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INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

D3.2.5 Technical and RAMS requirements/recommendations for the actuation system, the locking and the detection device for UIC 60-300/1200 switches

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CO	Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

Abbreviation/acronym	Description
DLD	Drive And Locking Devices
DTC	Design To Cost
LCC	Life Cycle Cost
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
RAMS	Reliability Availability Maintainability Safety
S & C	Switch and Crossing

1. Introduction

Major cost driver for S & C are:

- Preventive maintenance
- Corrective maintenance.

On installations in two Countries (Germany and Sweden) the analysis of the LCC indicates the highest potential for LCC reduction in the maintenance section. Therefore target configurations for S & C in the size UIC 60 300- 1200 are proposed (1). The switches in this range account for approx. 60-75% of the cost in Sweden and Germany

The purpose of this document is to brake down the general definition to the component level describing the features that need to me modified and the requirements to be met to archive the proposed LCC reduction.

The requirements in this document shall guide manufacturers to the development of components to meet the target LCC reduction.

2. Main section

2.1 System configuration for switch types

The target configuration for DLD components is derived from the work done on the LCC estimation in the InnoTrack project (1).

Actuator A2015 (Innotrack target)

- Modular design concept with
  - Drive unit
  - Locking unit
  - Detection unit
  - Control unit
- All components integrated into a hollow sleeper
- Each component individually replaceable within 30 minutes
- Maintenance interval 12 months, 1 h maintenance per year
- Cost for replaceable unit 2.000 € in average (exchange price)

Detector D2015 (Innotrack target)

- Detection unit
- Installed on a regular concrete sleeper (i.e B 70)
- Replaceable within 30 minutes
- Maintenance interval 12 months, 0,5 h maintenance per year
- Cost for replaceable unit 1.000 € in average (exchange price)

In order to achieve a high safety level and a better system performance the Innotrack team has decided to change the number of actuation and detection layers compared to the current standards in the railway networks.
Recommended is a system shown in Figure 1. This contains a position detector for each actuation point.

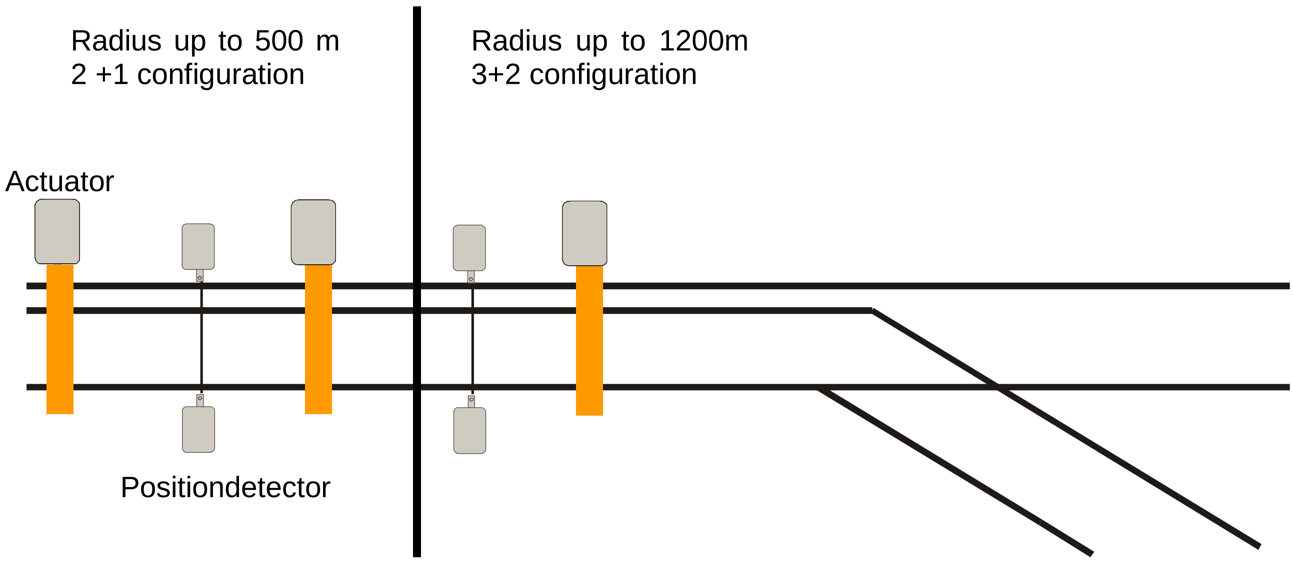

Figure 1: Position of actuators and detectors

2.1.1 300, 500 m radius

The target configuration consists of:

- 2 integrated actuation, locking and detection units (Actuator A2015)
- 1 detection unit (Detector D2015).

2.1.2 760-1200 m

The target configuration consists of:

- 3 integrated actuation, locking and detection units (Actuator A2015)
- 2 detection units (Detector D2015).

2.1.3 Geometry

Position of actuators in available solutions. The position refers to the tip of the switch blade (tongue).

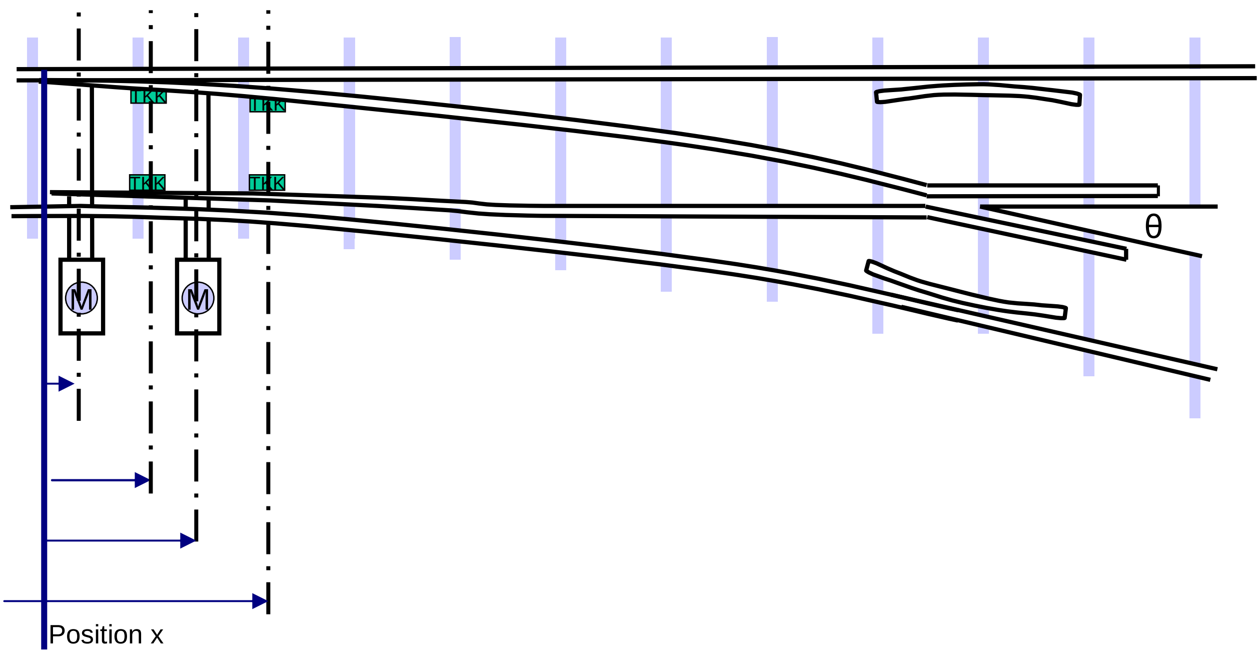

Figure 2: Reference, Actuator and position detector positions, example Banverket UIC 60-760 switch

Banverket	UIC 60- 760	Stroke		UIC 60- 1200
Actuator 1	**328**	Not available	328	Not available
Actuator 2	**7598**		9358	
Position detector 1	**3658**		4878	
Position detector 2	**12128**		15738	
ÖBB Hydrostar	60E1- 760		60E1- 1200	
Actuator 1	**534**	120	535	120
Actuator 2	**5244**	100	7179	100
Actuator 3	**10001**	72	12662	80
Position detector 1	**3449**		5343	
Position detector 2	**8198**		10820	
DB				
Actuator 1	**503**		**503**	
Actuator 2 (gear, rod)	**5903**		**7103**	
Actuator 3 (gear, rod)	**10651**		**11851**	

Table 1: Current positions in mm of Actuators and position detectors according to Figure 2

Banverket uses 2 single actuators at each position. The actuators are fixed on two extended concrete sleepers. The locking device is integrated into the drive unit which is not state of the art. The fixation of the external drive on two elongated concrete sleepers appears very robust and superior to current solutions with external drives adapted to wooden sleepers by means of adapter plates.

DB network uses 1 actuator. The force is distributed to the actuation points via one or more gear (twin rod) drives.

In opposite the most progressive solution for the ÖBB is designed for the application of a actuation system which is integrated in a hollow sleeper. This solution consists of 2 respectively 3 actuators. The positions of the actuatuors are very similar to the DB system. The differences are caused to the application of hollow sleepers which requires of course an adaptation of the actuation layers to stay in the same sleeper distance. The system meets the proposal for the target configuration with features such as:

- Integrated locking device between the sleepers
- Use of a hollow sleeper
- Position detector on a sleeper.

The ÖBB system has been successfully implemented on many switches. The safety level is among the highest since the number of actuators and position detectors is higher than for the other applications. Therefore thus design can be taken as a reference for the Innotrack proposal as described in the framed part of table 1.

The edge of the switch blade can be designed and manufactured differently according figure 3.

It needs to be taken care that the distance X from the milling of the switch to the position of the first actuator doesn`t exceed a maximal value. Recommended for the profile ZU1-is 60 - 300mm.

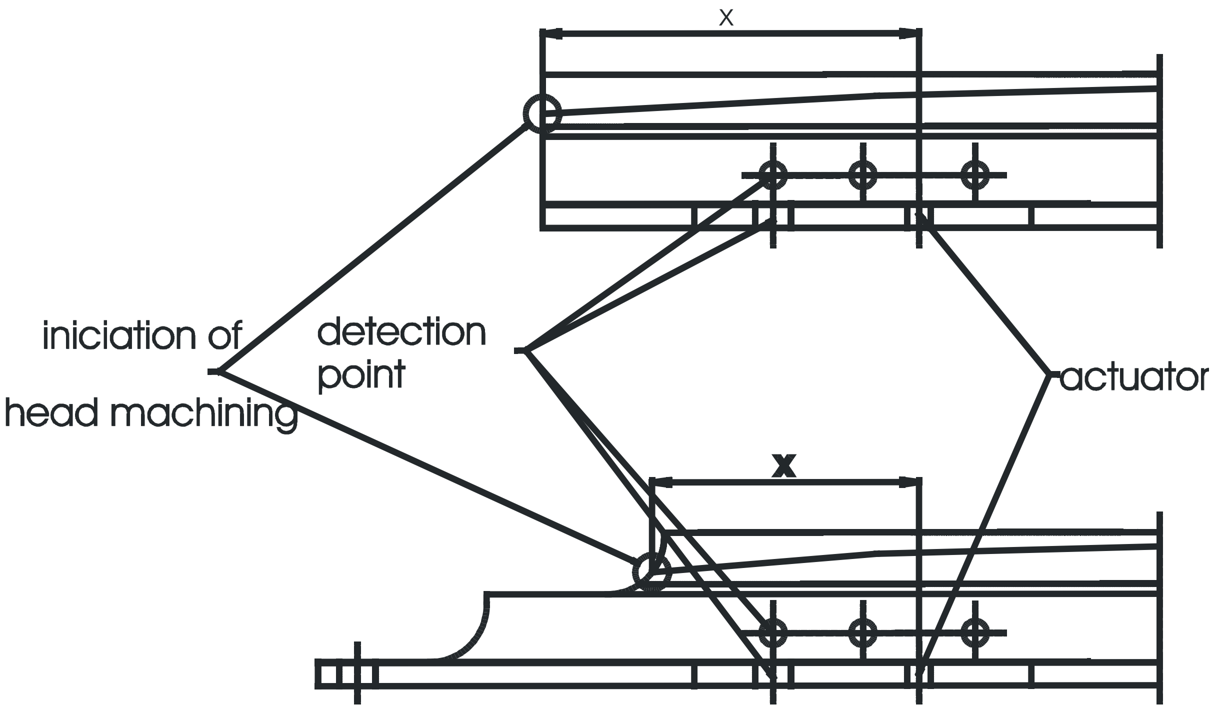

Figure 3: Different head machining of the switch blade tip (above and below).

2.2 DLD Technical requirements

In the following table the requirements are listed. A detailed description for motivation, benefit or a example illustrating the benefits is given under the individual topics following this table.-

No	Description	Benefit/Motivation
2.2.1	Auto-diagnostic system with monitoring of operation parameters	Extended maintenance cycles Condition based maintenance concept possible
2.2.2	3-phase brushless asynchronous motor	Low cost, industry standard motor
2.2.3	Clear separation between power and signal lines	No nuisance trapping on signal line, no switching, More functionality
2.2.4	Stroke adjustable from 60 mm to 220 mm	Needed for multiple drive points, size UIC 60-500 up to 1200 m
2.2.5	Switch not trailable	Simplified DLD design, improved safety, harmonized requirements in Europe

No	Description	Benefit/Motivation
2.2.6	Defined and tolerated actuation force	Damage protection of switch blades
2.2.7	Closed switch rail with no gap to stockrail,	Safety, less or no inspection, less wear, enhanced MTBF
2.2.8	Automatically temperature compensation of the tongue movement (-40 - 70º Celsius)	Allow for tongue movement of ± 25 mm
2.2.9	Open protocol interface	Enabling of condition based maintenance strategies, increased independence from the interlocking system supplier, standardization of components, simplified installation and commissioning of systems

Table 2: Summary table of technical requirements

2.2.1 Auto-diagnostic system with monitoring of operation parameters

- Extended maintenance cycles
- Condition based maintenance concept possible

Condition based maintenance bears the potential for failure and hence downtown reduction. This leads to an improvement in availability and hence operational cost benefits. It requires a monitoring system for key parameters of the DLD system that indicates incipient failures.

Useful parameter to monitor

- Motor current, actuator force
    - o increased force is an indicator for non-sufficient lubrication(maintenance problems of the switch/DLD)
- Switching time
    - o Elongated switching time is a indicator for greasing / maintenance problem of the switch/DLD
- Temperature
    - o Temperature can be used to trigger a device heater to prevent ice failure. Controlled and smart heating of the switch and /or component can reduce the energy consumption Also the temperature information can be useful in combination with other sensor signals for the condition monitoring.
- Counter
    - o A counter that counts the number of switch throws is a simple but useful indicator to extend the maintenance intervals. In some cases a earlier inspection may be indicated
- Acceleration measurement on the crossing nose
    - o The acceleration could be used to determine the quality of the switch installation or changes to the condition of installation.

The Auto diagnostic system requires local controllers at the switch/DLD components. The data may be analysed and pre-processed by the local controller or by a remote system.

The functional requirements for such a system are described in more details in (2)

2.2.2 3-phase brushless asynchronous motor

In most European countries alternating current (AC) motors are in use. Some Countries (for example GB) use Direct Current (DC) motors. The installation of these devices has historical reasons.

	Investment/price	**Reliability**	**Durability**	**Measurement and Control**
AC Drive	low	high	No wear (except for bearings)	
DC Drive	higher	Lower due to wear of brushes	Brushes wear	

The Advantage of a 3-phase brushless asynchronous motor is, that an industry standard motor can be used with little or no adoptions to the climatic requirement on the track.

2.2.3 Clear separation between power and signal lines

To reduce the power line interference with signal lines (such as sensor outputs) a strict and clear physical separation of those is recommended. Also the crossing of wires needs to be avoided.

The advantages compared to the frequently used 4 wire system are:

- Sensors can measure and control the switching process,
- Component replacement and installation is easier,
- No nuisance trapping on signal line,

This requirement is associated with a new interlocking standard.

2.2.4 Actuator with Adjustable stroke

When a mechanical or hydraulic backdrive is not used multiple actuation points are required to move a UIC 60 switch. The stroke at each actuation layer is different and depends on the design and size of the switch.

Locking device	**Stroke (mm)**	**Overlap**
Tip	220	60 +/- 10
Lock 1	173	37 +/- 10
Lock 2	129	24 +/- 10
Lock 3	89	14 +/- 5

Table 3: Stroke for 4 actuators, EW 60-2500 (4)

Proposal: Stroke to be adjustable from 60 mm to 220 mm

2.2.5 Switch not trailable

Trailable switches require the independent movement of the switch blades. The switch can only be trailed when the inner switch blade is pushed by the wheel by applying a certain force to the switch blade.

The trailing process:

- wheel hits the inner switch blade
- Force on the inner switch blade is high enough (for example 7000N) to open the coupling in the drive unit that locks the actuator bar.

- Wheel pushes the switch blade further, the locking of the closed switch blade (contacting the stockrail) is released
- Both switch blades are free to be moved by the wheel, switch is trailed.

Opposite to this a non-trailable arrangement has the following benefits:

The inner switch blade is locked with the same locking force as the outer side.

The non-trailable switch has the following advantages:

- Both switch blades are fixed in the end position with the same (high) locking force
- The actuator can be simplified. Trailing device can be removed. This reduces the cost and complexity; the safety and reliability is improved
- The distance of the switch blades is defined by the length of the stretcher bar. Wear in the locking device does not lead to a variation of the switch blade distance
- The requirements in Europe are harmonized
    - safety risk analysis can be compared one to one between different countries
    - advertised bidding for equipment installation can be simplified and installations standardised

2.2.6 Defined and tolerated actuation force

UIC 60 Switches require a certain force / energy to perform the switching operation reliable under the allowed operating conditions. Since this specification is limited for UIC 60-500/1200 switches only switches with 3 actuation layers need to be considered. For longer switches higher actuation forces may be required. Therefore multiple drives can be used.

In order to limit the cost per DLD the actuation force is limited to the mentioned switch size.

On the other hand the force applied to the switch rail needs to be limited. In case of a blockage of the switch rail (for example the presence of a foreign object between switch and stockrail) the switch rail must not be bent by the actuator.

- Max actuation design force: 6000 N +/- 10 % at a temperature range of -30 to + 70º Celsius).
- For switches having 3 and more actuation points it is recommended to use a higher force of

  at least 8000 N +/- 10 % at the actuation point near the crossing nose (for example actuator 3 out of 3). This recommendation is based on the experience with installed switches by VAE.

2.2.7 Closed switch rail with no gap to stockrail,

The presence of a gap between the stock rail and the switch rail can lead to extra wear when wheel sets pass this gap.

This wear can be avoided or reduced my pre stressing/preloading of the tongue (switch rail). A typical test in the railway companies is established to check whether the gap is within the tolerated boundaries or not. This test and hence the cost can be avoided with a pre stressed system.

A pre-stressed system enables the safe use of a integrated locking device (hollow sleeper) since small deviations in the switching system can be compensated by the pre-stressed system.

2.2.8 Automatically temperature compensation of the tongue movement

Depending on the length of the tongue (switch blade) a certain temperature related tongue movement has to be tolerated by the Drive system.

The switch blade of a UIC 60. 1200 switch changes the length by +/- 11,5 mm at a temperature change of +/- 50℃. Since InnoTrack focuses on switches up to 120 0 m radius this dimension includes the requirement for smaller switches.

The design of the DLD components is required to fulfil the tongue movement +/- 11,5 mm. In total this number needs to be further increased since other tolerances add to this change of length:

- installation tolerance (+/-5mm)
- tolerance in displacement limited at the end of the switch +/-2mm
-

The total tolerable tonque movement shall be +/- 25 mm.

2.2.9 Open protocol interface

With a open protocol interface

- DLD components of different suppliers can be mixed
- The dependency from the interlocking system can be reduced
- Upgrading or integration of modernised into the existing systems is simplified
- Condition based maintenance strategies can be implemented with the centralised access of the components signals
- Third party software independent by the system supplier can be implemented for data analysis, monitoring, etc.
- Commissioning of the system can be simplified
- enables railway companies to combine the components
- Enabling of condition based maintenance strategies
- increased independence from the interlocking system suppliers
- standardization of components
- simplified installation and commissioning of systems

More details are described in (10).

2.3 DLD RAMS requirements

No	Description	Benefit/Motivation
2.3.1	DLD components integrated in the EU hollow sleeper	LCC reduction
2.3.2	Regular inspection interval	Inspection cost reduction
2.3.3	Inspection time for complete drive	Inspection cost reduction
2.3.4	Automatically tampable switch components	Maintenance cost reduction
2.3.5	No greasing and adjustment of DLD components	Maintenance cost reduction, enhanced availability
2.3.6	No manual operation	Complexity reduction, investment reduction
2.3.7	Each DLD component to be individual replaceable within 30 minutes	Maintenance cost reduction

No	Description	Benefit/Motivation
2.3.8	Switch with DLD assembled, adjusted and tested in the workshop	Installation cost reduction
2.3.9	Locking at the switch blade tip (driver position 1) redundant mechanical	Safety
2.3.10	Availability on Component level: MTBF > 50 years	Maintenance cost reduction, LCC
2.3.11	MTBF of DLD > 10 years	Maintenance cost reduction, LCC

Table 4

2.3.1 DLD components integrated in the EU hollow sleeper

The integration of DLD components in the sleeper has the following potential benefits

- Protection from dust, water and ice by housing of the sleeper
- Compact design with the components assembled and tested in the factory
- Defined fixation of the components, damage and vandalism protection
- Automated tamping of the switch possible ***Figure 7***.

2.3.2 Regular inspection interval

The Regular inspection interval shall be larger than 12 months to reduce the operation cost. The preventive maintenance is a mayor cost driver of LCC. The reductions can be reached by a combination of different measures such as:

- maintenance free or maintenance reduced design
- remote monitoring of the component condition (6)

2.3.3 Inspection time for complete drive

Inspection time regular 1 hour (2 workers). This value has been assumed in D 3.2.1 to fulfil the LCC reduction target.

2.3.4 Automatically tampable switch components

The switch components have to be arranged at the switch and designed, so that automatic tamping of the switch is possible.

2.3.5 No greasing and adjustment of DLD components

2.3.5.1 Detection device

Detection devices can be designed to have no moving mechanical parts. An example is the inductive position detection system IS2000 Figure 5.

In case this is not feasible or the vendor is not capable to use this technique all bearings of detection device have to be designed with lifetime lubrication (for example rolling contact support) , or lubrication free.

2.3.5.2 Actuator

Most of the actuators currently in use need to be greased frequently. In case of a failure the service of components of the actuator unit is not possible. Some solutions offer a modular approach (for example the Ebiswitch) In this case the locking device can be removed separable.

2.3.5.3 Locking device

Greasing is a cost driver for locking devices. The standard procedure for example at DB network ist greasing of the locking device every 2 weeks on high loaded railway lines.

Existing solutions promise lower maintenance cost. For examples the Spherolock offers extended maintenance intervals of 12 months and a MTBF of 50 years (projected by vendor).

2.3.6 No manual operation

For the manual operation of the switch actuators are often equipped with a crank handle or a port for a crank handle. In hydraulic system the system can often be actuated with a manual pump.

Discussions indicate that the main reason for a manual operation option is the unavailability of power during the installation process of a switch/ actuator. Historically there has been no power available on installation sites because machinery was not very sophisticated. Nowadays installation of switches and infrastructure requires power to be available on the site.

A new interlocking interface makes the manual operation obsolete. With the power lines separated to the signalling lines (such as addressed in D 3.2.3) the switch can be either powered by the normal power source or by a transportable generator during the installation of the switch or repair.

With the actuator connected to the power the actuator can be controlled by a operator on the site using a portable computer or a heavy duty handheld PC.

The manual control of the switch in such a manner will be demonstrated with the installation of the Demonstrator in July 2009.

2.3.7 Each DLD component to be individual replaceable within 30 minutes

The use of a modular design bears the opportunity to exchange defective modules in a very short time. The system design needs to be in such a manner, that the replacement of modules is simple.

- Few other parts are allowed to be removed in order to exchange any defective module
- The modules need to be fully independent with reliable and solid connection to the system
- Modules need to be designed to be repaired.

Only some additional time is required to find the defective module in the system. The replacement time of 30 Minutes gives the opportunity to reduce the downtime.

2.3.8 Switch with DLD assembled, adjusted and tested in the workshop, no on site adjustment required ("plug and play")

The preassembly of the complete switch bears significant advantages:

- Adjusted slide or roller support for the switch blades and hence reduced variance in the required actuator forces over lifetime and number of installed applications. This enables the use of smaller actuators (reduced switching force)
- Better quality of the assembly work due to assembly in dry and heated shop environment compared to assembly work at the rail track
- Switch can be completely tested and dimensions verified using instruments and measurement equipment design for indoor use
- Improvement of logistics, all subcomponents are collected in the assembly shop and the finalised switch is delivered just in time

This concept has been already demonstrated by different vendors in different countries.

2.3.9 Locking at the switch blade tip (driver position 1) redundant mechanical

The redundant locking of the switch blade tip (actuator position 1) is a must to ensure safety in case of proved fail safety. By individual locking of both switch blades (which are connected with a stretcher bar) the failure of one component does not lead to a failure of the switch. Another (saver option) is the redundant locking of both switch blades with two independent locking devices.

2.3.10 Availability on Component level: MTBF > 50 years (f.e. drive, locking device, electronic module)

For a significant reduction of downtime the MTBF at component level needs to be larger than 50 years. The RAMS requirement calculation is part of deliverable 3.2.1 were the LCC is calculated and the required MTBF is calculated.

2.3.11 MTBF of DLD > 10 years

For a significant reduction of downtime the MTBF for all DLD components needs to be larger than 10 years. The RAMS requirement calculation is part of deliverable 3.2.1 were the LCC is calculated and the required MTBF is calculated.

3. Conclusion

The technical and RAMS recommendations for DLD components are described in order to archive a standard for components and arrangements on the S & C. By reducing the number of European variants the project cost for installations of S & C can be reduced. The standardisation allows the railway infrastructures to reduce the cost for buying such equipment.

Additionally the recommended RAMS requirements will help to reduce the operational costs significantly. The current LCC composition is dominated by the maintenance and service cost. With future systems following the recommendations given in this paper the LCC will be dominated by the initial investment simplifying the LCC calculation for the infrastructures.

Historical features are recommended to be discarded since future and modern signalling architecture and maintenance processes makes them obsolete.

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4.1 Appendix

Figure 4: Sperolock locking device (2)

Figure 5: IS 2000 Position detector

Figure 6: Installation of a hollow sleeper drive into a already installed switch (6)

Figure 7: Machined tamping of a switch equipped with multiple actuators