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Feasibility Study **Odometry and DMI Interface**			
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1.6	07.06.2013	Part ODO/DMI	First release of draft final report	WM

Table of Contents

1 Introduction

1.1.1.1 In April 2012, a Memorandum of Understanding [1] was signed between the Railway Sector, the Commission and the Agency aiming at facilitating the deployment of ERTMS.

1.1.1.2 One aspect deals with internal vehicle interfaces concerning the DMI as well as the odometry:

> (d) ERA, with the support of the signatories, will produce a concept paper setting out the main options, challenges, costs and benefits related to the definition of the DMI interfaces and of odometer interfaces by 1 June 2013. A first draft should be ready by the end of 2012.

1.1.1.3 A questionnaire has been launched towards ERTMS/ETCS On-board suppliers and vehicle suppliers to collect base information in order to perform such study.

2 References, Terms and Abbreviations

2.1 Reference Documents

Table 1 : reference documents,

Ref. N°	Document Reference	Title	Last Issue
[1]	MoU	Memorandum of Understanding (MoU) between the European Commission, the European Railway Agency and the European Rail sector Associations (CER - UIC - UNIFE - EIM - GSM-R Industry Group - ERFA) concerning the strengthening of cooperation for the management of ERTMS	27/04/2012
[2]	CLC/FprTR 50542	Railway applications - Communication means between safety equipment and man-machine interfaces (MMI)	2009
[3]	IU-ExtScope-20090807-FinalReport-Annex01_2-LocPas	Extension of field of application of TSIs. Annex01-2-LocPas. Existing extensions of the geographical scope, 2009	2009
[4]	UIC Leaflet 612, 1st edition	Display System in driver cabs (DDS): General Requirements, Set Up and Technical Specifications	2010
[5]	UIC	Compendium on ERTMS, 1st edition 2009	2009

2.2 Terms

Table 2 : Terms

Term	Definition
Agency	European Railway Agency (ERA)

2.3 Abbreviations

Table 3 : Abbreviations

Abbreviation	Definition
CCD	Control Command Display
COTS	Commercial Off-The-Shelf
DMI	Driver Machine Interface
ETD	Electronic Timetable Display

Table 3 : Abbreviations

Abbreviation	Definition
ETH	Ethernet
EVC	European Vital Computer
FIS	Functional Interface Specification
FFFIS	Form Fit Function Interface Specification
HS	High Speed
IM	Infrastructure Manager
MoU	Memorandum of Understanding
MVB	Multifunction Vehicle Bus
ODO	Odometry
RAMS	Reliability, Availability, Maintainability, Safety
RU	Railway Undertaking
SDMU	Speed Distance Measurement Unit
TCMS	Traction Control and Motion System
TDD	Train Diagnose Display
TRD	Train Radio Display
TIU	Train Interface Unit
WG	Working Group

3 Analysis of the Odometry Interface

3.1 Current Situation

3.1.1.1 There are a number of applications requiring odometric (measurement of speed/ distance/ acceleration) information, nevertheless with different requirements concerning accuracy, RAMS and timing.

3.1.1.2 Today, different types of odometry sensors exist to measure distance and/or speed related information such as radars, accelerometers, wheel sensors,...

3.1.1.3 A number of applications such as brake control/ slip slide control and train protection systems (ERTMS/ETCS and Class B systems) work as autarkic, closed systems each of them requiring specific odometry sensors installed on specific axles on the vehicle.

3.1.1.4 This leads to the following problems:

- The retrofitting of vehicles with ERTMS/ETCS and the integration of ERTMS/ETCS in a new train is a complex issue due to the fact that there is only a very limited number of free space at the axles available or the on-board unit has to be connected to existing wheel sensors (if no space is available). This is one of the reasons why one time ERTMS/ETCS integration costs are very high today.

- The components of the ERTMS/ETCS on-board system (e.g. on-board unit/EVC, odometry, balise reader, juridical recorder) have different lifetimes. Competition in case of renewals is very limited. Today only the supplier of the complete system can offer renewals at components level (component spare parts). Other suppliers will likely need to renew the complete system due to the unavailability of interface specifications to the components.

- The high number of odometry sensors inside a locomotive lead to increased maintenance costs of the vehicle. The management of spare parts is complex as well due to the number of types of odometry sensors and different suppliers.

- Already today vehicle suppliers try to limit the number of odometry sensors as much as possible by installing a central odometry (e.g. Train Computer/CAF or SDMU/Siemens) which provides odometric information to all “open” applications. Another way is to ask the suppliers of “closed” applications to make their odometric information via MVB available for other applications.

3.1.1.5 In addition, a number of railway undertakings report about a bad performance of the ETCS odometry leading to performance losses. They look for solutions to increase the performance. Although this is not an interface issue, they would like that this aspect is addressed in the report as well.

Objective	Priority (low; medium; high)
1. The standardisation of the odometric interface should facilitate the renewal of the ERTMS/ETCS on-board system;	High
2. The standardisation of the odometric interface should contribute to an improvement of the performance of the odometry;	High
3. The standardisation of the odometric interface should reduce the number of odometric sensors within a vehicle;	Low/Medium
4. The standardisation of the odometric interface should allow interchangeability of odometric sensors;	Low/Medium

3.2 Overview of applications using odometric information

3.2.1.1 The following table summarises the different vehicle applications requiring odometric information:

Application	**Closed/ Open**[1]	**Reliability**	**Accuracy**	**Cycle Time**	**Safety Level**	**Remarks**
ETCS	Closed	High	High	500-1000 ms	High	Some suppliers offer the possibility to distribute odometric information via MVB to other applications
Class-B	Closed	High	Medium	500ms – 10s	(Low-High) depending on functionality	As STM, they could receive odometric information from ETCS on-board. In this case they do not need their own odometry/ wheel sensors
Brake and Traction Control	Closed	High	Medium - High	>200 ms	High	for reference speed information
Slip Slide Protection (Adhesion Control)	Open/ Closed	High		>200 ms	High	For reference speed information
Automatic Train Operation	Open/ Closed	Medium	High	100 ms – 1s	No	Limited number of applications It usually receives odometric information from ATP
Passenger Information System	Open	Medium	Low	10s – 100s	No	Usually these applications receive odometric information from a GPS sensor – sometimes supported by wheel speed sensor
Train Recorder Unit/ Event Recorder	Open/ Closed	High	Low - Medium	10 ms – 100 s	Low	
Cold Movement Detection	-	Medium	Low	1s – 1000s	High	No supplier
Door Control	Open	High	Low - Medium	1s – 5s	Medium	

[1] Open: Vehicle Supplier knows the interface, Closed: Vehicle Supplier does not know the interface

3.3 Market Estimation for Odometry Sensors

3.3.1.1 The product costs of a sensor vary between € 1.000 and € 10.000 (reported average € 2.000) mainly depending on the type of sensor.

3.3.1.2 Each application needs different number of sensors. The following table provides an overview for some applications:

Application	Number of Sensors
ETCS	2 – 4 Some suppliers do not need radar
Event Recorder	0 Usually using odometric information from other applications
Slip Slide Protection and Brake Control	>4 At least one per axle, dual channel for direction detection
Class B	0 – 4 As STM, using odometric information from ETCS on-board system

3.3.1.3 The one-time costs for the mechanical integration of a new (not integrated before) sensor type in a new vehicle type are about € 50.000. For a critical integration, costs can reach up to € 1 M (including authorisation costs).

3.3.1.4 In a locomotive, about 5 up to 30 sensors are installed. One factor influencing the number is the number of Class B Systems installed on the locomotive. Another factor results from the integration of traction and breaking system and the number of controlled, powered axles.

3.3.1.5 The average lifetime of a sensor varies between 5 and 10 years.

3.3.1.6 For a conservative market estimation we assume the following:
a) 60.000 vehicles (loco/DMU/EMU) operate on the European Network (see [3])
b) a minimum of 5 sensors per vehicle
c) an average lifetime of 7,5 years for a sensor
d) average product costs of €2.000 per sensor

3.3.1.7 This would result in at least 40.000 sensors to be exchanged each year which represents a market volume of at least € 80 M/ year

3.4 Option A Interface to a Centralised Odometry

3.4.1 Description of the Interface

3.4.1.1 This interface is an “application internal” interface where the subsystems of the application are connected to a centralised odometry. In case of ETCS, it would be the interface between the EVC subsystems and the SDMU.

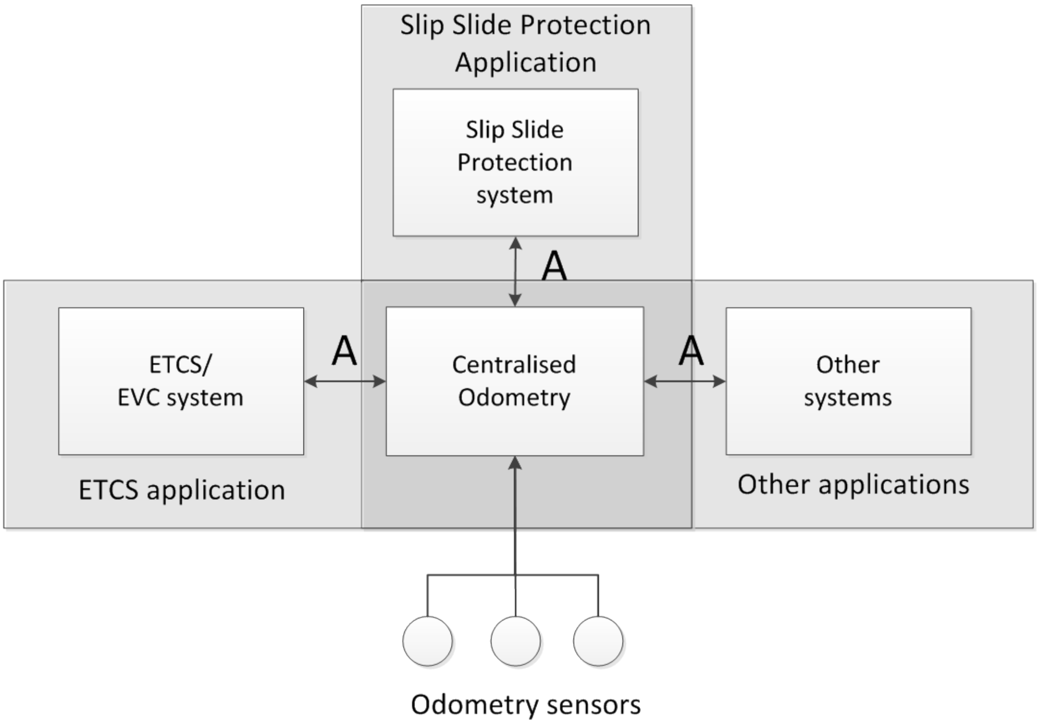

Figure 1: Interface to Odometry

3.4.1.2 The centralised odometry has to be designed and optimised according to the needs of the different applications. These needs differ, e.g. for slip slide protection and propulsion control, accuracy and timing of the information is relevant whereas for ETCS, the safety requirements are very demanding.

3.4.2 Cost Impact Analysis

3.4.2.1 The introduction of such interface requires a complete re-engineering of all applications receiving odometric information via the centralised odometry.

3.4.2.2 The study analysed the cost impact for ETCS on-board systems:

- ERTMS suppliers estimated the re-engineering costs between € 2 M up to € 10 M to modify and re-certify their current on-board products in such a way that it would use the odometric information from such centralised odometry. The costs depend on the system architecture of the product (e.g. does the system architecture already separate functions in relation with the measurement of distance and speed from the other ETCS related functions).
- Currently, there are 7 ERTMS suppliers in Europe which offer at least one on-board product. The one-time cost impact for the ETCS suppliers would therefore vary between € 14 M and € 70 M.
- For other performance critical applications like slip slide protection, the likely one-cost impact for their manufacturers might range at a similar level.

3.4.3 Potential Benefit Analysis

3.4.3.1 Depending on the number of connected applications to the centralized odometry, the number of sensors installed in a train can be reduced to a minimum. We assume at least one sensor per axle has to be installed in a vehicle for brake and traction control. This equals the maximum number of sensors needed by a single application.

3.4.3.2 For an ETCS on-board application without integrated odometry, we estimate, that hardware costs will reduce at least by € 5.000 – 10.000 € (based on 2-4 odometric sensors which can be saved; in addition there is no need for mounting, cable, wiring, EMI-protected interfaces).

3.4.3.3 On the other hand, the costs of the odometry have to be added. We assume costs in the same range as the cost reduction potential for ETCS without integrated odometry. Real savings will only be realised if the odometry can provide odometric information for other applications as well (adhesion control, brake control).

3.4.3.4 The integration of an ETCS on-board without integrated odometry inside a vehicle will be simplified:

3.4.3.5 Less sensors have to be mechanically integrated. Assuming € 50.000 for the mechanical integration of a sensor in a new vehicle type (see 3.3.1.3), this would result in € 0,15 M savings (2-4 sensors need not to be integrated) per new vehicle types (new design).

3.4.3.6 The number of vehicle types (new vehicle design) authorised per year is estimated with approximately 10 in the next year but will continuously decrease (the average number of vehicles/new vehicle type will grow significantly in future). For this reason savings due to an easier mechanical integration of the sensors into new vehicle types could reach € 1,5 M /year in the next years but these savings will reduce to less than € 0,5 M in the mid/long term.

3.4.3.7 Nevertheless these costs arise in the framework of the integration of the external odometry. Real savings are only gained if the external odometry provides odometric information to other applications as well.

3.4.3.8 Therefore, we estimate that the maximum total potential savings are in the order of magnitude of € 10 M per year (under the assumption that brake control/adhesion control and ETCS share the same centralized odometry).

3.4.4 Opportunities and Risks

3.4.4.1 The main opportunity is that an ETCS on-board connected to the external odometry can be renewed without the need to renew the odometry as well.

3.4.4.2 In addition competition could evolve for such centralized odometry. Some railway undertakings expect an improved performance as a consequence of competition – the Agency does not share this expectation concerning performance.

3.4.4.3 The centralized odometry could likely evolve from the brake and traction control applications (as a “side product”) which evaluate odometric information from all (powered and braked) axles of the vehicle.

3.4.4.4 Although there are significant savings for the railway market expected, ETCS on-board and vehicle suppliers emphasised two main risks:

- One risk is to merge the needs and requirements respect to odometric information of the vehicle applications resulting from the different vehicle applications. It might be not possible or not feasible. The solution today chosen by some vehicle manufactures to provide at least two centralised odometries – one for ETCS/ high safety critical applications and another one for performance critical applications could be the only feasible one. On the other hand a centralized odometry based on a probabilistic approach could provide several confidence intervals for differing confidence levels. A high confidence level would be safer but more frequently too wide for maximum performance and vice versa.

- Another risk addresses responsibility and system integration. Due to the fact that this interface would replace an internal interface in a vehicle application, the question arises who will do the system integration and take over the responsibility for the application.

3.5 Option B Interface to Odometry Sensor

3.5.1 Description of the Interface

3.5.1.1 This interface is at sensor level. In this way, the different vehicle applications could share a sensor. The communication between the sensors and the different odometry applications can be made in 2 ways.

- bus: sensors and application systems connected to a bus (as presented in the picture below); the application might need a specific “driver” software to communicate with the sensor via the bus.
- direct connections from each sensor to each application (each sensor with multiple connections to the applications).

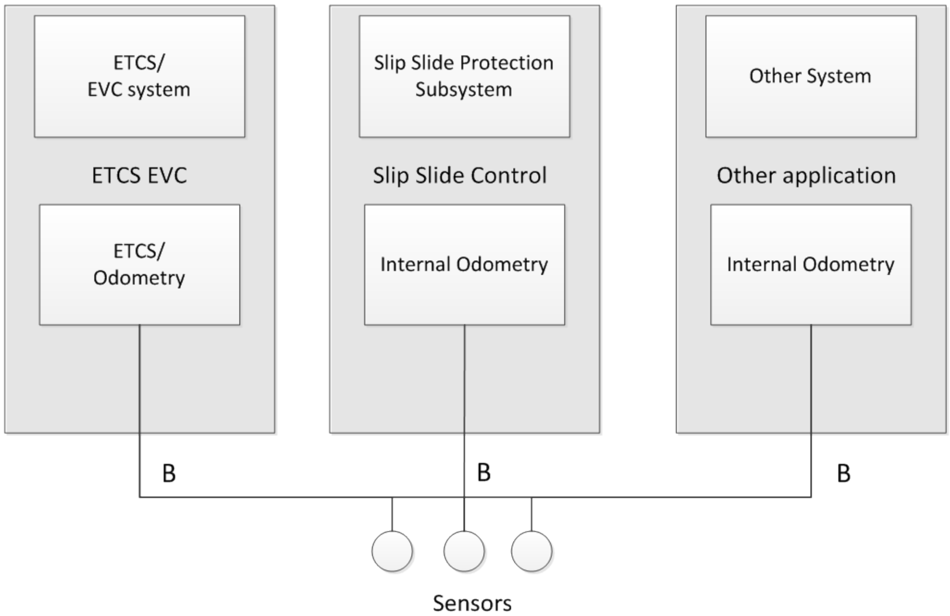

Figure 2: Interface to an odometry sensor.

3.5.2 Cost Impact Analysis

3.5.2.1 The modifications inside the applications are very limited and already nowadays common practice (e.g. in cases where the applications have to use specific sensors already installed in a vehicle)

3.5.2.2 The one time impact to modify and re-certify the current ETCS products in such a way that they can connect via this interface to any sensor is between € 0,1 M and € 1 M.

3.5.2.3 This would result in a one-time cost impact between € 0,7 M and € 7 M for all ERTMS/ETCS on-board suppliers.

3.5.3 Potential Benefit Analysis

3.5.3.1 This interface would generate the same benefits as Option A. We neglect the fact that the signal treatment (inside each "internal odometry" in Fig. 2) is still redundant – for each application a signal treatment is required whereas Option A requires only one signal treatment.

3.5.3.2 We estimate that the maximum total potential savings are in the order of magnitude of € 10 M per year due to the multi-use of odometry sensors.

3.5.4 Opportunities and Risks

3.5.4.1 It has to be mentioned that already today odometric sensors offer the possibility for multiple outputs so that in principle different applications could share a sensor. (E.g. one supplier of a traction and brake control system stated, that their odometric sensors already offer such functionality.)

3.5.4.2 On the other hand interchangeability is only possible, if the interface is fully (FFFIS) specified meeting the needs of the different applications:

3.5.4.3 For safety related applications there is a risk resulting from the existing different safety philosophies of each supplier. For brake control applications some suppliers require specific sensors with integrated health control.

3.5.4.4 One railway undertaking expressed doubts concerning the re-use of sensors for adhesion control/ brake control for ETCS applications.

3.5.4.5 The high safety requirements (SIL4) for the ETCS odometry result in architectures based on diverse measurement principles. As a consequence a measurement only based on wheel sensors used in adhesion control/ brake control is not sufficient enough.

3.5.4.6 For this reason, additional specific sensors for ETCS (e.g. for speed/acceleration measurement) are needed.

3.5.4.7 In addition the interface has to be standardised for the different types of odometric sensors

3.5.4.8 The timing of sensor signals was regarded as a critical issue especially if sensors are connected to a bus.

3.5.4.9 The problem of the bad performance of the ETCS odometry is not addressed by this option (as option A)

3.5.4.10 The option provides opportunities as well:

3.5.4.11 The interface is simple and manageable. The interface specification shall be a FFFIS covering aspects like signal quality (think of noise like jitter and wobble in case of a square-wave signal and delay in case of telegram messages) and safety (failure modes, diagnostic info).

3.5.4.12 The implementation of such interface is possible in a short timeframe.

3.5.4.13 The management of spare parts will be simplified due to the fact that any defective sensor can be replaced by a sensor meeting the requirements of the interface.

3.6 Option C Interface between Adhesion Control/ Brake Control and ETCS On-board

3.6.3 Description of the Interface

3.6.3.1 This interface is at application level.

3.6.3.2 It is a specific interface between the main performance and safety critical applications (ETCS, brake control and traction control) to exchange

- Odometric information
- Status of the brake and the traction control
- Commands to ask for a specific status of an axle at the time x (e.g. unbraked/ unpowered)

3.6.3.3 This interface could lead to a reduction of sensors at least for the ETCS application, nevertheless not for the brake and traction control due to the fact that it already requires odometric information from each powered/ braked axle. .

3.6.3.4 In addition it could increase the performance of the ETCS odometry due to the following reasons

- The ETCS odometry algorithms could take into account the status of the brake and the traction.
- The ETCS on-board could command a specific status of an axle for their own measurement. (ETCS requests an unpowered axle at a specific time to make at that time a specific measurement)

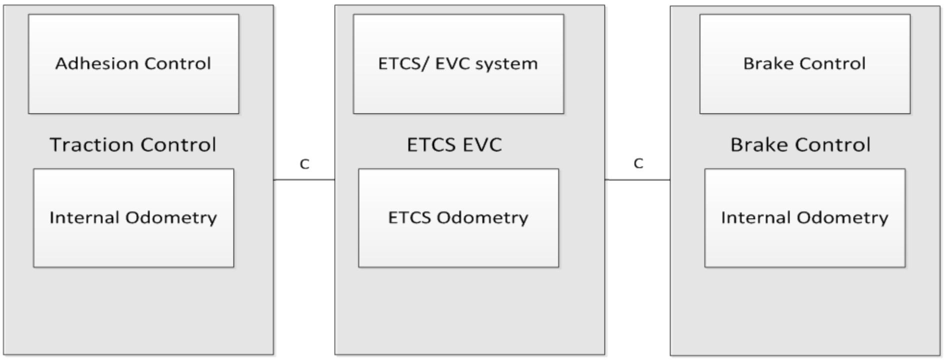

Figure 3: Interface between Traction Control/ Adhesion control and Brake Control.

3.6.4 Cost Impact Analysis

3.6.4.1 Suppliers for traction and brake control could not estimate the (one-time) costs for the development, implementation of such an interface and the re-authorisation of their modified products.

3.6.4.2 The Agency expects the cost impact in a similar range as for Option B due to the reduced complexity of the interface.

3.6.4.3 The Agency does not expect any other cost impact

3.6.5 Potential Benefit Analysis

3.6.5.1 Due to this interface, it is expected that the performance of the ETCS odometry will increase.

3.6.5.2 In addition as a “side-benefit”, savings could be realised due to a reduction of sensors within ETCS odometry.

3.6.6 Opportunities and Risks

3.6.6.1 The implementation of the interface seems to be feasible from the view of suppliers of traction and brake control. Nevertheless it would depend on the functional interface specification (FIS) which has to be jointly specified by the suppliers of traction and brake control as well as ETCS.

3.6.6.2 One railway undertaking reported that a vehicle supplier already realised this interface for a specific fleet.

3.6.6.3 A side-benefit could also concern the data entry from the train-driver in ETCS. This is still a human action with some safety risk. With such an interface it could be possible to send the braking performance of the train from the TCMS towards the ETCS thus allowing the verification of the entered braking performance of the train.

3.7 Conclusions

3.7.3.1 The analysis demonstrated that significant benefits can be gained in the framework of all three interfaces due to a reduction of sensors for speed and distance measurement in vehicles.

3.7.3.2 Option A and B mainly address cost reduction potentials due to a more efficient use of sensors – either by sensor sharing or by functionally dividing the odometry from the ETCS on-board.

3.7.3.3 Option B – sensor sharing – offers the same cost reduction potential as option A but with a limited risk for ETCS on-board suppliers.

3.7.3.4 In addition Option B offers the conditions to open the market at sensor level and would contribute to standardisation. The management of spare parts for the vehicle owner could be simplified.

3.7.3.5 Option A offers the flexibility to exchange the ETCS on-board independently from the odometry. This is especially interesting where the lifetime of an odometry is different from the lifetime of an ETCS on-board. (Option B would allow an exchange of the ETCS on-board independent of the installed odometric sensors)

3.7.3.6 Option C mainly addresses performance improvements for the ETCS odometry. Due to a direct connection between ETCS on-board and brake control/ adhesion control important information about the status of the traction and the brake can be exchanged in order to improve the odometric algorithm. In addition it would allow a direct exchange of odometric information as well.

3.7.3.7 Considering the opportunities and risks, the Agency recommends to the railway sector to start with analysing option C in more detail e.g. by specifying a first FIS (functional interface specification). This requires specific commitment from both: the suppliers of ERTMS/ETCS on-board systems and of traction and brake control systems.

3.7.3.8 This could contribute to a reduction of sensors (e.g the traction and brake control provides a reference speed information including confidence intervals) and could improve the performance of the ERTMS/ETCS odometry.

3.7.3.9 Overview of objectives/options:

Objective	Priority (low; medium; high)	Option A	Option B	Option C
1. The standardisation of the odometric interface should facilitate the renewal of the ERTMS/ETCS on-board system;	High	Yes	Yes	Yes (in case of providing reference speed with confidence intervals)
2. The standardisation of the odometric interface should contribute to an improvement of the performance of the odometry;	High	No	No	Yes (unbraking/unpowering of axle)
3. The standardisation of the odometric interface should reduce the number of odometric sensors within a vehicle;	Low/Medium	Yes	Yes	Yes (in case of reference speed with confidence intervals)
4. The standardisation of the odometric interface should allow interchangeability of odometric sensors;	Low/Medium	No	Yes	No
5. Other benefits/opportunities	Low/Medium			Verification of the data entry from the train-driver in ETCS.

4 Analysis of the DMI Interface

4.1 Current Situation

4.1.1.1 The DMI for the ETCS-application

- delivers the necessary signalling information to the train-driver (output)
- allows the train-driver to enter data and to interact with ERTMS/ETCS

4.1.1.2 The interface between the DMI and EVC for the ERTMS/ETCS-application is currently not standardised.

Figure 3: Train Driver Desk

4.1.1.3 Multiple DMIs are available on a train driver's desk for different applications, such as:

- Signalling systems such as ETCS or other Class-B systems;
- Traction Control / Motion System (TCMS)
- Automatic Train Operation (ATO)
- Other systems e.g. door control, eco-driving, …

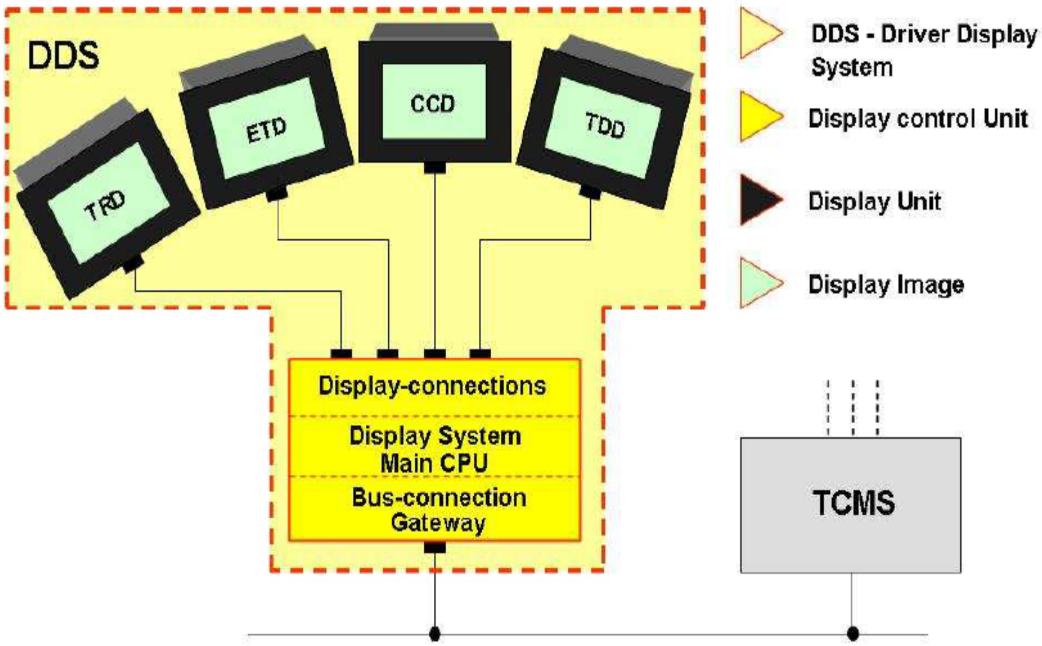

Figure 4: Train Driver Desk – picture from UIC Leaflet 612 [4]

4.1.1.4 The main problems related to the DMI interface are enumerated in the following points.

4.1.1.5 Problem 1: DMI-displays for ERTMS/ETCS applications are currently not interchangeable due to the fact that the DMI is not a plug & play interchangeable spare part based on standardised requirements which includes the interface between the DMI-display and the DMI-controller or directly to the EVC (in case of no DMI-controller). This could lead to a single suppliers market and/or a higher stock in case of different DMI-display interface designs across the fleet.

The consequences are:

- High number of spare parts
- Long term maintenance contracts

4.1.1.6 Problem 2: some train drivers desks have limited space availability.

The consequence is the following:

- The need to share existing DMI-displays for different applications (example: information of Class B signalling systems and ETCS-system on the same display).

4.1.1.7 Problem 3: the failure of the DMI-display leads to delays in train operation due to the unavailability of the ETCS-information to the train-driver. Some suppliers emphasize that this problem is less and less the case due to several evolutions (LED-technology with high MTBF, second backlight, preventive maintenance);

Following mitigation measures are currently addressed:

- Placing redundant DMI-displays
- Switching between DMI-displays for different applications (legacy, ETCS, TCMS, ATO, …)
- Scaling of DMI-information of different applications on one DMI-display

4.1.1.8 Problem 4: the components of the ERTMS/ETCS on-board system (e.g. on-board unit/EVC, odometry, balise reader, juridical recorder) have different lifetimes. Competition in case of renewals is very limited. Today only the supplier of the complete system can offer renewals at components level (component spare parts). Other suppliers will likely need to renew the complete system due to the unavailability of interface specifications to the components.

4.1.1.9 Objectives of the standardised interface: following ranking of the importance of the problems is estimated based upon the information received during the interviews:

Objective	**Priority (low; medium; high)**
1. The standardisation of the interface should facilitate the interchangeability of the EVC (e.g. in case of upgrades/renewals);	High
2. The standardisation of the interface should allow the interchangeability of the display;	Medium
3. The standardisation of the interface should facilitate the scaling of different applications into one display;	Medium
4. The standardisation of the interface should allow the switching of applications between the available displays on the train drivers desk;	Medium

4.2 Identified Options

4.2.1.1 The 2 options to be analysed are summarised in [5] – section 5.4.6.2 (ETCS Driver Machine Interface DMI – Technical details). *"The design and development of the DMI is completely open to industry solutions, and two main design philosophies have been adopted by industries. One philosophy considers the DMI as an instrument capable to animate the display based on high level information provided by the DMI-EVC interface. The DMI analyses the stream of information and decides where to show the information, the colour to be applied, the sounds, etc… In the other philosophy, the DMI is considered as a terminal, and is displaying information where it is told to do so. It has a reduced level of intelligence."*

4.2.1.2 In following chapter, 2 options are analysed in line with the above philosophies. Option A focuses at the standardisation of the interface at application level (between the EVC and the Train Display Controller/System), while option B focuses at the standardisation of the interface at graphics card level (between the Display itself and the Train Display Controller);

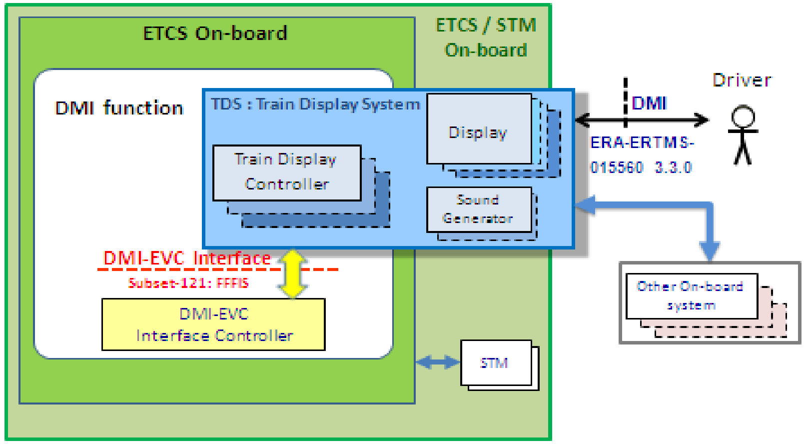

Figure 5: slide from UNISIG subset 121 (DMI-EVC IF)

4.3 Option A: DMI Interface at application level

4.3.1 Description of the Interface

4.3.1.1 In this option, we assume that the interface is standardised at application layer level. Therefore, a clear split between the functionalities of the DMI and the EVC is required.

4.3.1.2 Qualitative assessment of the objectives:

Objective	Fulfilled (yes; partially; no)
The standardisation of the interface should facilitate the interchangeability of the EVC (e.g. in case of upgrades/renewals);	Yes
The standardisation of the interface should allow the interchangeability of the display;	Yes, in case of smart DMI-displays (including the train display controller functionality) Partially, in case of use of individual train display controller (depends on the interface between TDC-DMI)
The standardisation of the interface should facilitate the scaling of different applications into one display;	Yes
The standardisation of the interface should	Yes

allow the switching of applications between the available displays on the train drivers desk;	

4.3.2 Cost Impact Analysis

4.3.2.1 The cost impact is partially borne by the ETCS/ERTMS on-board suppliers and partially by the vehicle suppliers. Mainly, one-time redesign and re-authorisation costs are identified.

4.3.2.2 The redesign and re-certification cost of the driver desk is estimated lower than the redesign and re-authorisation cost of the on-board ETCS system due to the complexity of the interface and the possible reallocation of functions between the DMI and ETCS.

4.3.2.3 The estimated total impact for the ERTMS/ETCS on-board suppliers is between € 10 M and € 100 M based on following assumptions:

- The cost impact for the ETCS supplier is mostly estimated between € 2 M to € 8 M, with a maximum estimated value up to € 50 M. The cost impact depends on the end solution for this interface. The complexity increases in case of management of STMs;
- Currently, there are 7 ERTMS suppliers in Europe which offer at least one on-board product;

4.3.2.4 The cost impact for the vehicle supplier ranges from a minimum value of € 100.000 up to € 2 M.

4.3.2.5 The redesign and re-certification cost can be lower if the DMI-EVC interface is integrated within an overall redesign and re-certification project due to other reasons (e.g. redesign of TIU-EVC interface according to TI FFFIS subset 119). The interface specifications of subset 121 and subset 119 are based on IEC-61375.

4.3.3 Potential Benefit Analysis

4.3.3.1 The interchangeability benefits of the EVC depend not only on the interface of the TDC-EVC, but also on other interfaces of the EVC (e.g. odometry, balise reader, juridical recorder). The interface at application level will also facilitate the use of a central train display controller for different applications. No quantification is made for these potential benefits.

4.3.3.2 As the lifetime of a display is around 5 to 10 years, the CCD-display is replaced several times during the lifetime of a vehicle. A standardised interface will allow second source supplier and reduce the cost of the replacement parts. Previous study on interchangeable spare parts indicates a potential cost decrease of 30%.

The **interchangeability** benefits of DMI-displays can be estimated around 9 MEUR/year based on following assumptions:

- 60.000 vehicles (loco/DMU/EMU) operate on the European Network (see [3]);
- an average lifetime of 8 years for a DMI-display;
- average product costs of €4.000 for a DMI-display;
- savings of 30% due to interchangeable spare parts;

4.3.3.3 Although the interface is not directly at graphics card level, the interchangeability is feasible in case of smart displays (without DMI-controller) or at DMI-controller level (including DMI-displays) – see figure 5.

4.3.3.4 A harmonised interface at application level allows an easier transition towards **full redundancy management** as described in [4] (such as scaling of information from different applications into one display).

4.3.3.5 An interface at application level is more **sustainable** to **withstand technological evolutions** at the communication layer ; Currently, Ethernet (long term solution) and MVB layer (short term solution) will be developed as physical layer within the subset 121 FFFIS (based on the OSI-model used in IEC 61375) as these 2 technologies are evaluated as mostly used in future vehicles with longest technology lifetime; The standards IEC 61375 is evaluated to become the standard for railway train on-board communication architecture and already used by other WGs (e.g. TI FFFIS).

4.3.3.6 2 RUs also mentioned the potential benefit to use electro-mechanical devices instead of displays for a part of the retrofitting of the existing fleet (non TSI compliant) as these devices are easier to integrate (less space) in existing train drivers desks and could be more reliable than displays.

4.3.3.7 The split of functionalities between the rolling stock display system and ETCS on-board system is done in such a way that all SIL4-safety functions are allocated to the ETCS on-board system in order to avoid costly safety requirements within the rolling stock display system. Equal philosophy should be applied for other interfaces between applications (such as TCMS,…) and the rolling stock display system.

4.3.4 Opportunities and risks

4.3.4.1 The standard DMI-EVC interface allows the development of an automated test bench that includes the driver interface. This could decrease the testing costs.

4.3.4.2 One supplier stated that the reliability of the ERTMS system could increase.

4.3.4.3 One supplier stated that other applications should also be considered in the framework of a complete integrated desk approach, although another supplier mentions that the DMI-interface should not cover specific functions resulting from Class B systems connected to the on-board system.

4.3.4.4 Some suppliers mention the risk of unclear responsibilities due to the split of functions between the on-board supplier and vehicle supplier.

4.3.4.5 One supplier mentions the risk of reduction of functionalities (and innovations) due to the standardisation process (maintenance aids, optimised data entry, …).

4.4 Option B Standard DMI Interface at Graphics Card Level

4.4.1 Description of the Interface

4.4.1.1 In this option, we assume that the interface in option B is standardised between the display and the Train Display Controller, meaning at graphics card level. This can be compared with connecting a monitor to a computer.

4.4.1.2 Characteristic of having the standardised interface at this level is that all DMI logic is kept inside the ETCS on-board system (DMI being considered as a terminal with low intelligence);

4.4.1.3 Qualitative assessment of the objectives:

Objective	Fulfilled (yes; partially; no)
The standardisation of the interface should facilitate the interchangeability of the EVC (e.g. in case of upgrades/renewals);	Partially (DMI-logic inside EVC)

The standardisation of the interface should allow the interchangeability of the display;	Yes
The standardisation of the interface should facilitate the scaling of different applications into one display;	No
The standardisation of the interface should allow the switching of applications between the available displays on the train drivers desk;	Yes

4.4.2 Cost Impact Analysis

4.4.2.1 The one-time cost impact to redesign the interface between the DMI-display and the DMI-controller (or directly to the EVC) is estimated a factor 10 lower than the option A based on suppliers estimates. This would result in a total one-time cost impact for ETCS on-board suppliers between €1M and to €10M.

4.4.2.2 Assumption: Integrating a function into a system with a high SIL-level leads to a higher cost than integrating a function into a system with a lower SIL-level. In this option, the EVC will need to integrate the functionality of the graphic controllers requiring more performance of the CPUs. As the EVC-hardware and software has an overall higher safety integrity level than the train display controller hardware and software, this option B could lead to higher overall EVC-costs in comparison to option A.

4.4.3 Potential Benefit Analysis

4.4.3.1 Similar benefits related to interchangeability of displays as in 4.3.3.1 are expected.

4.4.3.2 In option B the management of spare parts will be simplified due to the fact that any defective display can be replaced by a display meeting the requirements of the interface.

4.4.4 Opportunities and risks

4.4.4.1 The main opportunity is to reuse COTS-graphic cards based on an available standard (e.g. APIX-interface – standard used for the automotive industry).

Definition of APIX standard from Wikipedia:

‘The Apix standard defines a way to transmit control signals and image data. It physically separate the generation of an image from the display of it.’

However, the APIX-standard risks to have limited suppliers choice.

4.5 Conclusions

4.5.1 Comparison between option A and B

4.5.1.1 Objectives of the DMI-interface

Objective	Option A Objective fulfilled (yes; partially; no)	Option B Objective fulfilled (yes; partially; no)
The standardisation of the interface should facilitate the interchangeability of the EVC (e.g. in case of upgrades/renewals);	Yes	Partially (DMI-logic inside EVC)
The standardisation of the interface should allow the interchangeability of the display;	Yes, in case of smart DMI-displays (including the train display controller functionality) Partially, in case of use of individual train display controller (depends on the interface between TDC-DMI)	Yes
The standardisation of the interface should facilitate the scaling of different applications into one display;	Yes	No
The standardisation of the interface should allow the switching of applications between the available displays on the train drivers desk;	Yes	Yes

4.5.1.2 Costs: the one-time cost of developing option A are estimated higher than for option B. However, some uncertainty is remaining on potential additional costs of allocating the display functions to the safety system EVC in option B.

4.5.2 Current workgroups dealing with the DMI-interfaces

4.5.2.1 After the Memorandum of Understanding [1], the sector has agreed to adapt following structure in order to address the different interfaces:

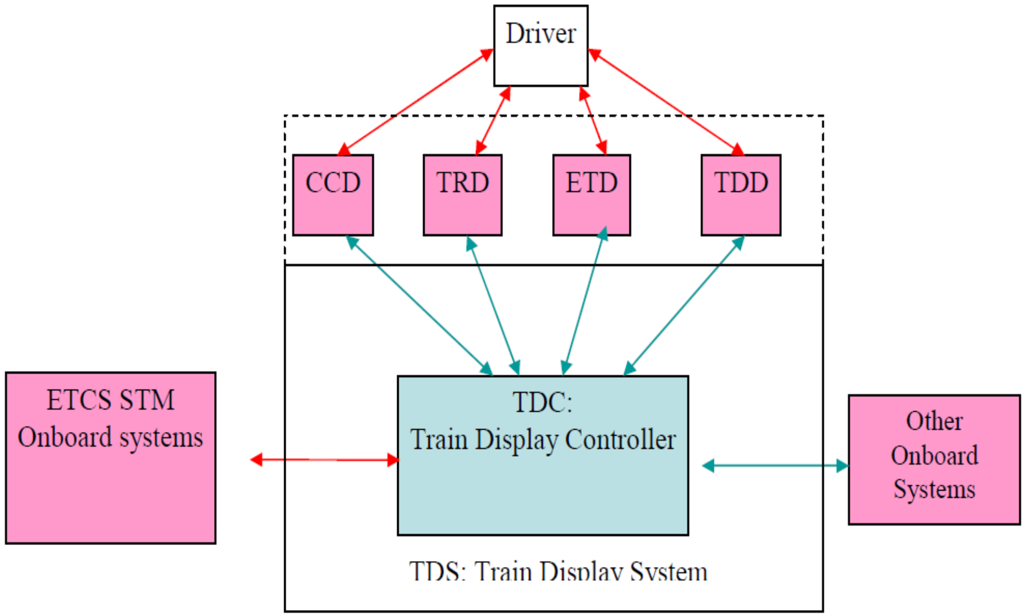

Figure 6: scope of CENELEC TC9X/WG12 (blue arrows)

UNISIG develops option A for the interface between ETCS on-board and train display controller (application CCD – red arrow), while CENELEC develops option A for the interface between other applications and the train display controller. The interface between the Train Display Controller and Display itself is also part of the scope of CENELEC (option B).

4.5.2.2 Timeline of working groups: the UNISIG DMI-EVC WP has planned to deliver the subset 121-FFFIS by end of 2014, while the CENELEC WG normally requires several years to develop a standard.

4.5.2.3 The ERA supports the activities to address the interchangeability aspect of the EVC, TDC and of the DMI-displays. The basic principles made within subset 121 should be taken over by the CENELEC WG in order to apply similar philosophy of defining the interfaces of the other applications (e.g. standard based on IEC 61375 using MVB and ETH as main technology layers, safety concept in which SIL4-functions are not allocated to the TDC or to the displays).