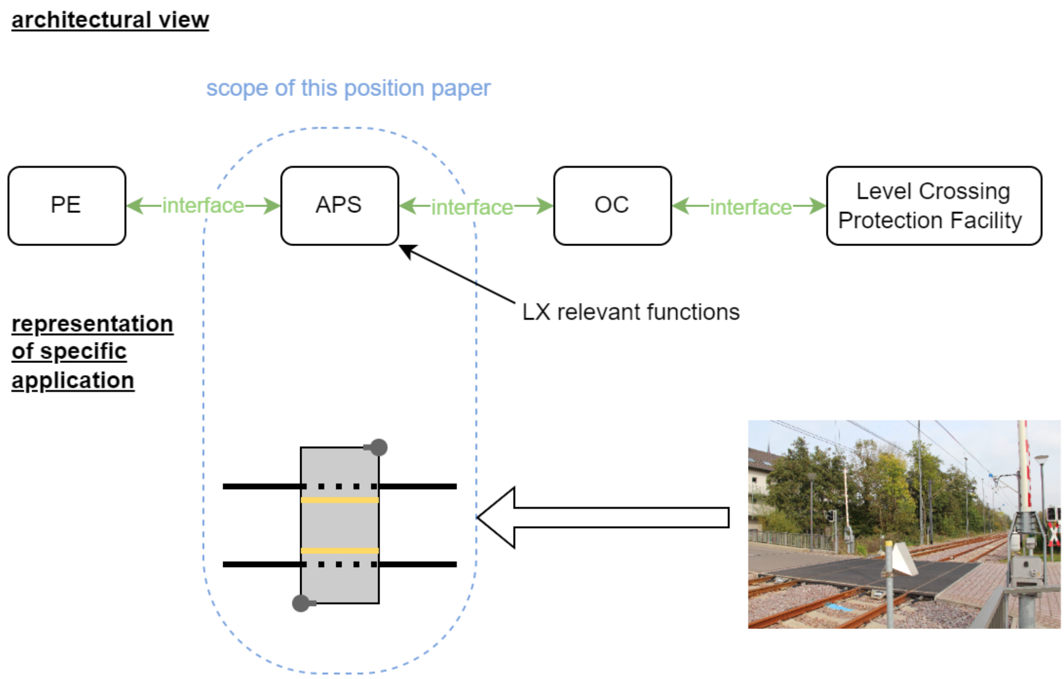
5.1 Definition of the system under consideration

At Level Crossings, rail traffic has absolute priority in most countries and operational situations. To ensure the priority and to avoid the collision between railway vehicles and Level Crossing users, there are various kinds of protection measures used. The various functions enables the reach of an acceptable safety level for railway and non railway traffic. In the best cases they are already compliant to Common Safety Targets (CST) defined per Member State or Infrastructure Manager.

In some instances Command-Control and Signalling systems interfaces specific level crossing protection facilities, ensuring safe activation and granting the movement permission when given conditions are fulfilled. These conditions may differ by operator and installation, but in general some examples can be listed: Road traffic warning lights must be activated a sufficient time ahead of an approaching train so that road users, that have already passed the beginning of the stopping distance, can still safely pass the Level Crossing. The barriers shall be fully lowered before the railway vehicle reaches the Level Crossing and the area is cleared. In some cases a clearance check is needed to mitigate the risk of level crossing users accidentally being locked between the barriers.

By technical solution or operational rules the Level Crossing Protection Facility should be operated for the time required. In addition, the level crossing protection facility should remain closed to public traffic for the minimum time possible in order to mitigate against the risk of trespassing due to impatience or the believe the system is defective.

For handling Level Crossing within this document, a rough system definition is needed. The following diagram shows the overall architecture view of the system under consideration, and a representation of an specific application within APS.



The system under investigation is the relevant functional part for the handling of Level Crossing in APS. The representation by APS Domain Objects is described in further detail in /RCA.Doc. 61/. This representation covers the relevant topological part of the Level Crossing within APS.

The Level Crossing Protection Facility is an external actor interfaced directly or as it is shown via an Object Controller (OC) towards APS. Many of these external actors can be connected to one APS. Although Plan Execution (PE) is part of RCA architecture, from the point of view of APS within this document, PE is seen as an external actor too. PE is the interface partner towards the Railway Operation. From it the need of protection activation of LX to enable an unrestricted train movement is derived.

A categorisation concerning different types of activation process is performed in chapter **APS LX classes**. These defined classes shall enable a handling concerning different ability profiles of the interfaced Level Crossing Protection Facility and its equipement.

5.2 Linking to RCA objectives and field of consideration

/RCA.Doc.53/ does not yet break down specific objectives for Level Crossing interfacing. Same applies for the breakdown in /RCA.Doc.47/, where Level Crossing is not a specific topic mentioned yet.

General issues concerning handling of switchable field elements which are also valid for LXs can be however extracted frpm /RCA.Doc.53/. These are named in the following table and linked as to the potential coverage within the system under consideration:

Objective	Potential coverage	issue of this position paper
APS@Support interfacing to additional field elements during runtime	no exclusion of update during lifetime by APS;	no
A.P.M.@Standardize all main CCS processes, functionalities and interfaces	new development of needed functions in modular architecture	partially: first definition of needed functions in APS
APS@Provide a set of safety functions with a basic configuration that enables safe railway operation		
A.P.M.@Apply a generic safety approach in encapsulating smallest possible safety relevant functions in building blocks that allow a separate safety assurance	best fitting architecture, development and safety demonstration per object without knowlege of behaviour of interface partners	partially: general issues on interfacing considered, no rework of RCA architecture yet made
APS@Separate railway network topology data from functional code	architectural approach with MAP	partially: consideration of data storage requirements outside of specific APS solution
APS@Delegate non-safety relevant functions to planning system	functional split between APS and operational responsibilities	yes

Objective	Potential coverage	issue of this position paper
APS@Use standard interface towards Field Elements to separate the lifecycles of hardware and software components	strict implementation of standard interface usage	partially: consideration for usage of SCI-LC and approach taken defining Level Crossing Protection Facility as external actor.
APS@Support EULYNX standards for interfacing with field elements via Object Controller		
A.P.M.@Reduce the number of individual systems, components, field elements sharing non-standardised interfaces		

Not all objectives named above can be handled by the first version of this document due to the overall character in the wide target architecture of RCA.

In conclusion main fields on consideration within this paper are:

- elaborate stepwise main safety function in core of APS - Safety Logic - refering to the handling of Level Crossing within a Movement Permission Extent
- define safety functions and further functions in APS, for efficient handling of Level Crossing by the Safety Logic
- clear split of functions of the interface Level Crossing Protection Facility and APS including first summary of alternatives for further detailing of the target approach in RCA
- consider the interface to the Railway Operation (task of PE/TMS) with the impact to APS, while no full coverage of Level Crossing is given in /RCA.Doc.47/ yet
- derive the optimal responsibilities-split for the functional handling of LXs between PE, APS and the level crossing protection facilities themselves to provide a base for the investigation of a best possible one-solution-fits-all approach without misjudging the resultant efforts in the Railway Operation
- provide a base for later investigation on possibility, if one solution can fit all situations; including figuring out potential responsibility to implement the perceived gaps lies with the hardware design (e.g. for specific APS LX classes)

5.3 Problem description with current solution

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5.4 APS LX classes

With introduction of APS, some facts will be changing like the need of the removal of the signals and the utilisation of moving block (when feasible) will by definition already provide a lot of improvements for both rail and road users, this because the safety check point won't be required at sighting distance anymore. This in itself is a huge attraction towards APS solution.

A best-fit integration of a Level Crossing in a signaling domain including changes if needed, respect the Off time for Level Crossing users as capacity issue for the rail system and more important as a safety issue. National rules imitating the Off time here may apply.

In order to facilitate the discussions about how APS should handle through abstraction the many different types of level crossing solutions currently in existence, the following three APS LX classes are introduced. They group the level crossing based on their characteristics regarding activation and supervision sequence.

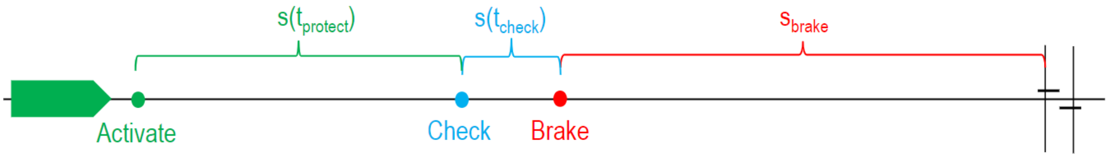
For visualisation of the different APS LX classes, some variables are used and explained in the following table.

variable	meaning
s(*time variabe*)	specific distance depending on the named *time variable* and further input data like train speed/line speed *Note: This can be also a maximum of considering different time values)*
s_{brake}	specific braking distance depending on train speed/line speed
$t_{activate}$	time to be needed for activation process of a specific Level Crossing Protection Facility, up to all required actions are performed *Note: This does not imply, that all actions are performed within that time span if this is allowed by system design.*
t_{check}	required time span for processing further safety checks enabling a granting of a Movement Permission in time
t_{clear}	required time for safe clearing of the Level Crossing by Level Crossing users
$t_{protect}$	time for activation and full securing process of a specific Level Crossing Protection Facility, no further actions apply for the Level Crossing Protection Facility afterwards

- APS LX class (a): protection state of LX is 'closed' or 'closed and no obstacle between the barriers'

  This APS LX class can be compared to the current full barriers Level Crossings protection principle. A main signal protecting the level crossing from rail traffic shows a restrictive or a permissive signal aspect depending whether the passage for the train is possible or not. Therefore, for a permissive aspect to be shown, the correct state of the Level Crossing Protection Facility will be checked before granting a train movement over the LX. This requires that all level crossing equipment reaches a defined status (depending on the equipment of the Level Crossing and on the rules of the Infrastructure Manager, minor failures can be treated as acceptable). In the most cases all related road signals shall show a defined aspect, the barriers shall be lowered and, in some instances, a level crossing area clearance check shall be successfully performed.

  The following figure introduces the main elements of this operative principle.



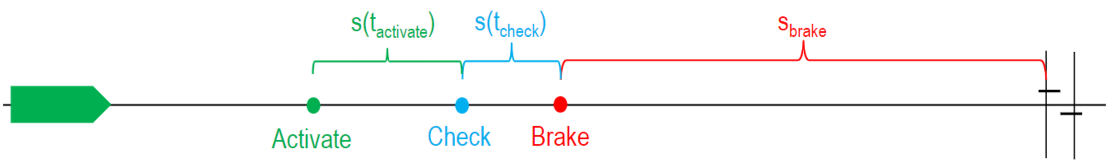
In addition of the time span for the operation of the protective measures ($t_{protect}$), a time span (t_{check}) is needed for further checks (e.g. the safety check required for granting the movement permission) before the specific braking distance (s_{brake}) is reached. From the point of view of the total time required - from requesting the activation of a specific Level Crossing Protection Facility until the moment which the train really reaches the Level Crossing - this is the worst case for all the proposed APS LX classes.

- APS LX class (b): protection state is 'activated'

This APS LX class is introduced to represent level crossing solutions for which only some specific conditions of the Level Crossing Protection Facility must be checked before the train movement can be authorised, meaning that some protection processes are only checked to have started. In some countries this is only applicable, if no full barriers are present - i.e. half barriers only.

The change compared to APS LX class (a) is that the full time span ($t_{protect}$) is not needed in this case. Only a time span for activation ($t_{activate}$) is taken into account and, based on a positive feedback, the movement permission can be granted. This implies that, at the time of granting the Movement Permission, only a smaller number of safety checks are executed (e.g. road signals shall display the correct aspect towards public users) and it is assumed other protection measures will finish their operation correctly - i.e. the closing of barriers is performed in parallel, while train is approaching the crossing. As such, the activation point must consider the minimum time required for the whole level crossing protection operation to take place before the train reaches the level crossing. This is the fundamental safety principle for this APS LX class

Compared to the APS LX class (a), the figure shows a shorter distance is needed from activation until the Level Crossing is reached.

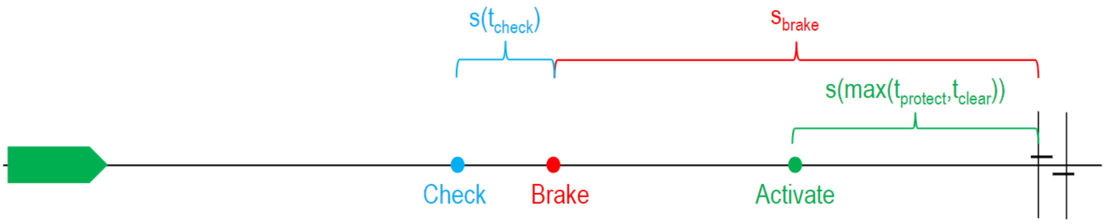


Note: This solution implies the acceptance of a resulting risk, that the further activities are not performend sucessfully. This approach is common sense for some installation nowadays and is taken as possible for detailling the handling of Level Crossing in RCA. It *demands a specific reaching of a safety target of the Level Crossing Protection Facility in place, for limiting the risk on a acceptable level.*

- APS LX class (c): protection state is 'activation is feasible'

  In this APS LX class the fundamental condition is that no safety-critical failure is reported by the Level Crossing Protection Facility prior to the authorisation of the movement. Thus as the Level Crossing Protection Facility is reported functional, any risk that the activation cannot be performed is regarded to be of an acceptable low level.

  The operational concept behind this is that this check is performed early enough - based on worse case between the maximum of braking distance and the minimum required activation time to enable the full operation of the adopted protection measures. This leads to a comparable changed sequence, as shown in the below figure, regarding the points of control. It starts with this functional check before braking distance is reached, and in case of positive outcome the movement does not need to be restricted. The actual distance for activation generally starts later due to short securing time of the installation compared to the longer braking distances in case of higher speeds at approach.



  This kind of solution is the most efficient from the point of view of operational optimisation, to reduce a level crossing Off-time.

  Note: This solution implies the acceptance of a resulting risk, that the further activities are not performend sucessfully. This approach is common sense for some installation nowadays and is taken as possible for detailling the handling of Level Crossing in RCA. It demands a specific reaching of a safety target of the Level Crossing Protection Facility in place, for limiting the risk to an acceptable level.

As already mentioned, there must be a decision whether the APS LX classes will be implemented for interfacing current installations, or only one kind of approach is considered. This may imply further consideration within detailing of APS. For the handling of different APS LX classes following questions shall be taken into consideration in RCA development and coordination of migration towards RCA defined with the several stakeholders as a starting point:

- Which kind of installations must be replaced based on the expiration of life-time or reduced safety level?
- What is the current safety level of an installation and does this fits to APS safety approach (including later derived conditions for integration)? Does the current safety level of an installation fit to the Infrastructure Managers goals?

- Are there changes needed in the installation to be compliant with APS? How many requirements must be derived form a generalised approach using configuration data?
- How to increase the added value for which to justify the additional costs required for changes in the installation (e.g. increased capacity or reduce costs by releasing of different work principles in the direction of travel)? This shall be treated as additional added value on top of what is already achieved by the further gains introduced by RCA.
- Is there a need of the fluent transition between APS LX classes (meaning should there not be 1:1 sorting to class)?

5.5 Basic requirements and basic working conditions

A basic requirement concerning a Level Crossing involved in train movements in normal operation can be derived as:

- Enable safe passage of the Level Crossing by a train, nearly without restrictions.

This basic requirement can be enlarged by the Level Crossing user perspective:

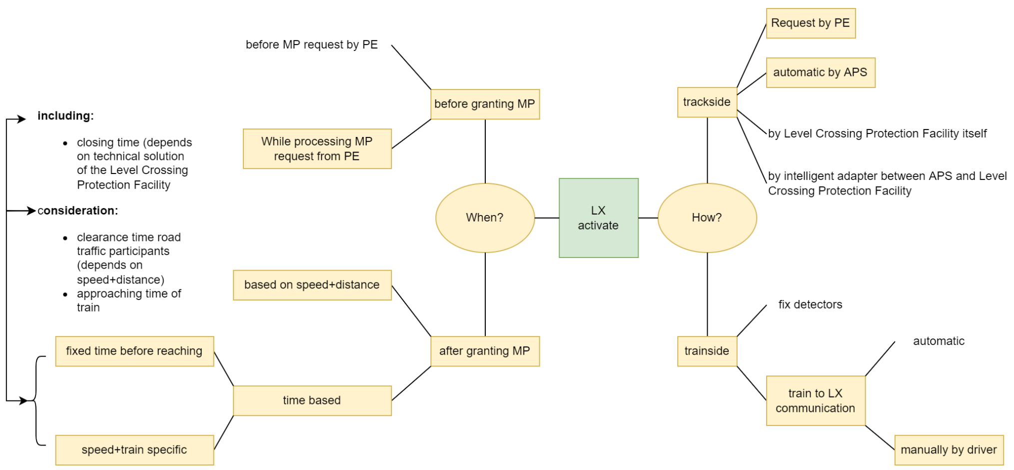
- Reducing the time of interruption of possible passage by Level Crossing user on the lowest possible level.

This enlarged viewpoint influences also the safety perspective of avoiding risks at Level Crossing as fundamental target of railways and the rail sector in general (noting of course that considerations towards a consistent off time of Level Crossing - which would then become traffic-dependent - is also an important characteristic when assessing such behavioral risks at Level Crossings and it should not be discounted).

This leads to the following main questions regarding the activation of a Level Crossing Protection Facility: **When** and **How** to do it?

The following figure shows an outline of the main possible solutions and serves as an overview of the wideness of this topic.

Note: The items highlighted in yellow are taken into account within this document. This does not mean that any solution must be implemented but that, as a first investigation, APS will consider as many potential solutions as possible.



This overview, and the resolving of the mentioned issues, refer to basic working conditions to be applied by the application:

- The Level Crossing Protection Facility has fully completed their closure process before the train reaches the LX. This can be ensured prior to granting the rail movements or during the approach of the movement towards the LX.
- All Level Crossing users have cleared the conflict area before the train reaches the LX. (*Note: This is in general a design consideration of the Level Crossing Protection Facility itself. It is either assumed supported by the selection of technical equipment and a time based sequence, or ensured via additional detection equipment.)*
- For solutions designed as such that the Level Crossing does not reach the specific protected status against road traffic before the train movement must be granted, the minimum approach time must be greater or equal than maximum clearance time from Level Crossing users.
- In any case, the required Protection State of LX must be reached at such point in advance of the crossing in order to avoid any restriction to the movement of the approaching train - i.e. if no further restriction applies, the train shall not enter the braking curve up to LX boundary (node). (*Note: this requires knowledge of the specific time span of Level Crossing Protection Facility by design, the considering of the APS process times itself and the optimal 'strike-in'.)*

It is necessary therefore to investigate solutions for the handling of LX activations in itself, particularly when considering the responsibility-split for the handling of optimised operation. These solutions are of course dependent on the different types of applications. To derive a standard toolbox suitable for various operational needs requires a balance between striving for a simplistic abstractions and scalability. This will be the aim of the next chapters.

Supplementary some facts must be considered. The type of transmission of the authority to move will be changed compared to today solutions with the RCA approach. This must be reflected by the ideas for interfacing LX as well . Concerning the integration of the RCA approach in a specific application, a check against the need of application of safety principles in APS development including a discussion on changing IM or Member State specific rules must be performed in parallel. Only the sum of technical solution, suitable safety demonstartion and legal base is the fundament of introducing new operational and technical approaches. This will lead also to specific investigation by each IM for changes in specific applications not following the outlined principles. Examples can be here LX, where currently no technical supervision by systems on correct function is present, but an operator has to check the condition e.g. by observing the health state on a display.

5.6 Type of activation, optimisation and optimal handling

5.6.1 Type of activation

The activation of a level crossing protection (closure) process can be trackside-based or trainside-based.

By introducing APS as part of RCA, some changes in architectural and functional philosophy occur, impacting the activation of Level Crossing. New possibilities arise and, based on the working target of reducing trackside assets, some of todays largely used technical solutions - such as the activation by fixed devices - may reduce in significance. The following table depicts the already introduced variants of activation and link them towards possibilities and the consideration in the following chapters.

activation triggered by	variant	example	handling within this paper
trackside	request by PE	direct request of securing a Level Crossing by command	yes, normal pre-condition based on handling of switchable Field Elements given in /RCA.Doc.61/
	automatic by APS	APS considers based on the current *operating state* and/or the APS LX class the specific Level Crossing belongs to, the need of automatic trigger towards the Level Crossing Protection Facility	yes, behaviour for specifc APS LX class
	by Level Crossing Protection Facility itself	the Level Crossing Protection Facility is independent, with its own sensors for activation	no, see chapter 'delimitations'
	by intelligent adapter between APS and Level Crossing Protection Facility	the independent Level Crossing Protection Facility is updated, e.g. receiving information of APS for efficient activation process	no, see chapter 'delimitations'
trainside	fix detectors	activation by passage of trackside sensor like axle counter	no *)
	automatic	activation by direct command of approaching train	no
	manual by driver	activation by driver using devices like control panel, push buttons or infrared transmitters	yes, typical case for manual operation

Note: The activation in case of incidents mentioned in /RCA.Doc.51/ is not a variant of activation but only a specific reason. This can be sorted into the variant 'automatic by APS'.

*) Here this variant is named later only as alternative in some cases. The types of activation will be elaborated and compared in a later stage of the document.

5.6.2 Timing of securing a Level Crossing, optimisation and optimal handling

In addition to *How?* - to secure a Level Crossing, the *When?* - meaning the specific timing of securing is a further aspect. Different stakeholders involved directly and indirectly will have diverging interests and requirements. For the railway perspective, the Infrastructure Manager, the Railway Undertaking and the railway customers will have an interest in a timely securing, avoiding any impact on the current mission passing the Level Crossing. The activation and securing must start as early as possible from this view, to ensure an unrestricted train movements also for the case of sudden disruptions.

The Level Crossing users, on the other hand, demand an Off time as short as possible. This requires an intelligent timetable planning, especially, for situations where numerous train movements occur. Thus the closing time per movement and the sum of all interruptions of the road traffic crossing, shall be as low as possible.

These two view points have an impact on the definition of the process and the timing of the securing tasks. Two terms are common to be used within this context:

- optimal handling
- optimisation

Note: Optimal handling describes in this context a general process for activation and securing without any delays and unnecessary extended process times. The optimisation forms the best-case handling of the specific operational situation considering all present data in near real time. This means in context of activation of Level Crossing, an activation as late as possible by adapting the strike-in at a specific movement. This means an activation at latest point based on all available data of the movement, but in time to avoid any operational restrictions.

The general optimisation concerning the activation and securing of a Level Crossing is performed by one instance. Concerning RCA the working hypothesis the handling on Railway Operation can be provided by Plan Execution (PE). This is not agreed at the moment, but based on this hypothesis a further detailing can be made as a proposal. Some facts are present considering this fundamental principle:

- PE needs the acknowledgment of all applications and their specific behaviour;
- derived from this knowledge need by PE, all installation shall be centralised connected via APS (stand-alone Level Crossing Protection Facilities cannot be optimised) for enabling the data exchange;
- PE covers the knowledge of specific movement itself, derived from the *operational plan;*
- PE does not know how road user behaves, but the behaviour shall be limited by installations and process to be forecastable;
- PE is responsible for processing the request for movements passing through the Level Crossing in time, inclusive of the activation of the LX by usage of all necessary information of the specific application;
- PE can optimise this request based on the *operational plan* and the *operating state* by a specific function to be implemented in PE for this purpose.

APS itself will cover the aspect of optimal handling. Optimal handling refers here to make the Off-time as small as possible. This is covered by an approriate internal handling in APS of the specific Level Crossing functions and the overall system approach in RCA. If having solution variants is deemed attractive, an APS tool-box with adaptable behaviour would be required. E.g. in the case where optimal activation handling would be required for a level crossing type 'LX not secured prior to granting of MP' (LX class (c) as defined in the below chapter), this function becomes also a safety issue. Thus optimal handling becomes a balancing act between operation and safety needs. And therefore, if this should be implemented in the generic RCA architecture, this balancing task must be performed on system specification level.

To be investigated	The worksplit between PE and APS must be aligned.

To be investigated	In addition to the safety aspects of functions, the safety demands towards APS and PE considering maximum acceptable off-times and minumum opening-times between two rail movements must be discussed if this is an issue for RCA system development. It must be checked, if this time must be given as specific parameter to be detailed by the needs of the Infrastructure Manager.

Optimisation and optimal handling in this context can be achieved by different means:

- The handling of the specific Level Crossing installation can be optimised by best-fit of so-called APS LX class. This includes in some cases the need of changes of present installations of the Level Crossing by introducing APS.
- Using the full picture of the *operating state* by PE based on all data of the train movements for transforming the *operational plan* towards discrete requests to APS.
- Triggering in-time activation by PE, APS or the train itself depending on the APS LX class.

To be investigated	Based on the already planned optimisation of Level Crossing handling by PE and considering the potential optimisation by design in the specific interfaced Level Crossing Protection Facilities, the benefit of an APS LX-class-based tool-box (a more complex approach in APS) must be discussed for final decision of implementation.

5.7 Handling of situations

5.7.1 General issues

The following chapters shall form as a derivation of overall requirements for Level Crossings from exemplary scenarios and specific situations beeing part of several scenarios.

The development of a solution depends on whether specific operational situations are possible and on whether there is weight concerning the possibility and the need for technical assistive solutions. Main operational situations are explained in the next chapters. Some are used later for description of the detailed technical handling of scenarios.

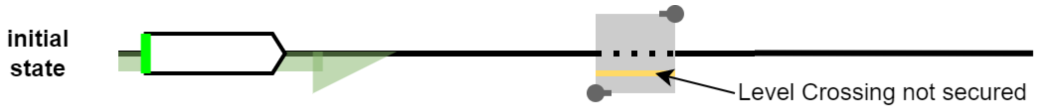
Besides this specific explanation some general issues must be considered for Level Crossings interfaced to RCA applications. The focus of RCA is to enable highly automated operation. Thus any solution must be capable for operation up to the Grade of Operation 4 (GoA 4), lower GoA application to be used for normal operation, degraded operation and in cases of emergency situations.

GoA 3 and 4 means less involvement of train staff in operation compared to legacy application. More process steps must be automated and the non-presence of drivers taken into account when considering risk mitigation in normal operation as well as when defining feasible solutions for recovery from degraded situations.

5.7.2 Single track scenario

The first scenario is a very simple one setting the base for the following scenarios. In it, a single track is present over the Level Crossing which the train shall pass.

This scenario can be illustrated by:



The pre- and postconditions are described below:

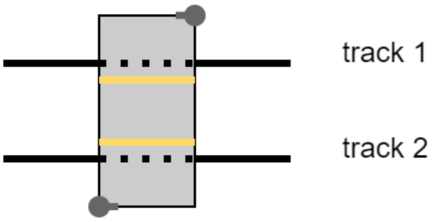
- Preconditions:
  - The Level Crossing is not protected,
  - The need to pass the Level Crossing is present recognised by APS derived from a MP Request issued by PE,
  - Train is approaching the Level Crossing and is located outside the strike-in distance and the specific braking distance towards the Level Crossing

- Postconditions:
  - Train has fully passed the Level Crossing
  - Level Crossing is not protected and made available for Level Crossing users

A separate chapters deals with functions handling the single track scenario.

5.7.3 multiple track scenario

In addition to the simplified situation, where the Level Crossing covers only one track, a multiple track arrangement can be present where the Level Crossing extends over two or more tracks, enabling parallel train operation. The following depiction :



In case a train must pass the Level Crossing, the movement over one track results in the protection of the whole level crossing area. This principle is currently always present in Level Crossing Protection Systems. The pre and postconditions are similiar to the single track scenario.

Several operational situations can occur during normal operation:

- only one movement is present, over one track only;

- a second train movement is present closely following a movement on the same track, without enough time in between to enable a full level crossing protection release (e.g. open barriers);
- train movements are present covering both tracks at the same time or as a sequence (without enough time in between to enable a full level crossing protection release).

When operating multiple subsequent train movements over a level crossing, two contradicting needs are present: keeping the level crossing closed for road traffic as much as possible not to disturb rail operation capacity, and open level crossing in between train movements as often as possible to allow for public usage and minimise the risk of trespassing. The legal conditions for handling these issues are given per Infrastructure Manager. For the Level Crossing Protection Facility this leads to the need of assisting both operational variants.

5.7.4 Optimal handling of the strike-in time

In general an optimal handling of the strike-in time is recommended, for allowing a short period where the Level Crossing cannot be used by road user and pedestrians. Todays specific applications with or without optimisation are present.

Refer to chapter **Type of activation, optimisation and optimal handling** for an overview of the responsibilities and possible solutions. No single solution exist. In general optimisation scenarios depend on an already applied stepwise optimisation of current applications with possible changes in the technical or the operational handling. Thus optimisation is named here with reference to the chain of possibilities and their operational impact, to guarentee an optimal handling of the strike-in time.

The following consideration shall introduce the general possible approach for optimisation from the point of view of the system functionality and not only from perspective of APS. These approaches feature different levels of optimisation.

Level 0 - reference scenario with no optimisation (fixed strike-in point)

In the reference scenario, no optimisation is present. A fixed calculated point for the activation dependent on the line speed, worst expected train characteristics and type-specific protection operation time is used. It indicates a point where strike-in of activation must start.

This level is used by, for example, a fixed activation by the operator/operating system (with disregard to the specific train movements characteristics) or by fixed sensors installed with specific purpose of LX activation.

Level 1 - operational optimisation by timed request adapted to movement constraints

A first optimisation can be present if the several constraints of the movement can be considered. In this scenario, the strike-in of activation is based on the expected resulting train movement, i.e.: in terms of the RCA system approach it focus on the consideration of the Movement Permission constraints such as speed restriction and train braking profile. As such, rather than the static worst-case characteristics, the dynamic most restrictive characteristics are used instead.

Note level 1 does not yet consider that the movement is optimised according to schedule considerations. This is taking into account in level 2.

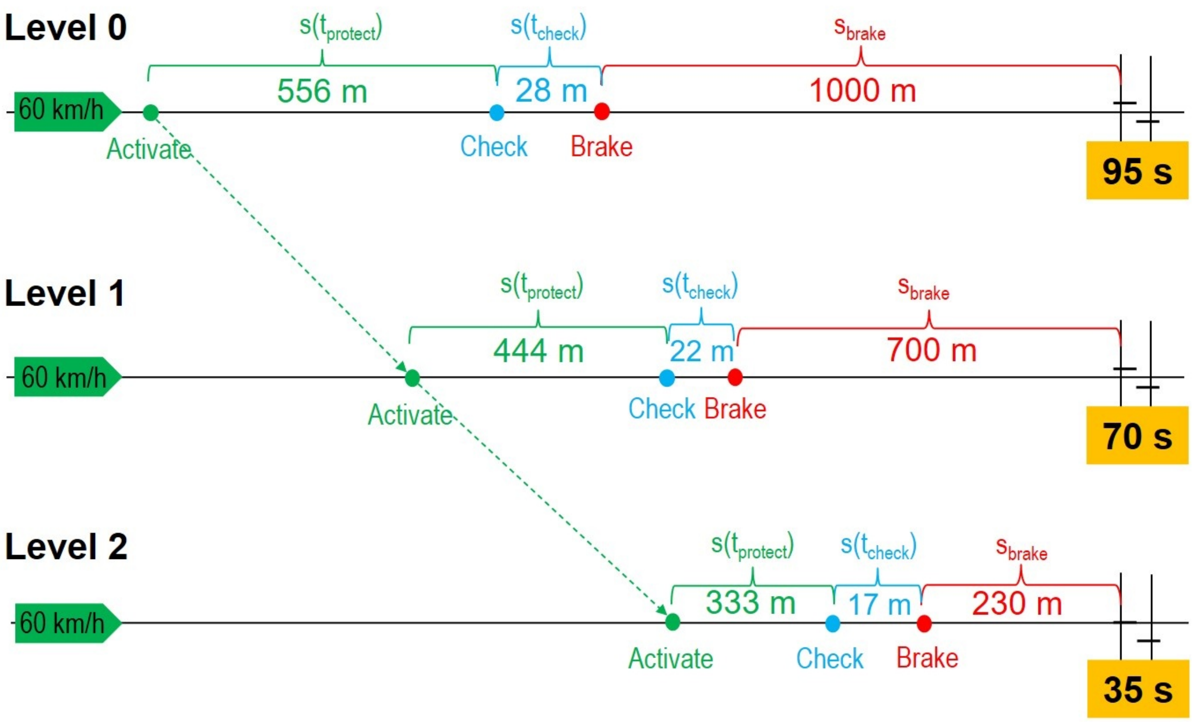
Level 2 - operational optimisation by timed request adapted to journey profile

As an improvement of the introduced Level 1, instead of using the Movement Permission regarded constraints to derive to optimum of the Strike-in time, the optimum movement characteristics based on a Operational Plan could be used for deriving the optimal point for strike-in. The highly automated operation is based on the assumption that PE knows the exact schedule to ensure the timely arrival at stopping points. If the requested MP is derived from the needs of the journey profile (considering constraints of line, train formation, operating state and time table) a best-case optimisation is possible. In current architectural solution PE, does not know the specific journey profile derived by ATO Execution (AE). Thus, an issue for further detailing is derived:

To be investigated	In case of optimisation on the specific movement is needed, the fitting between PE and AE related task must be demonstrated. The different possible solution with functional and architectural impact must be checked.

The following example should demonstrate the general linking between the levels. Lets assume a line with a line speed of 100 km/h and a Level Crossing working according to the principles described on the APS LX class (a), and based on given conditions, movements are restricted to 80 km/h. However, based on the specific time-table schedule, the train is travelling at a speed of 60 km/h to enable an timed arrival.

The required braking distance, the distance needed in protection time and the distance derived from the checking time are taken based on the corresponding speed for each level and general signalling principles, i.e. line speed for level 0, restricted maximum speed for movement for level 1 and the actual travelling speed for level 2. As the train is travelling at the defined coasting speed of 60Km/h the impact on the level crossing Off-time is as highlighted (in yellow) shown in the following figure.

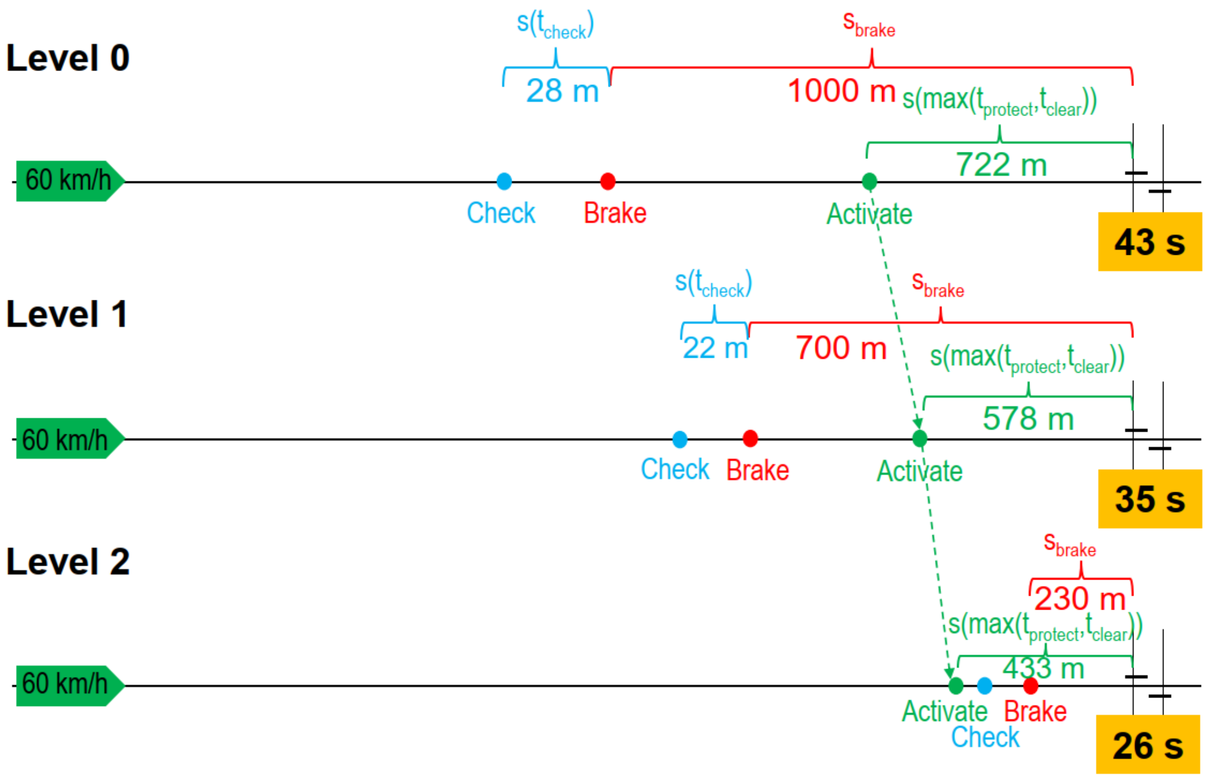


The proposed optimisation leads to a shift of the named point "Activate" (Strike-in point). This specific example shows a high grade of optimal handling of the strike-in time, dependent on the conditions and the specific installation. The example shows only one of many possibilities for improvements achieved through a sophisticated Level Crossing approach.

In general optimisation is depending on:

- quality of data and planning of movements
- the precision of real movement following the operational plan
- the presence of assistance systems like ATO or Driver Advisory System (DAS) for stabling the order of the operational plan
- current LX installation and their improvement measures (lack of optimisation or already present measures by IM)
- national conditions and law to be respected

The following figure depicts the same scenario as above but applied to a APS LX class (c). When compared with the APS LX class (a), it becomes evident that although an optimisation can be achieved, it is obtained on a lesser scale.



Note: Optimisation Level 2 in the figure above is limited by defined minimum value for strike-in time of 26 s, which considers the time for switching on the light signals, closing the barriers and a time buffer. The value is a specific example on a typical installation and can deviate.

This sheds light on an important point that must be considered when deriving the overall RCA requirements for the handling of Level Crossings: a trade-off analysis is required to establish the optimum level of complexity that RCA must absorb when handling the many Level Crossing applications.

In this instance, although further optimisation can be made in RCA (i.e. outside of the specific level crossing installations), the gain in terms of the resulting reduction in level crossing Off-time is comparably low. Furthermore, as it will be discussed in chapter **solution approaches** specific functions and attributes must be created in order to enable the full operational control of specific level crossing application types - such as LX class (c) - even in normal operation scenarios.

Utilising simple fixed physical activation sensors would be a suitable alternative compared to a specific calculation of point of activation according Level 1 and 2. This can be used in such a case, as they are already present in current solutions and could ultimately lower the development effort for the functions required for the RCA activation and optimised handling of these specific Level Crossing without impairing much of the operational benefits, which are by design already accounted for on the applications fitting to this APS LX class (c).

Note from the APS point of view this is acceptable, because a degree of operational optimisation is already given by the Railway Operation (represented by functions of PE) and the specific installation in the field. The Level Crossing Protection Facility would be activated by sensors and APS would recognise this by their abstracted state change (through the SCI-LC interface) and will not treat this changes as unexpected - i.e. there would be no changes to a previously granted Movement Permission.

5.7.5 Start of a movement within the strike-in distance

A train starting within the theoretical strike-in distance means, that there might be not enough time to close the Level Crossing without restricting or delaying the train movement. That is why RCA needs further functions to detect and react appropriately to these cases. General possible approaches would be

- The MP Request is sent by PE , considering the needed time-span for activation depending on the APS LX class. This avoids any reject of the MP Request. It is assumed as the standard solution.
- The delay of the MP granting by APS - this goes against the principle of segregation between operation and safety subsystems currently adopted in RCA development

Otherwise PE can restrict the MP, e.g. use lower velocity in requested speed profile compared to line speed. In this context based on the requested MP the movement will not start in strike-in distance, this approach is a kind of avoiding the scenario.

Consequently, PE must know when an activation must be requested, i.e. the minimum time for the overall process of activation of a Level Crossing up to the required state is reached. These data must be stored in RCA as so-called MAP Data an be made available to PE.

The handling of this scenario is sufficiently supported by the correct sequence of requests towards APS.

To be investigated	The detailed functional sequence must be investigated in the future as overall topic in RCA, especially on behaviour of PE.

5.7.6 Level Crossing located in Risk Buffer of Movement Permission

A specific scenario is presented when the stopping point of an authorised train movement is located near a Level Crossing as such that the MP's Risk Buffer partially or fully covers the Level Crossing. Nowadays, several operational and technical rules exists concerning the need of securing a Level Crossing in such situations. For example, the minimum safety distance between a signal and a level crossing must be considered. In case this distance cannot achieved, the Level Crossing must be activated while the movement is only approach this signal without any operational plan to pass the signal.

Four particular situations can be derived based on the present view-points of national or IM-specific definition in legacy applications:

- in general no securing is needed if any part of the Risk Buffer extent is covering the DPS of the Level Crossing → no securing of Level Crossing
- the Risk Buffer extent covers the DPS of the Level Crossing, but a sufficient distance from the end of the MP extent is present → no securing of Level Crossing
- the Risk Buffer extent covers the DPS of the Level Crossing, but a sufficient distance from the end of the MP extent is not present → securing of Level Crossing
- the Risk Buffer extent covers the DPS and no distinction for sufficient distance is present → securing of Level Crossing

Note: The current simplified approach of detailed APS functionality based on abstraction of switchable field elements described in /RCA.Doc.61/ demands the securing of Level Crossing located in Risk Buffer of a Movement Permission.

If all particular situations shall be assisted by APS, three issues must be covered:

- the specific data to be applied must be configurable, per DPS Group, to allow a different behaviour also in one Area of Control
- the sufficient distance for distinction on need of securing must be given by configuration data
- the functions of APS must consider this sufficient distance

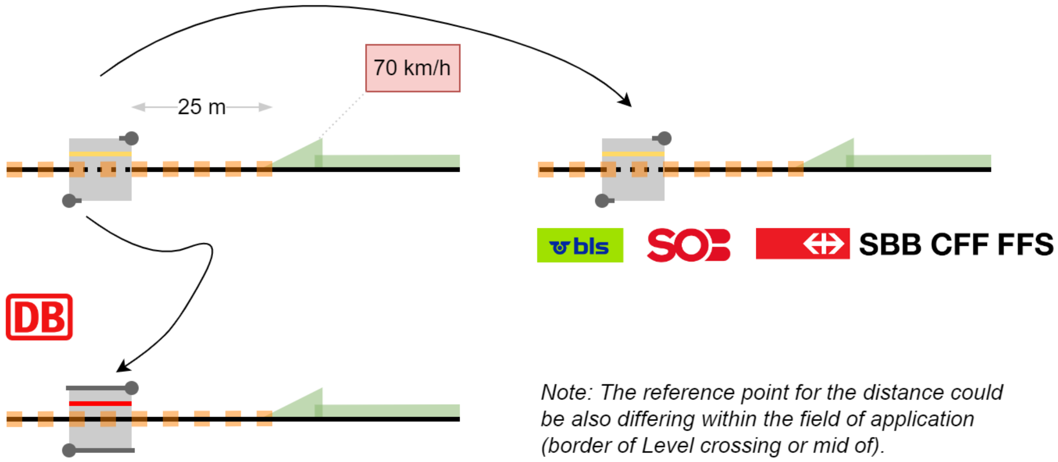
The approach ensures any operation of existing facilities according the current legal standard of Infrastructure Manager or Member State. This is recommended, because any change of (national) standard is not simply a railway issue. The integration of the concerns of the road users and the road authority is needed. Furthermore, such solutions are often required because of the physical (land rights or constructions) around the infrastructure.

Existing systems shall be interfaced with APS, if they comply with the interface conditions yet to be defined. They are suitable according the defined interface between APS and the Level Crossing Protection Facility, or a specific functionality such as the provision of safe notifications of malfunction on a specified level of APS mitigate any differences between the present and the required interface conditions.

To exemplify this discussion the following table presents the current existing rules for main lines in two countries:

country	sufficient distance	reference speed
Switzerland	20 m	no constraints
Germany	10 m	<= 40 km/h
	30 m	<= 80 km/h
	50 m	> 80 km/h

Assuming a practical distance of 25m and a speed of 70 km/h, the handling of this scenario exemplary would currently require different applications in the two countries considered :



The current analysis can only highlight the issue. Specific objectives on this issue are not present yet (see chapter **linking to RCA objectives and field of consideration**). The needed functions are in direct dependency to the definition of the generic operational handling in RCA, considering safety and the legal background in the various countries. Thus changes or the avoidance of changes in the legal rules by the Member States has a direct impact on the requirements to be covered by APS.

To be investigated	The need of implementation of a distance-based handling of Risk Buffer covering Level Crossing based on objectives relevant for APS must detailed.

If a functionality for the handling of Risk Buffers associated to the location of Level Crossing in normal operation for any risk mitigation for the railway and the Level Crossing users is seen as potentially needed for implementation, this could be also used for the handling of incidents comparable to "signal passed at danger" events for an automated activation of Level Crossing.

5.7.7 Manual operation

Appart from automated operation for movements, manual operation of Level Crossings must in general be assisted by RCA. Manual operation is required for many reasons. It can be used for example for test or maintenance purposes, or for the handling of degraded and emergency operations (see next chapter). But it could also be used as mitigation measures in early stage of implementation of a RCA-based system - e.g. where in the current method of operation the operator has to supervise the Level Crossing by Closed Circuit Television (CCTV) and no technical interface is otherwise provided between this type of supervision towards the current Level Crossing Protection Facility.

From functional point of view, a direct request given by PE does not harm the behaviour of APS as it is directly interfaced to the Level Crossing Protection Facility. For APS only the reaching of the required checking state is important for the granting of a requested of a Movement Permission.

5.7.8 Degraded and emergency operations

Besides normal operation serving as the main premisses of consideration (see chapter **delimitations**), further means of operation are essential to be assisted by technical solution and operational procedures.

Degraded operation and handling of emergency situations means in terms of definition in the European Rail the absence of the full functionality, a change of safety responsibility to further actors and the overall behaviour outside of the safe integration condition of vehicles into a specific trackside application. As the correct functional behaviour is only supervised at the trainside actors under normal operation, the responsibility of the definition of the functional requirements and the safe handling of operations outside the normal realm is a fundamental area of responsibility of trackside actors.

It should be possible for APS to let a train pass a Level Crossing under certain conditions, if e.g.:

- the Level Crossing Protection Facility must be treated as defective;
- parts of the Level Crossing Protection Facility are not working properly leading to a lower grade of protection, e.g. absence of obstacle cannot ensured.

As it is true to any other systems interfaced to APS, the handling of these situations must be considered in a system wide approach also for level crossings to enable an efficient and safe operation. Any known abnormal behaviour and incident must be reported to APS in order for handling it safely. This could enable not only the use of a set of standardised possible mitigation measures, but also the setting of parameters depending on specific level crossing application types.

The main working items within this domain for Level Crossings are:

- the recognition and classification of errors and incidents referring to Level Crossing; this includes making information about failures visible to APS or providing information where the required state cannot be reached by the Level Crossing Protection Facility,
- the integration of sensors and technical solution on site for fallback operation for example,
- the usage of measures for mitigation, e.g. restriction of speed in a Movement Permission or other specific means for the securing of train movements,
- the use of operational measures directly by operators to enable mitigation of risk
- the check, coordination and potential update of current safety principles to allow for a safety approach for the general RCA-based solution coping with different needs of the Infrastructure Managers. (currently, the same technical issue can lead to a required different handling in different applications).

5.8 Specific aspect - Open Level Crossing

As Open Level Crossings does not provide any technical interface to the signalling system, APS cannot interact functionally or gain any safety targets considering Open Level Crossings.

Besides APS some changes of the overall approach are possible, for handling degraded operation and incidents by use information like obstacle detection to trigger safety reactions in order to further improve the protection of Open Level Crossing. This issue is out of scope for APS and must be handled on RCA as overall item for investigation, if RCA in general allows Open Level Crossing as an integration condition.

APS itself covers the possibility of including Level Crossing by adding a Level Crossing Protection Facility. In case of grown capacity of the rail line, this shall be the approriate measure for including present Open Level Crossings.

In case Open Level Crossing will be still in a certain line present, APS must only know the limitations for operation passing this area. This can be easily performed by using the APS tool-box and the associated train control function of ETCS. This implies speed restrictions and/or stopping in front of the Level Crossing. Any further needs like usage of additional sensors on-board or trackside for recognition any trespassing enabling risk reduction must be checked by system development considering the overall impact of high-automated operation on such applications.

5.9 Solution approaches

5.9.1 General thoughts on integration of Level Crossings in RCA and its responsibilities

The integration of Level Crossings in RCA means focusing not only on present applications in Grade of Automation (GoA) 1, but it must be ensured a system-wide examination with a view to bring operations up to GoA 4 level. Thus normal operation and each other mode of operation must be considered based on this target picture as the functional and technical requirements can only be correctly derived and detailed when respecting this target.

The different parts of the RCA architecture must therefore embody the responsibilities for enabling the integration of specific installations as required.

Parts of RCA and external actors	Responsibilities
TMS	• Provide the operational plan for a movement, • Detailing of operational needs and considerations as basis for all system-wide functions.
PE	• Detailing of the operational plan based on the current Operating State known to PE, • Derive the required Protection State of the Level Crossing, based on the operational plan given by the TMS, • Send a request to change the state of the DPS representing a Level Crossing within the relevant track of the Level Crossing, • Send the DPS request at the most appropriate point in time regarding operational performance.

Parts of RCA and external actors	Responsibilities
APS	• Enabling the abstraction for different installations, • Supervise the state of the abstracted Level Crossing continuously, updates the operating state accordingly, • Perform safety checks before granting requests referring to Level Crossings, • Command activation and deactivation of a specific Level Crossing by specific commands towards the OC/Level Crossing Protection Facility, where this function is available, • Ensure that MP over a level crossing is only allowed when a sufficient protection status is present, • Ensure the fulfilment of additional conditions for granting a MP, depending on the movement supervision type, • Maintain the health system state, by exposing malfunctions, • Support degraded and emergency operation by the tool-box of functions, suitable also to Level Crossings.
Incident and Prevention Managament (IPM), Perception (PER)	• Optimal handling of degraded situations and incidents for automated operation, • Where available, support by further sensors for degraded operation.
Level Crossing - interfaced to APS	• Execute commands from APS • Monitor the state of physical equipment of a Level Crossing • Report needed status information of Level Crossing to APS

5.9.2 Use of the APS tool-box

/RCA.Doc.61/ defines the abstraction principle and several APS Domain objects. Thus an APS tool-box exists with the various categories of APS Domain objects. For Level Crossing the categories 'Infrastructure Object' and 'Control Object' are important for the system functions. Any further considerations can enlarge the present definition of already defined objects if needed.

The description of the proposed approach for Level Crossing is based on the 'Infrastructure Object' Drive Protection Section (DPS) grouped on a so-called Drive Protection Section Group. This is already used by the abstraction of point-switches present in any infrastructure. For Level Crossings geometric properties must be used in general too. The only differentiation is, that points are located in minimum at a node of the track net given by a Track Edge Point. As for point, the geometric abstraction is then defined by a relevant extent of the track depending on the node and representing the relevant part of the switchable field elements, for Level Crossing this is a specific extent on a Track Edge Section representing the crossing part.

The 'Control Object' Movement Permission could be granted as the result of a specific handling of a Level Crossing, assuming any other safety requirements are also met. Usage Restriction Areas and Warning Areas could be used for handling degraded operation. Therefore the current APS tool-box seems to be a good base for investigating the handling of Level Crossings by this subsystem.

Note that at this stage no full comparison has been performed between the abstracted functions for level crossings and point-switches. Although it is expected that they can be quite similar, depending on the evolution of the functional requirements towards RCA, some specific functions may differ between them.

5.9.3 Use of the EULYNX SCI-LC

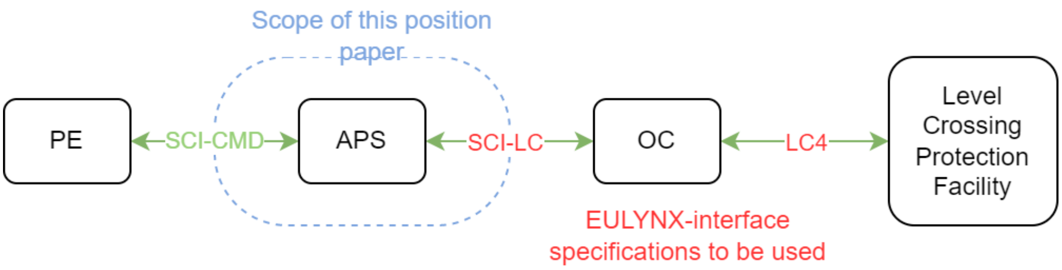
In chapter **definition of system under consideration** a overview was given about Level Crossings themselves and their interfaces with APS, in which the Level Crossing Protection Facility and the Object Controller are seen as external actors and be connected via a standard interface.

APS interfaces with this OC or the Level Crossing Protection Facility to send commands to and receive information. For communication towards APS the interface 'Standard Communication Interface Level Crossing' (SCI-LC) specified by EULYNX may be used, as RCA is based on the usage of EULYNX-compliant interfaces to the level of field elements. The SCI-LC is an update of a former present interface specification in EULYNX.

The intention of the SCI-LC is to support a central steering of activation and deactivation of a Level Crossing. This fits to the approach of APS.

In comparison, the SCI-LX is mainly focussing on Level Crossing Protection Facilities being responsible for activation and deactivation by its own (see EULYNX System Definition, chapter 5.10 "External Level Crossing System").

The figure below shows an example of a level crossing interface with APS via OC through the SCI-LC interface. The interface LC4 is internal in EULYNX definition, shown for given the complete view only.



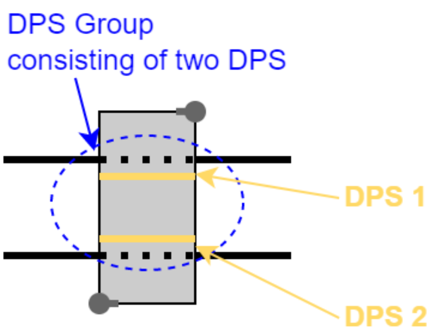
The information on SCI-LC are currently defined based on current interlocking functionality. No abstraction with DPS was taken into account based on RCA context. Thus a translation of SCI-LC compliant information towards the abstraction to be used in APS is needed. This must be performed on a lower level in APS, to avoid any specific-coded artefacts in the core Safety Logic. Any changes in the EULYNX specification must be accompanied by the RCA development in order to avoid weak points in the system integration.

5.9.4 Functional approach

5.9.4.1 General handling of LX by DPS

RCA will make use of the Domain Objects DPS and DPS Group as introduced in /RCA.Doc. 61/.

According to the principle of a generic safety logic, APS abstracts a Level Crossing with a DPS Group. Each DPS Group consists of one or more DPS depending on the amount of tracks the Level Crossing area contains. The following graphic illustrates a Level Crossing with two tracks:



Whilst further delimitations are not available regarding the levels of optimisation and standardisation which shall be resulting from the consultation with the relevant stakeholders (the aim of this position paper), the below described solution seeks to demonstrate how a solution to cater to all functional topics discussed in the paper could be reached. It becomes self-evident that the more the requirements lead to more specialised abstraction solutions (as opposed to a generalised one), the more complex would be the resulting architecture.

Considering the previously defined chapter **APS LX classes**, abstraction of field elements from the APS LX class (a) can be seen similar to the abstraction of point-switches - i.e. the securing of the level crossing must be fully performed before the granting of the MP. In other words, all actions at Level Crossing must be successfully performed, similar to the full switching process up to the locking of a set of points, before APS executes the safety check for the authorisation of a train movement.

On the other hand, the field elements belonging to APS LX class (c) follows the principle of executing the securing process in parallel to the train approach the crossing. Only the availability state of the protection system is verified at the time of the request - and therefore the execution of APS safety checks - for the authorisation of a train movement. This means that, if RCA is to be responsible also for the activation of this type of level crossing, the request for activation must be issued after the authorisation of the movement, contradicting the scenario described above. For this type of Level Crossing it cannot be derived from the DPS state alone, whether the Level Crossing is technically secured - i.e for example, warnings lights towards road users switched on).

The handling of field elements belonging to APS LX class (b) does follow in majority the characteristics of APS LX class (a).

At Level Crossings, degraded operations may be possible in case of faults, shifting responsibility from movements with the highest safety level to a driver or to other systems. This can be marked with a specific state to indicate this need, derived from information received from the Level Crossing Protection Facility. Differentiation of operational cases - including restrictions - and specific functions required for securing the route path could be needed by the various Infrastructure Managers.

States of DPS and DPS Groups as well as their relevance to Level Crossings are described in the following tables.

DPS Group states are used to represent inside RCA the reported availability state from the switchable field element.

DPS Group state	Description in context of Level Crossing
READY	The Level Crossing Protection Facility is available to process incoming command within the required functionality. *Note: specific failures of equipment can be accepted, if they do not affect the safety or function.*
PROCESSING	The Level Crossing Protection Facility is processing an activation request from APS. *Note: This Group state can indicate the ongoing activation, due to compared to points no emmidate state change of the DPS drivability attribute is present. Alternative workarounds with an additional DPS drivability attribute are possible too. At this early stage, this shall serve as a potential information for any recognition on the ongoing actions for PE and the PAS first. The further need of investigation is documented in chapter* ***open tasks/ issues***

DPS Group state	Description in context of Level Crossing
DISTURBED	The Level Crossing Protection Facility is disturbed, i.e. there is a minimum of one unacceptable malfunction.

DPS drivability attributes are used to represent inside RCA, under which conditions a train might pass the Level Crossing.

DPS drivability attribute	Description in context of Level Crossing
FULL	The Level Crossing Protection Facility is in the Protection State: • 'activated', • 'closed' or • 'closed and no obstacle between the barriers'.
FEASIBILITY_CHECKED	The Level Crossing Protection Facility is in the Protection State: • 'activation is feasible'.
LIMITED	The Level Crossing is in the Protection State 'not protected'. The Level Crossing can be passed by a train by considering degraded operational rules/restrictions. *Note: This state is foreseen as placeholder for any movements based on Movement Permissions for degraded operation.*
NONE	The Level Crossing is in the Protection State of LX 'not protected'. The Level Crossing cannot be passed by a train on regular base. *Note: This state is foreseen as placeholder for specific degraded-type movements outside the rules/restrictions allowed for Movement Permissions for degraded operation.*

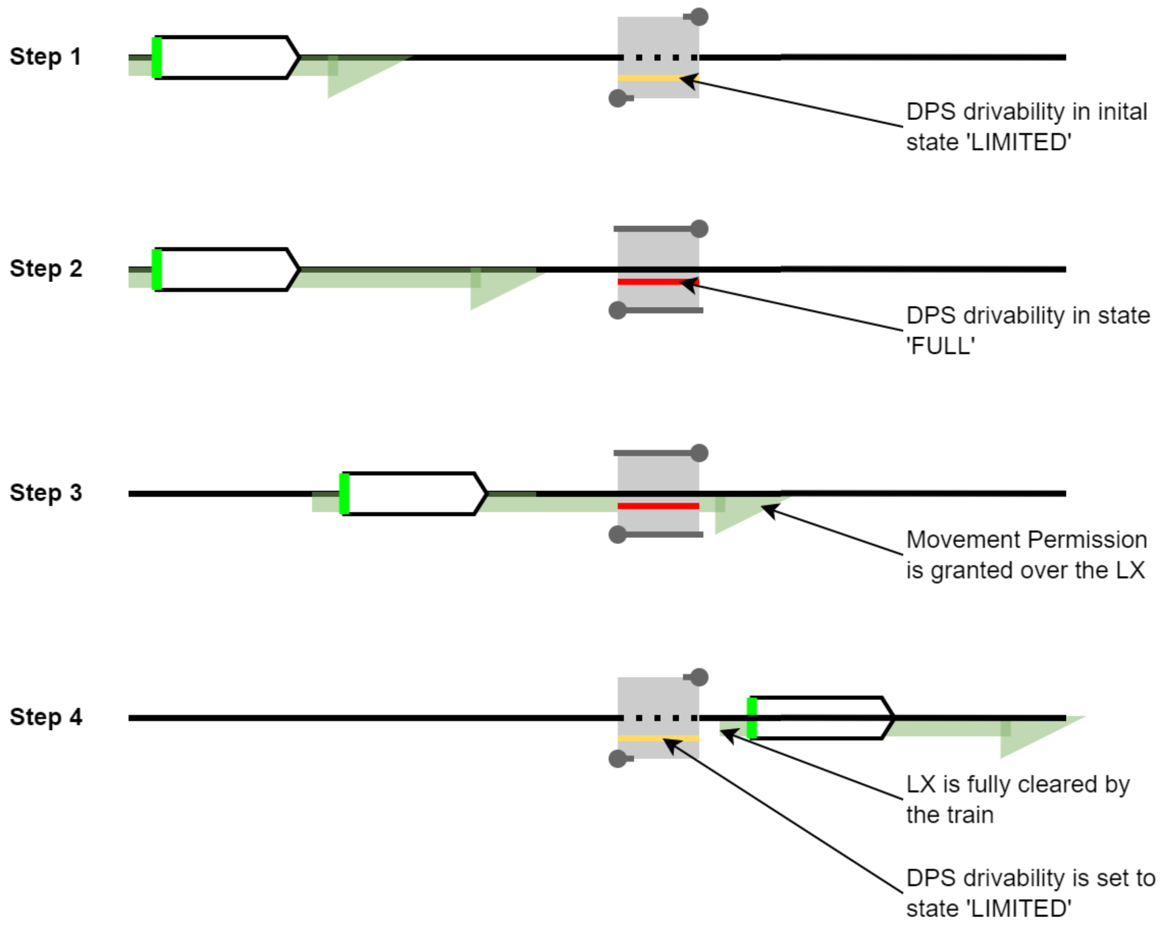
The following fact, shall be considered:

To be investigated	The specific handling of the DPS Group states must be checked in detail, covering also multiple requests.

The following sub-chapters will describe the foreseeable functions for the implementation of the mentioned scenarios. The scenarios will focus on the DPS drivability. The DPS drivability attribute 'LIMITED' is assumed as the initial state of a non-activated Level Crossings, 'NONE' could also be used as an alternative use case. The consideration of DPS Group states will be added in a later version of this document.

5.9.4.2 Functions handling single track scenario

Following figure illustrates the several steps of the scenario, based on the general definition previously given in the chapter **single track scenario**.



Step 1 illustrates the operating state at the time when the preconditions are present. The Level Crossing is not protected. As the Level Crossing consists of only one track, one DPS in the DPS Group is present. The DPS is in the initial state 'LIMITED'.

Should a Movement Permission be set over the Level Crossing, the DPS must first be changed to the required DPS drivability state 'FULL' or 'FEASEBILITY_CHECKED' in advance for enabling an unrestricted movement. The change of the DPS state is triggered by PE by sending a DPS Group request to APS. The correct APS LX class is stored in application data for enabling the simplest check to reach the required state. The request is for all APS LX classes the same, only the time when the request must be issued by PE depends on the APS LX class and the specific situation including the information of the specific movement. This request for the DPS is transferred to commands towards the interfaced Level Crossing Protection Facility. After processing and the successful reporting that the tasks (when required by the specific installation) were performed, the DPS drivability changes to the state 'FULL' (depicted in **Step 2**). Alternativly state ' FEASEBILITY_CHECKED' is reached.

This change to the required state enables the subsequent request for a train movement authorisation by PE to be processed and granted (assuming no other conditions prevent it). To grant the Movement Permission covering the Level Crossing represented by the DPS, safety checks are performed by APS according to /RCA.Doc.63/.

Additionally, specific functions for Level Crossings associated to APS LX class (b) and (c) may be needed, as for them the securing process was started but not yet accomplished. That is why APS must check that the approach time of the train is sufficient to perform the outstanding tasks accomplishing the securing process (e.g. closing all barriers). This means the specific application data will become a additional condition for the granting of the Movement Permission. Therefore Engineering Data of the Level Crossing must be provided, such as securing time of the Level Crossing. This may contradict the approach of a simple APS, but will be needed to be functional. If all safety checks performed successfully, then the MP is granted over the Level Crossing **(Step 3)**.

After performing all outstanding tasks, the securing process of the Level Crossing is finished. The train movement can pass the Level Crossing.

Note in the case of APS LX class (c), the on-time issuing of the command for the activation would at this point still be outstanding (non-optimised scenario). This task is then safety critical and, assuming no physical strike-in is provided on the track, it shall be performed by APS. APS must then activate it on-time by means of a safe activation procedure, in which case the safe execution activation command must be guaranteed by the Level Crossing Protection Facility. Thus for the Level Crossing Protection Facility a high demand on safety and availability must then be present.

The following table gives an overview of all functions to be performed by APS to activate and deactivate a Level Crossing, covering all steps of the scenario. These functions are linked to functional blocks and marked up regarding their validity for the specific APS LX classes. Based on the single track scenario a first overview of the functions needed shall be demonstrated. As noted in the remark column, there are functions which currently differ from DPS handling of points and derailers (tagged with ' LX specific'). This implies that APS would require to know if a DPS Group abstracts a Level Crossing or a point-switch, as these functions would not be used directly for points and derailers. This could be ensured by appropriate parameter value. Furthermore some functions are not applicable to all Level Crossings. This means APS must additionally know by data, how to follow the function. Also these functions are named in column 'Function'.

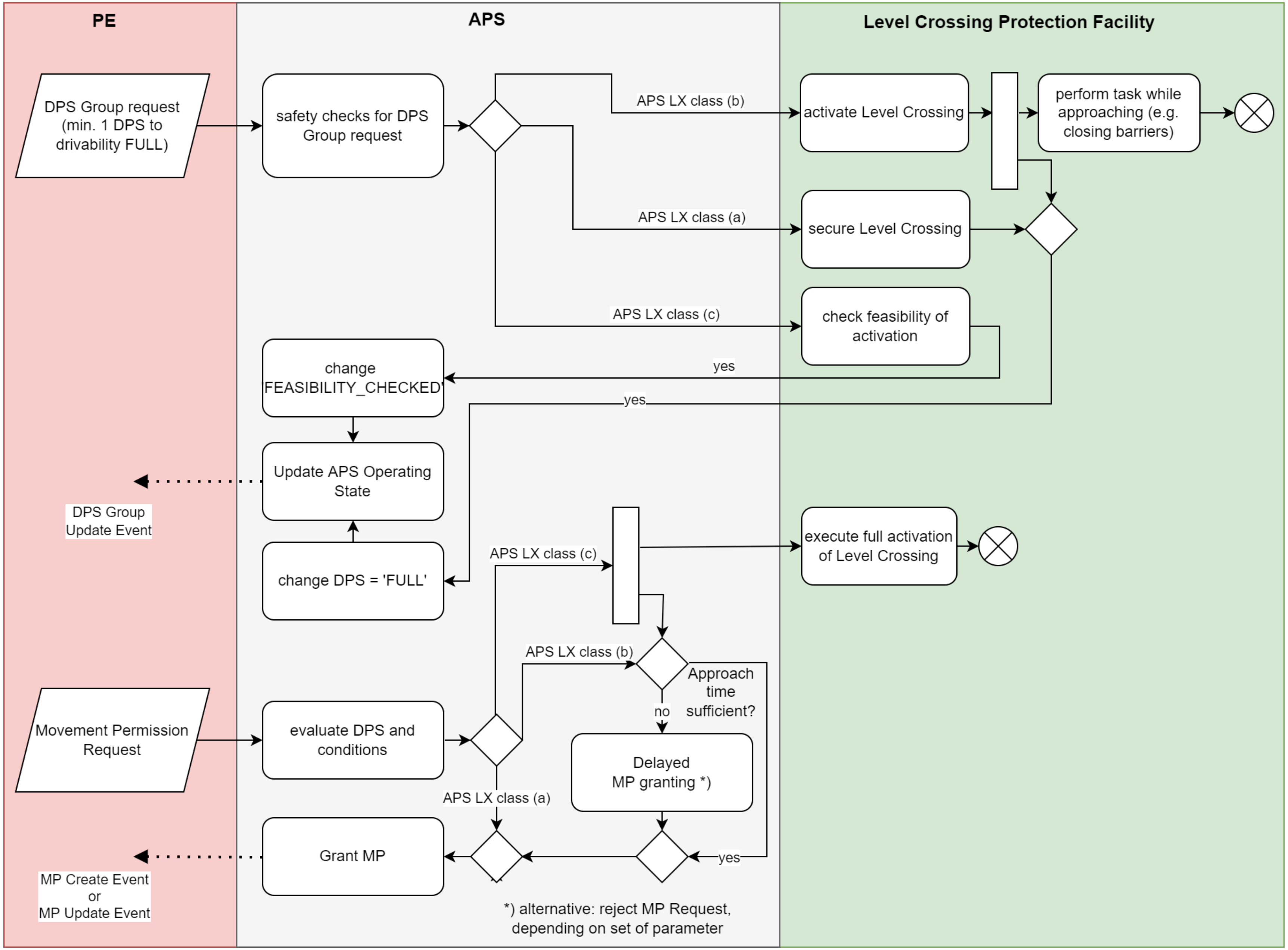
Functional block	Function	APS LX class			Remark
		a	b	c	
DPS Group Request (DPS = 'FULL' or 'FEASIBILITY_CHECKED') to establish the required Protection State of LX	general safety checks, see /RCA.Doc.62/ • DPS Group Request syntax check • DPS Group Request existence check	x	x	x	
DPS Group Request (DPS = 'FULL' or 'FEASIBILITY_CHECKED') to establish the required Protection State of LX	specific safety checks *(optional for APS, see remark)* • guarantee of the minimum opening time of a Level Crossing	x	x	x	LX specific, not valid for points and derailers. This check shall ensure, that an already opened Level Crossing cannot be closed in a short time span, see section multiple movements on several tracks. The realisation can be made in APS by known this per DPS and prohibiting any positive processing of the DPS request, or by a function in the Level Crossing Protection Facility.

<table>
<tr><th rowspan="2">Functional block</th><th rowspan="2">Function</th><th colspan="3">APS LX class</th><th rowspan="2">Remark</th></tr>
<tr><th>a</th><th>b</th><th>c</th></tr>
<tr><td>DPS Group Request (DPS = 'FULL' or 'FEASIBILITY_CHECKED') to establish the required Protection State of LX</td><td>the following functions of /RCA.Doc.62/ does not apply for Level Crossing:
• DPSGroup clear proving
• Conflict check of DPSGroup in MP extent
• Conflict check of DPSGroup in
• Conflict check of DPSGroup and protecting elements in 'riskPath' is undefined</td><td></td><td></td><td></td><td>LX specific, functions must be disabled by value</td></tr>
<tr><td>DPS Group Request (DPS = 'FULL' or 'FEASIBILITY_CHECKED') to establish the required Protection State of LX</td><td>DpsGroupRequest granting/reject</td><td>x</td><td>x</td><td>x</td><td>A DpsGroupRequest fulfilling all checks above will be granted.
If one of the checks is not successfully performed, the DpsGroupRequest will be rejected.</td></tr>
<tr><td>DPS Group Request (DPS = 'FULL' or 'FEASIBILITY_CHECKED') to establish the required Protection State of LX</td><td>additional function (optional for APS, see remark)
• start time to 'supervise the maximum Off-time'</td><td>x</td><td>x</td><td>x</td><td>LX specific, the timer starts at activation. This can be handled by APS or by a function in the Level Crossing Protection Facility</td></tr>
<tr><td>MP Extend request over LX</td><td>general safety checks and specific safety checks, see /RCA.Doc.63/</td><td>x</td><td>x</td><td>x</td><td>valid for MP request in general</td></tr>
</table>

Functional block	Function	APS LX class			Remark
		a	b	c	
MP Extend request over LX	perform additional safety checks if a LX is within the MP extent (and optional Risk buffer extent) • for APS LX classes types (b) and (c) it must checked, if the time /distance for performing the further tasks can be performed before train reaches the Level Crossing	-	x	x	LX specific, function must be handled with static time/distance or an algorithm
Activate LX on time	Perform on-time activation	-	-	x	LX specific, safe function APS
Supervision functions referring to timers	In case specific timer 'supervise the maximum off time' elapsed, a notification shall be send to PE as notification .	x	x	x	LX specific, a message "DPSOfftimeExpiration" is transmitted. No specific safety investigation for need of intervention is defined yet.
Supervision functions referring to timers	In case of a Level Crossing was deactivated, a timer to supervise the minimum opening time is started.	x	x	x	LX specific, could be implemented as alternative with check function of time stamps of DPS state change too

Functional block	Function	APS LX class			Remark
		a	b	c	
Automated deactivation of LX	If a movement passes the Level Crossing and clears the DPS the Level Crossing will be deactivated automatically, if: • block against automatic deactivation is not present for the Level Crossing • no further DPS of the Level Crossing is in state 'FULL' or 'FEASIBILITY_CHECKED' • the DPS Group is not in state 'PROCESSING' This leads to a change to the DPS state too.	x	x	x	LX specific The defined conditions must be managed by APS that e.g. there is no automated deactivation if a further movement shall take place the Level Crossing Protection Facility is not aware. The trigger of deactivation can the Level Crossing Protection Facility itself (in case of own sensors/TVPS) or by APS in case of clearance is recognised trackside.

Following graphic summarises the activation process of the LX as described beforehand.


PE
APS
Level Crossing Protection Facility
DPS Group request (min. 1 DPS to drivability FULL)
safety checks for DPS Group request
APS LX class (b)
activate Level Crossing
perform task while approaching (e.g. closing barriers)
APS LX class (a)
secure Level Crossing
APS LX class (c)
check feasibility of activation
yes
change FEASIBILITY_CHECKED
yes
Update APS Operating State
DPS Group Update Event
change DPS = 'FULL'
APS LX class (c)
execute full activation of Level Crossing
APS LX class (b)
Approach time sufficient?
no
Movement Permission Request
evaluate DPS and conditions
Delayed MP granting *)
APS LX class (a)
Grant MP
yes
MP Create Event or MP Update Event
*) alternative: reject MP Request, depending on set of parameter

Note: The graphic focus on the activation process of the Level Crossing and is not exhaustive in regard to further functionalities such as further safety checks for MP granting and the demonstration of all scenarios where checks fails.

After the train has fully passed the Level Crossing, the Level Crossing must be deactivated to make way for the road users. There are two ways of deactivation:

1. Automatic deactivation by APS (standard application in APS)
2. Automatic deactivation based on manual request by PE

For the automatic deactivation by APS, the shortening at rear end according to /RCA.Doc.63/ is used to trigger the deactivation automatically. If a movement passes the Level Crossing and clears the DPS, APS changes the DPS state. From timeframe issues, this might be the fast solution.

In case of a manual request, it is the task of PE to send a DPS Group request in the optimal timing point. The following functions apply:

<table>
<tr><th rowspan="2">Functional block</th><th rowspan="2">Function</th><th colspan="3">APS LX class</th></tr>
<tr><th>a</th><th>b</th><th>c</th></tr>
<tr><td rowspan="3">DPS Group Request to deactivate the LX (manual request by PE)</td><td>general safety checks
• DPS Group Request syntax check
• DPS Group Request existence check</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>specific safety checks
• DpsGroup clear proving
• Conflict check of DpsGroup in MP extent
• Conflict check of DpsGroup in risk buffer (optional)</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>DpsGroupRequest granting/reject</td><td>x</td><td>x</td><td>x</td></tr>
</table>

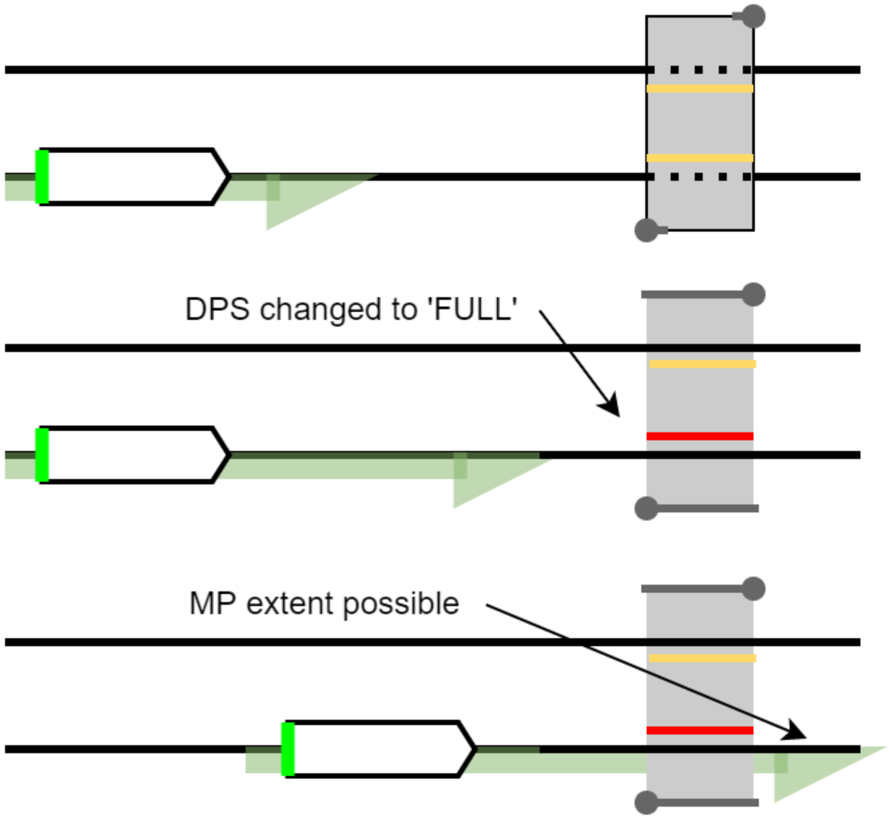
By finishing the deactivation process, the postconditions are achieved (**Step 4**).

To be investigated	The functional allocation towards APS or PE considering automated deactivation of a Level Crossing in terms of normal operation must be checked.

5.9.4.3 Additional functions handling multiple track scenario

In general, the handling of train movements over a multiple track scenario function does not differ to the single track scenario. The difference here is how to deal with several DPS in a DPS Group.

Following the general approach described in the previous sub-chapter, the required DPS is requested by PE before it requests the MP. This is represented in the follwing figure by marking only the relevant DPS to the required state. Nevertheless, even if one track only is needed, the whole Level Crossing must be secured.



These scenarios leads to further technical and operational demands:

- PE could request a DPS on a further track in-time to avoid a deactivation
- for following train movements a functionality hindering the release after passage would be needed, e.g. by a subsequent MP Request executed taking into consideration the otherwise required minimum opening time spam

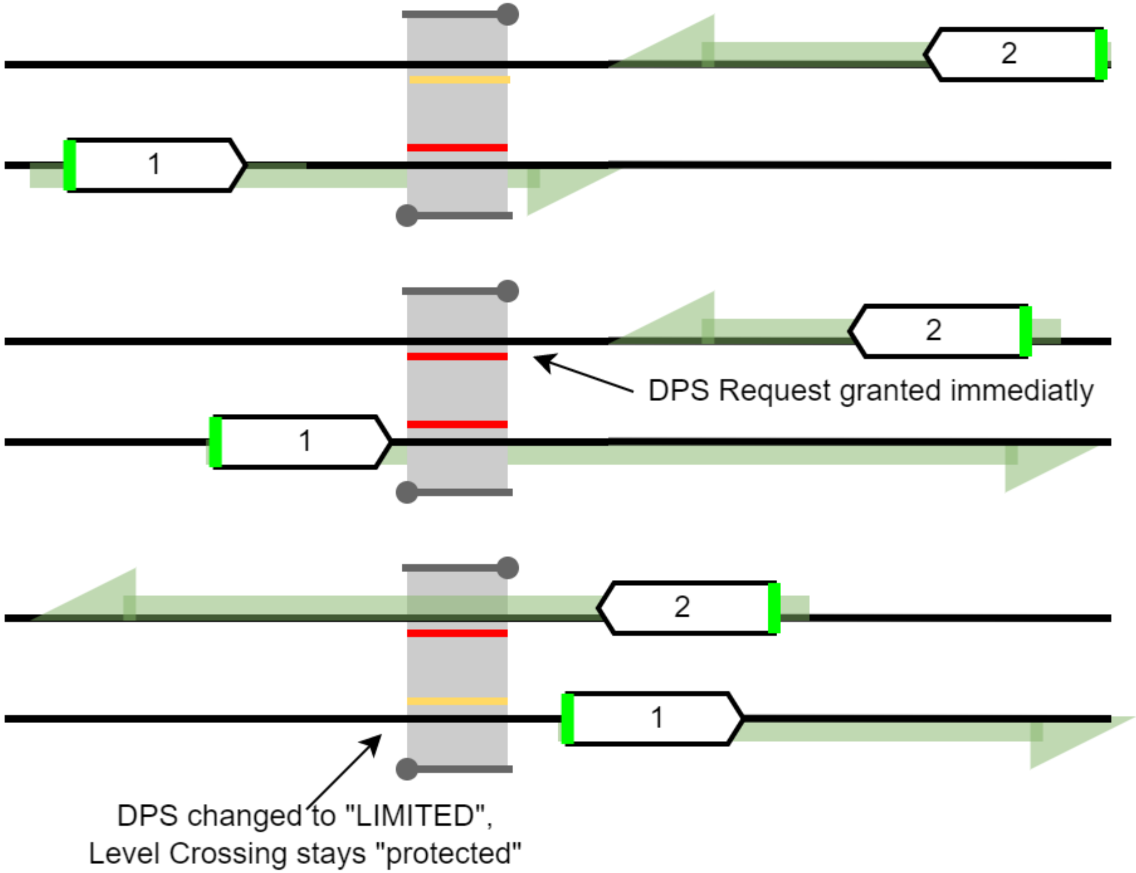
A potential workaround for simplification would be, to handle the DPS drivability states not track independently, setting the neighbouring DPS to the required state too. But this could complicate the image of which track was requested by PE and could hinder operation in degraded situations when the operational intention may not be clearly derived. This is yet to be investigated.

In case multiple movements occur at this topology, three functional areas shown in the next table are needed. Which function or functional usage is currently integrated in this concept is also noted.

description of situation	functional areas	responsibilities	compared to standard function on single track
in case a second movement approaches, a request for the DPS of the other track can be set in time, avoiding the automatic deactivation by APS of the Level Crossing	handled by usage of DPS Request in time by PE	PE	usage of standard function of this Level Crossing position paper; functions introduced in /RCA.Doc.62/ must be updated enabling state change of DPS if the DPS Group is already covered by a Movement Permission
in case a second movement approaches, the automatic deactivation of the Level Crossing could be blocked as alternative, by using the appropriate functions of the Level Crossing Protection Facility this situation could be used, if • the request for the DPS of the additional track/movement cannot be utilised • the movement covers the same track and a deactivation in between shall be avoided	handled with request by PE and avoidance of deactivation by APS (onetime or in general up to blocking is cancelled)	PE	implementation of function "block against automatic deactivation" PE can request and release this via the downstream messages 'DpsBlockAgainstDeactivation' and 'DpsReleaseBlockAgainstDeactivation' The current state is sent upstream with 'DpsDeactivationState' Note the operational safety responsibility for respecting maximal Off-times stays at PE.

description of situation	functional areas	responsibilities	compared to standard function on single track
in case a second movements does not follow close the other movement, APS must be able to process a deactivation of a Level Crossing and a further activation is only taken into account after a minimal time for passage for road user was guaranteed	check condition for APS	APS	implementation of check "LX was open for minimal time", this is covered by check of a timer (see also table of functions above in section single track scenario)

These functional areas apply, for the handling of movement '1' and '2' as an example. The in-time request of the additional DPS is shown as sequence in the following graphic. Based on the considered DPS stats this example applies for APS LX classes (a) and (b).



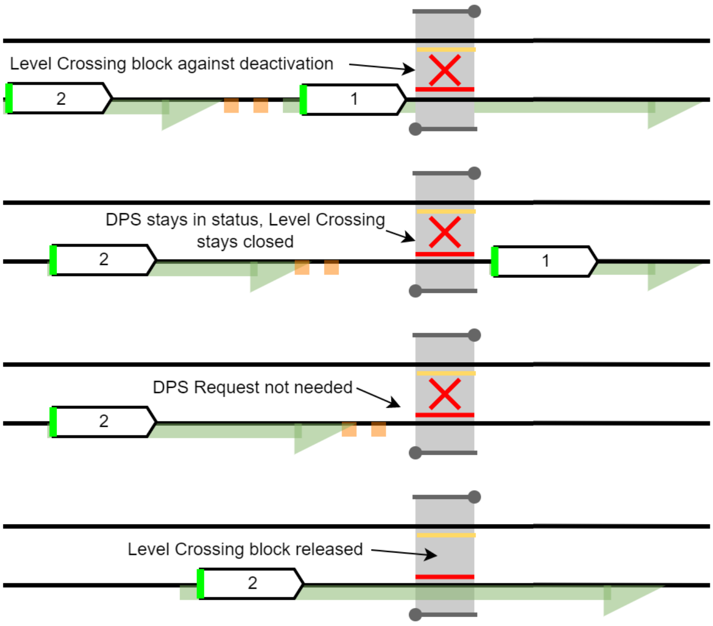
For the second movement, the additional DPS is requested. This both DPS's have the state 'FULL' and the DPS Group State is 'READY' over the whole time. Due to the Level Crossing is already protected, this change of the drivability of the DPS will be performed immediately, if no contradicting information is present from the Level Crossing Protection Facility. After change of DPS, the Movement Permission for the second train (indicated with "2") can be granted. The passage of the first train (indicated by "1") leads to a change of the DPS state. The Level Crossing stays protected, due to the second movement demands a securing.

If no further movements requires the protection, after passage of the second train the deactivation will be triggered and performed.

5.9.4.4 Additional functions handling multiple movements on single track

A specific use case occurs, if a closed followed movements on a single track is demanded- no matter whether on a single line or multiple track level crossing areas.

The figure shows a possible example on a double-track line:



Normally after passage of the first train the automatic deactivation is triggered, if no further conditions excludes this functionality.

The scenario can be handled by the already named 'block against automatic deactivation'. This implies an in-time request for this Level Crossing based on the operational situation. This functional block leads to the situation, that the DPS state would not change (as there is no need for it) following the passage of the first train. This holds the Level Crossing drivability status, while the Level Crossing is protected. For the second train, the MP can then be extended once the request is presented to APS. And if no further movement is planned after, the block against automatic deactivation can be released/cancelled.

Note if this release of the function 'block against deactivation' would be needed after the passage of the second train, a manual request for deactivation is necessary. A notification towards PE in case of elapsing of a defined maximum Off-time can underline this need. This assume a transmissing of information by the Level Crossing Protection Facility on the completion of the activation for all APS LX classes.

To be investigated	It must be checked, if in any case of the interfaced Level Crossing Protection Facility data is present, indication the start of the Off-time.

Note that although this scenario deviate from multiple movements on several tracks, it uses only the function introduced for blocking an automatic deactivation. I f the design choice would be not to independently handle track-individual DPSs, then the multiple movements on several tracks scenario described on the previous sub-chapter could be resolved in a similar fashion to this scenario described here above.

5.9.5 Derived requirements for handling of Level Crossing

Following the demonstrated functional approach, requirements can be derived for the handling of Level Crossing with APS. These can be grouped accordingly:

Specific knowledge of Level Crossing in general in APS and PE

- APS and PE must know direct or indirect, that a Level Crossing is abstracted in the system.
- APS and PE must know and consider in system design the operational and technical handling of Level Crossing in normal and degraded operation.

Specific knowledge of Level Crossing type/class in APS and PE

- APS, depending on the to be agreed functional needs, require to have specific knowledge of the Level Crossing including the kind of securing (named as APS LX class) it refers too.
- APS and PE must know the specific data, e.g. time for securing, for a correct time-based handling of request and safety checks.

Use geometric information or other given data to distinguish between Level Crossing and other switchable field elements in APS

- APS must use appropriate data while abstracting the real-world object to distinguish correctly between a Level Crossing and further switchable field elements abstracted.

Specific knowledge of dependency between Movement Permission and Level Crossing Protection Facility

- APS must trust on a appropriate safe handling by the Level Crossing Protection Facility and its Object Controller. For enabling APS, in system development it must be derived application conditions for the minimum required safety targets to be fulfilled by the installations.
- APS may need to assist the tracing of status information of the Level Crossing Protection Facility towards different kinds of securing levels by means of different kinds of operational handling. Based on this tracing APS must enable the possibility of introducing a matching table between the abstracted information data including the system functions and the received information via the standardised SCI-LC interface. APS must adapt these data streams outside of the safety core.

5.10 Solution alternatives based on APS tool-box

The considered approach until now is based on a usage of the abstraction of switchable field elements in general by one specific object - the Drive Protection Section (DPS). With regards to the current 'APS tool-box' defined by the APS domain objects in /RCA.Doc.61/ alternatives for handling of Level Crossing exists directly, like the Usage Restriction Area. In addition, the current 'APS tool-box' can be extended. At this stage, not all situations at a Level Crossing are fully defined, nor are those of other switchable field elements. This means that even for the demonstrated approach with the DPS some further development of the stepwise growing 'APS tool-box' might be used, especially for handling of degraded operation.

Two thoughts on alternatives shall serve as an outlook on possibilities for enabling appropriate feedback to this position paper.

Creation of additional abstraction object: Besides the defined DPS suitable for many kinds of switchable field elements, further element can be created. This means that as a minimum the Level Crossing but also further functionally relatable systems could be abstracted differently, like a point or derailer. APS must consider this specifically by their associated functions. As sets of functions can be assigned accordingly to new objects needs, a DPS must not be grown functionally-wise to cover of all kinds of switchable field elements. The complexity could be addressed instead, apart from by the careful delimitation of how much detailed functionalities are to be absorbed by RCA, also by having not only a single abstraction object per type of interfaced installations. The specific impact and weighting of this alternative cannot be made at this stage because RCA is not mature yet to have a full reference to enable a clear demonstration and comparison. This alternative does not change or delimitate the possibility of handling of different securing approaches. In case of this object is created also a split of Level Crossing according the APS LX class is possible. This means APS LX class (a) can be still use DPS while the further use a new defined object.

Use of Usage Restrictions Areas: Instead of using DPSs, the Usage Restriction Area (URA) could be used to control train movements too. I.e. in case the Level Crossing is unprotected, a restriction could be performed. A protected Level Crossing shall then release the restriction. in this case, to enable transparency, the "release" could be given by having an unrestricted URA. Otherwise the Level Crossing would not be visible if the data element is lost. With regards the type of activation, this does not have any influence here. This example is only a different usage of another APS domain object. But similar to the alternative described before, this one splits the system functions from the DPS. The weakness would be the overload of the URAs where normal operation is to be used.

5.11 Further considerations on operational handling of railway signalling and Level Crossing users

Following the description of the functions considering the technical solution interfacing Level Crossing towards APS as part of RCA, some considerations regarding operational handling of railway signalling and Level Crossing users must be given.

For the transmission of information to authorise the passage of a train at a Level Crossing, different means are common in current applications:

- Signal aspect route-protection: no specific signalling is provided for a Level Crossing. The Level Crossing is treated as element of the overall route to be secured. The signalling logic follows the principles of railway route signalling.

- Level crossing specific signals: The Level Crossing has its own signals indicating route related or level crossing specific aspects. In the most cases the signals are placed in advance of the level crossing, taking into consideration the worst braking distance of the line. Where level crossing specific aspects are used, the driver is able to recognise the current protection state of the level crossing by the displayed aspect.
- Remote communication on fallback operation: the operator is able to communicated remotely with the driver when a malfunction of a Level Crossing is detected. This includes also the issueing of written orders for enabling fallback operation. Thus the signalling can be based on paper.
- Protection status information issued to the driver's cab: the control system issues the state of the Level Crossing as additional information to the cab. This is common for radio-based ETCS application as an example and occurs mainly to warn the state "not protected".
- No information: In some cases no information is portraited to the driver, e.g. if a remote supervision of the level crossing's feasibility for activation or protection status is executed by an operator prior to issuing the driver with authorisation to proceed, in case any failures occur, the driver would be informed directly by the operator.

The interface to the Level Crossing users are given by road sign or signals, in some cases via a direct interface to railway systems e.g. by measures like lowered barriers.

The handling of Level Crossing in RCA connects therefore to the technical harmonisation (e.g. issues regarding radio-based ETCS integration in terms of EULYNX), the operational harmonisation (i.e. how to ensure the many technical solutions can operated in a similar fashion without impacting safety or performance targets), and specific legal aspects of handling the Level Crossing users from a national point of view. This should be treated as a stepwise development departing from the current situation.

The RCA CCS approach with less trackside assets and the enabling of up to fully driverless automated operation and busier networks have an impact on the current delineation of normal operation. In addition a better handling of fallback situations will be required from both safety and capacity points of view.

Focusing first on the signalling towards the railway operation two aspects must be considered:

- Due to movement start anyway (see /RCA.Doc.63/), no lineside signalling is possible. T here is no need for signalisation the Level Crossing in normal operation. For the driver the situation is similar to ETCS application in Level R today.

- In the case of degraded scenarios however, information must be present to the relevant actors to enable the corrective measures to be executed. Depending on the granularity of mitigation measures and functions (graceful degradation), there must be a clearly defined set of information available. E.g. in the current ETCS applications the 'not proteced' status is directly present, but ETCS tool-box handles the situation with specific movement authority, sharing some of the safety-assurance responsibilities with the driver, but with the advent of ATO this responsibility is required to be shift to another actor. Initiatives within RCA and OCORA currently investigate solutions for handling this. In addition an approach is named 'Remote Driving' where trains will be taken over by drivers placed in a control centre using several transmitted information like video.

In general the interface of Level Crossing users is not fundamentally changed with the advent of this workstream. But with parallel automation of road-vehicles, aspects like the potential communication between railway and crossing path control system, e.g. adjacent road traffic system installed on road-vehicle, could be used for risk mitigation in the future. In addition, the railway could consider the absence of the road-driver as a "risk reduction measure", when in system design, because it could remove the factor of road-users disregarding risk and not obeying traffic rules at level crossings.

6 Conclusion

6.1 Solution summary

APS can enable handling of Level Crossings by a tool-box principle. The level of granularity of required specific differentiation must be defined in coordination with various stakeholders. This includes different ways of handling the many kinds of the Level Crossing Protection Facilities - summarised in this document by the introduced APS LX classes, and the consequent transfer of responsibilities for the management of risk in each case.

APS can abstract the Level Crossing using the Domain Objects 'Drive Protection Section' (DPS) and 'DPS Group' so that each Level Crossing is controlled by generic functions. Additionally, APS could provide specific functions depending to specific installation types. And alternatively, the abstraction could also differ from that of other switchable field element like point-switches, thus allowing APS to respond to such Domain Objects with other appropriate functions. Other alternatives like usage of Usage Restriction Area (URA) indicating the drivability are also possible.

APS could also support optimised activation of the LX in order to reduce the Off-time of the LX to a minimum, utilising trackside and onboard information to specifically adapt each activation process. In this way APS could contribute to further improvement of usage of capacity, but maintaining the responsibility for operational optimisation at the Planning System (no part of RCA).

For the signaling to the train in normal operation the situation is easier with APS compared to nowadays applications. For the handling of degraded operation the complexity and possibilites grow-up. Based on the choice of one single solution handling Level Crossing with APS or having a tool-box like proposed, a matrix of possible operational situation is simple or complexe. This leads to efforts in system design, but enables an efficient handling of different situations. An APS tool-box enables the inclusion of different conditions of different applications too.

6.2 Questions to the reader/stakeholder

Some general questions are exposed to readers and stakeholders to encourage feedback for the ongoing conceptional design process in RCA:

- Is one single abstraction solution enough (possibly requiring some physical interfaces to be kept trackside at some LX types), or highly specialised tool-box for activation and securing LXs is needed in APS?
- Should standalone Level Crossing Protection Facilities solutions in main line application exclude knowledge share for safe operation with PE and APS (including instances where the safety measures are fully handled outside of the RCA system)?
- Shall PE manage the optimisation of activation of Level Crossing based on information provided by PAS?
- Is RCA required to absorb the management of safety-risks nowadays managed by design-solutions in current installations in order to justify the overall net increase of safety target?
- Is a differentiated handling of Level Crossing in the risk buffer required?

- Should RCA assume the pre-standardisation of interfaces by EULYNX (This includes the question concerning the focus in RCA only given on SCI-LC, no coverage of SCI-LX as interface standard is planned yet.), and if so, the need for a stepwise migration of current installations by IMs before RCA could be used as a product; or should RCA be required to support the interface also of current wide types of applications?
- What kinds of operational features are required with regards operational harmonisation - for example at first instance, for the authorisation of ETCS supervised movements over not fully technically secured LXs?
- Is it required to support obstacle detection standalone application outside of Level Crossing Protection Facilities, or should the integrated system approach with a EULYNX-compliant interface installation be the only allowed solution, in which the obstacle detection is directly used as criteria for route protection? This does not exclude any further detection of obstacles, e.g. by Perception (PER).

6.3 Open tasks/issues

As reference, the following topics were not covered by this position paper (non-exhaustive list):

- a detailed investigation of degraded and emergency operation scenarios,
- a detailed assessment on the (non-) handling of open crossings in RCA/APS environment
- the cross-check with ongoing EULYNX development detailing with focus of ETCS level R application,
- the assessment of human factors considerations based on operational introduction of GoA 2 and above,
- the check usage of DPS Group State 'PROCESSING' - e.g. in case of multiple requests per track by considering:
    - PE and PAS might need feedback on ongoing activation process of Level Crossing
    - the time-based handling of PE for DPS Request and MP Request for Level Crossing is different in case no activation is yet started or an activation is already ongoing (multiple track scenario)
    - it is currently not drafted in detailed time-sequence, how PE, APS and the Level Crossing Protection Facility will perform in case of multiple request for different tracks are needed
    - the scenario for handling multiple Request while the initial Request is not performed sucessfully, is not drafted
    - from interface view it must be clarified, if a kind of "busy information" from the Level Crossing Protection Facility towards APS is needed, based on the present integration conditions of the Level Crossing Protection Facilities
- the detail cross-check with APS' attributes and functions derived from DPS and DPS Groups attributed to point-switches, including the need of the ad-interim defined DPS Drivability State "FEASIBILITY_CHECKED' in terms of APS Operating State and the handling by PE and
- check of worksplit with parts defined under the Incident and Prevention Managament (IPM).