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HRMS conclusions

Harmonization – Running Behaviour and Noise on Measurement Sites

Laurent Schmitt (UIC)
Wolfgang Zottl (ÖBB)
Florian Saliger (ÖBB)

HRMS project governance

Project Director :
H.G. Kersten (UIC)

Management :
L. Schmitt (UIC)
W. Zottl (ÖBB)

WP 1: Categorizations of WTMS

Categorisation of sites
W. Zottl (ÖBB)

WP2: Limit values (Interoperable)

Limit values
A. Ekberg (Chalmers)

WP3: Noise measurements

Noise measurements
P.E. Gautier (Systra)

WP4: A(automatic)V(vehicle)I(identification)

Standardized output for data transfer and vehicle identification
W. Zottl (ÖBB)
L. Schmitt (UIC)

HRMS project governance

ÖBB INFRA

Axle load checkpoints

Categorisation of sites

Limit values

Noise measurements

Standardized output for data transfer and vehicle identification

D-RAIL

INNOTRACK Innovative Track Systems

iCargo

Introduction - HRMS project

Project Objectives

- **This project group had the objective to develop a methodology how to identify safety and commercial risk of running behavior from vehicles.**

- **A harmonized noise monitoring reduces the noise pressure from the population living near main rail routes.**

WP1 - Categorization of interoperable measurement sites

WP 1 Conclusions

- **Europe wide nomenclature and categorization of measurement sites for better and safer cross border data transfer between neighboring Infrastructure Managers**

YQN81_005BS

WP 1 Conclusions

YQN81_005BS

- **Y** & **Q** are the Forces, e.g. QFU, QYN
- **N** stands for noise,
- **81** represents the country code, e.g. 74, 80, 81, 85
- **005** is the sequential number in the country
- **BS** stands for Breitenstein.
  The last digits or letters can be chosen individually by each IM to meet their needs and merge in their IT-System

WP 1 Conclusions

Key letters of prefix		Measurement categories
Wheel load Q, Lateral wheel force Y, Longitudinal wheel force T, Derailment E	Q Y T E	Forces, derailment coefficient
Wheel Flats, Out-of-round wheels U	F U	Boundary conditions of the force effects
Noise, Vibration	N V	Environmental impacts
Bending, shearing, longitudinal stresses S	S	Rail stresses
Contact forces, Creep waves, Cracks	C C C	Boundary conditions of the contact effects
Buckling of rail	B	Temperatures related issues
Blocked brakes F	F	
Hot box detection	H	
Hot Disk brake detection	D	

WP 1 Conclusions

Integrating WLCC and RAMS in the process of using WTMS

Detailed Description of the technique/system in use

- Used system and measured values
- based on system approach and definition of boundary conditions by WP's

RAMS relevant parameters

- Reliability (MTBF, failure rate)
- Availability
- Maintainability (MTTR)
- Safety (nr. of accidents, redundancy)

LCC relevant parameters

- Investment, Re-Investment
- Disposal
- Inspection
- Operation
- Maintenance
- Migration
- Socio-Eco effects

Overall Assessment

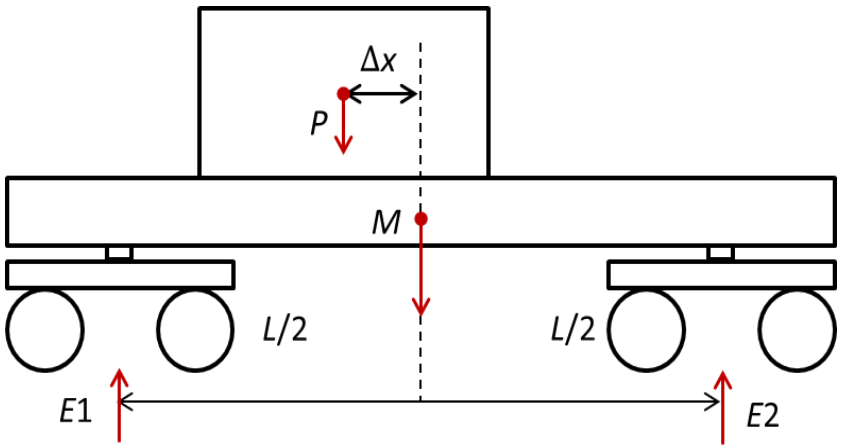
- RA(M)S analysis for best and worst case scenarios to identify the impact of the monitoring systems on the Reliability, Availability and Safety of the railway system
- Economic assessment of monitoring systems including migration with regard to LCC and social economic effects

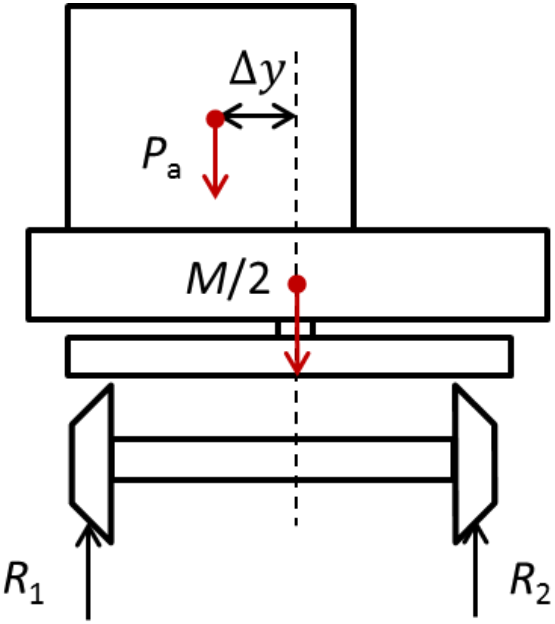
WP2 – Limit values, assessment concept

WP 2 Conclusion load distribution

Limit Values for load distribution suggested in HRMS:

- **1:3 longitudinally for the vehicle**
- **Tare (unloaded vehicle for max. diagonal/skew imbalance): suggested maintenance limit: 1:1.3 suggested stop limit: 1:1.7**
- **For Loaded vehicle skew imbalance: 1:1.7**
- **These limits are in practical use at SBB and ÖBB already**





WP 2 Conclusion

Limit Values for dynamic forces and axle loads in HRMS:

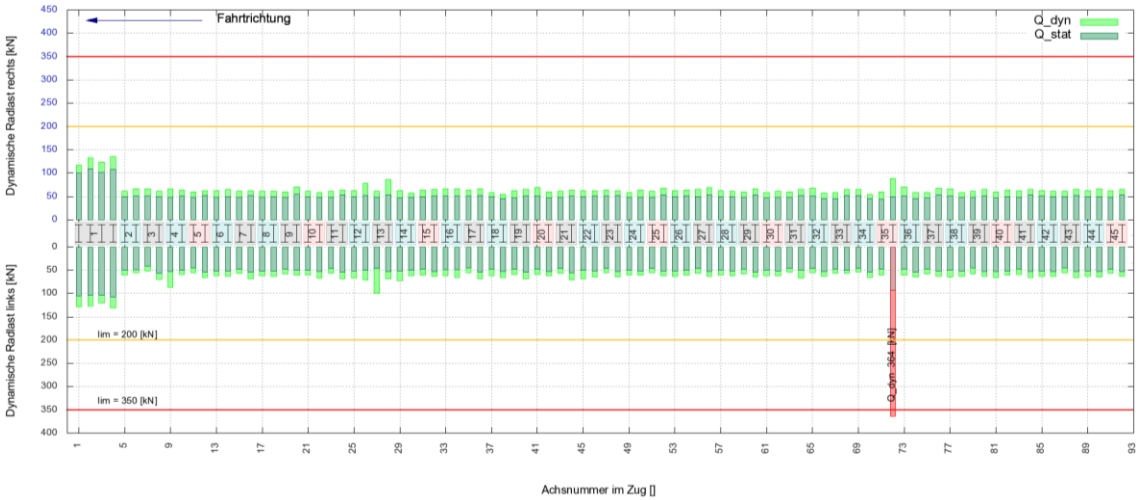
- **Dynamic forces:**

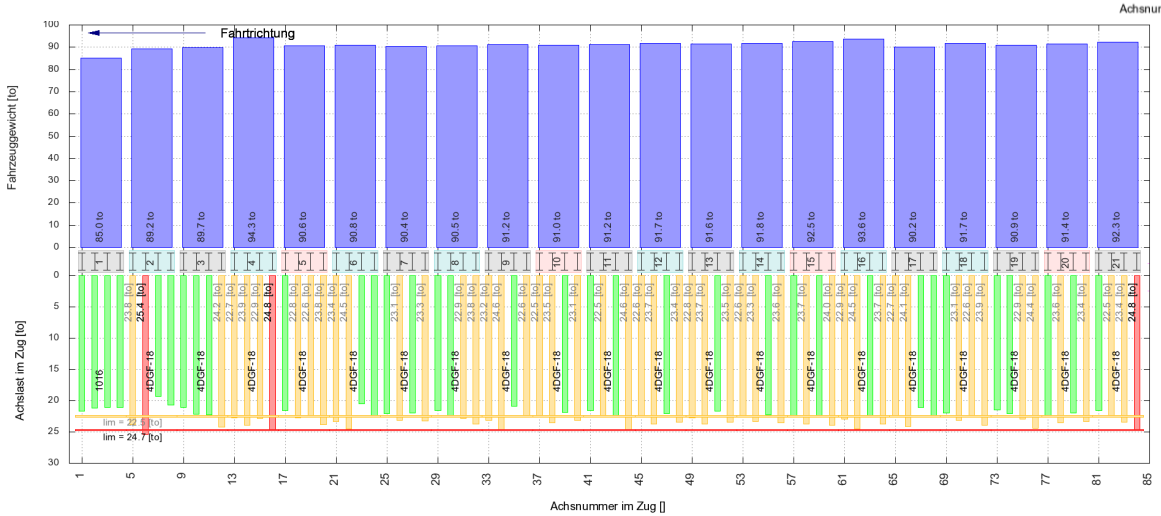
  350kN

- **Axle loads**

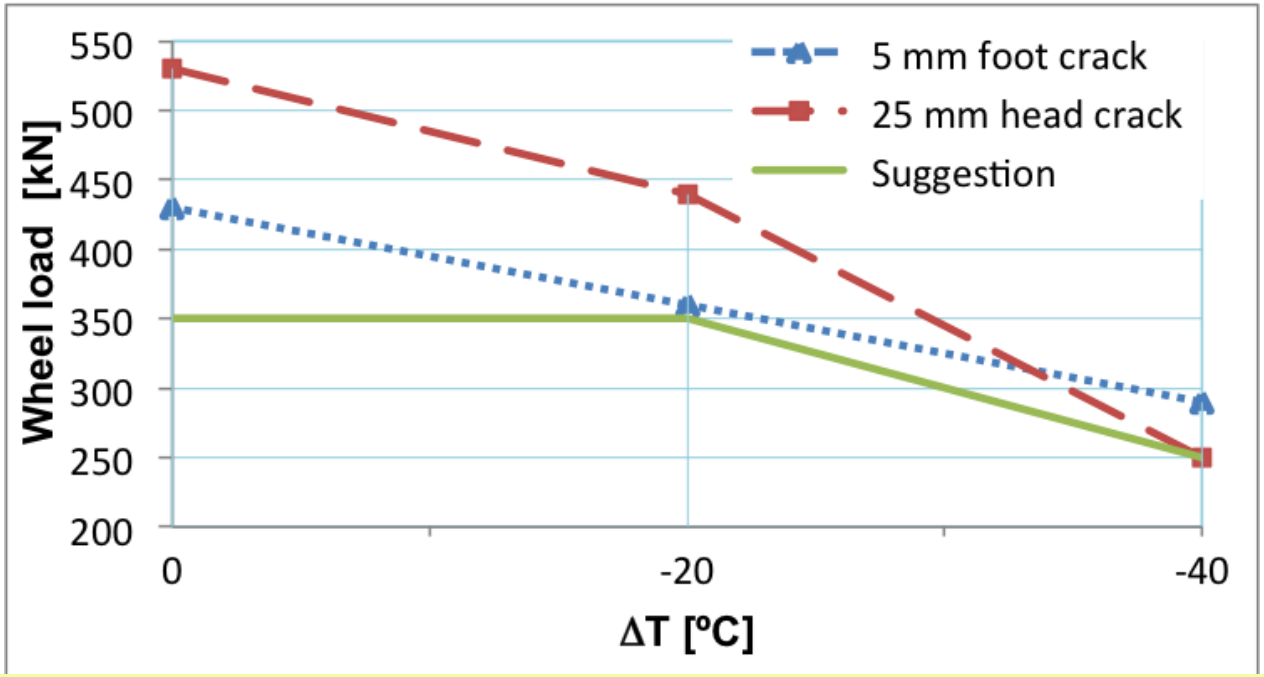
  25,5t (SBB)

  24,7t (ÖBB)





WP 2 Conclusion



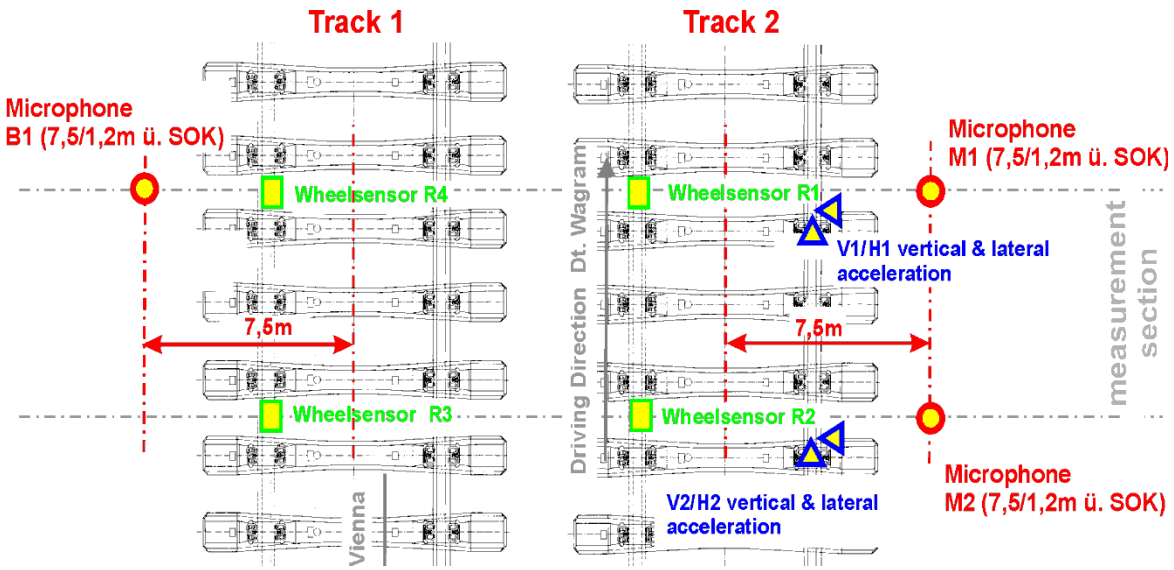
This will correspond to critical crack sizes of about 5 mm and 25 mm for foot and head, respectively.

Need for discrete ramping (e.g. 350kN, 300kN, 250kN)

For ΔT<-40°C extra caution is needed.

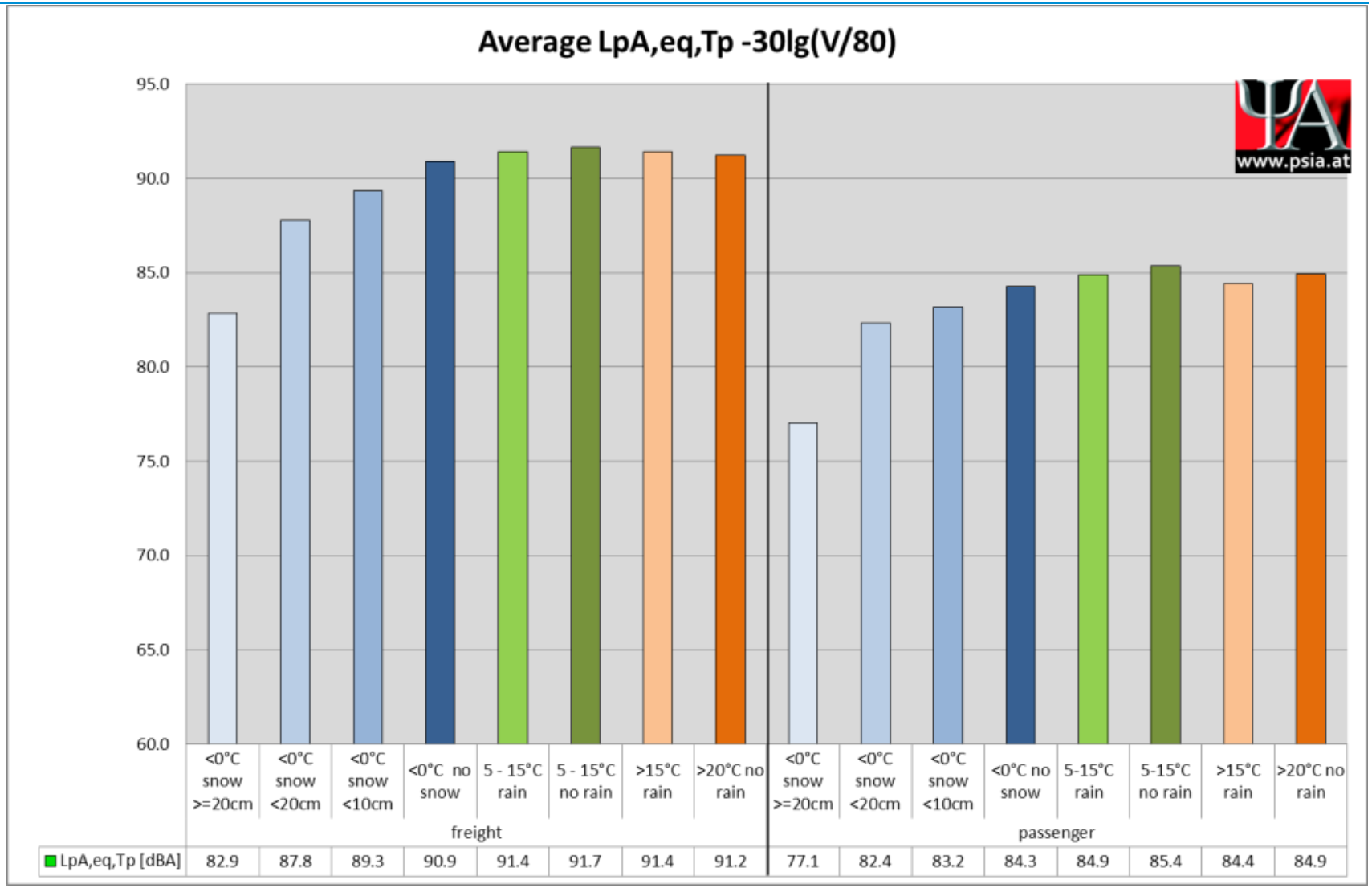
WP3 – Reproducibility of noise measurement

WP3 Conclusion



	weather condition	# trains
freight	<0°C snow	75
	<0°C no snow	84
	5 - 15°C no rain	639
	5 - 15°C rain	73
	>20°C no rain	161
	>15°C rain	48
passenger trains	<0°C snow	526
	<0°C no snow	211
	5 - 15°C no rain	1556
	5 - 15°C rain	169
	>20°C no rain	567
	>15°C rain	87
	Total amount of datasets	**4196**

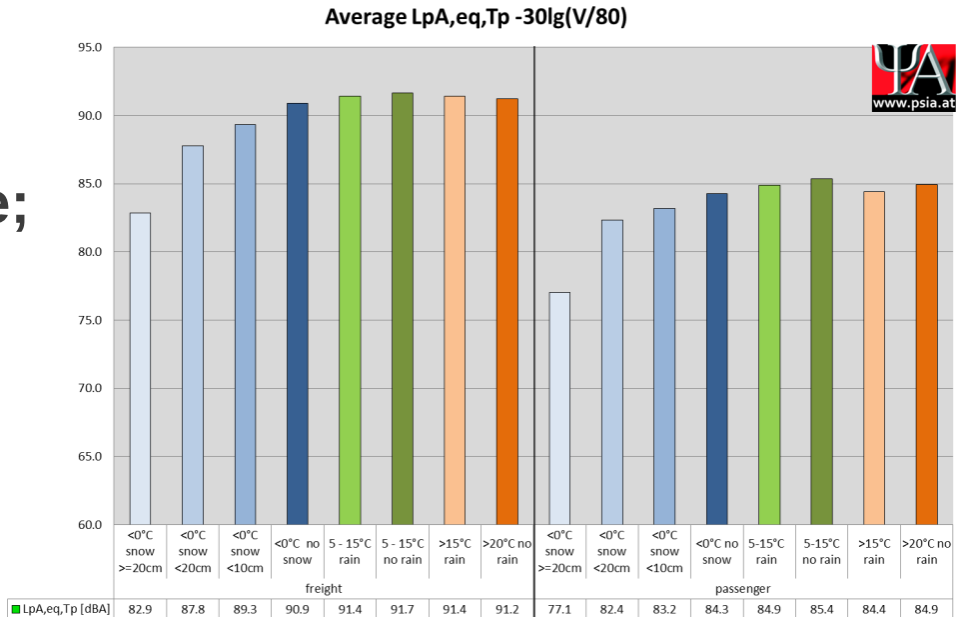
WP3 Conclusion



	<0°C snow >=20cm	<0°C snow <20cm	<0°C snow <10cm	<0°C no snow	5 - 15°C rain	5 - 15°C no rain	>15°C rain	>20°C no rain	<0°C snow >=20cm	<0°C snow <20cm	<0°C snow <10cm	<0°C no snow	5-15°C rain	5-15°C no rain	>15°C rain	>20°C no rain
	freight								passenger							
LpA,eq,Tp [dBA]	82.9	87.8	89.3	90.9	91.4	91.7	91.4	91.2	77.1	82.4	83.2	84.3	84.9	85.4	84.4	84.9

WP3 Conclusion

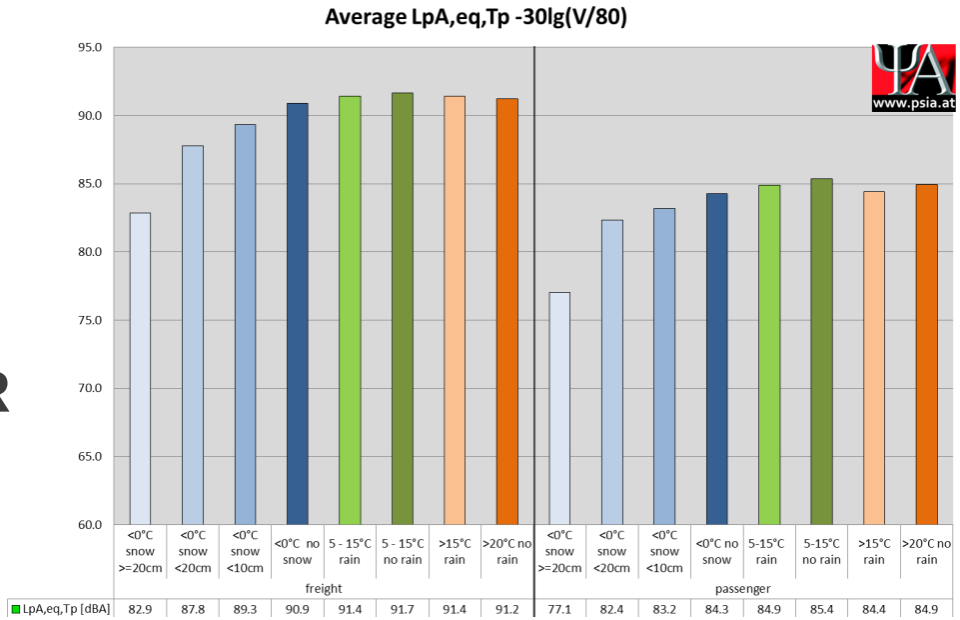
- **The influence of ground surface level is higher when surface is reflective; grass/soil is preferred**
- **For grounds with low reflection, the influence of ground surface level between 0.2 and 2.0 m is in the order of 1 dB**



- **Track design at Deutsch-Wagram (stiff rail pads and low influence of temperature on TDR) is relatively insensitive to variations in temperature**

WP3 Conclusion

- **Strong effect of snow on track (depending on snow height, uneasy to quantify)**
- **Stiff tracks with high TDR are recommended (minimization of track noise vs. vehicle noise)**



- **Rails should be maintained as low as possible to be sensitive to wheel roughness variations from one trainset to an other**
- **Autocalibrating microphones are recommended**

WP4 – Standard for vehicle identification and interoperable output and data transfer

WP4 Conclusion

Example for RFID Tag mounting

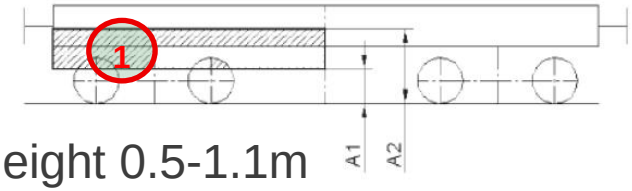
ANNEX F

COMMUNICATION

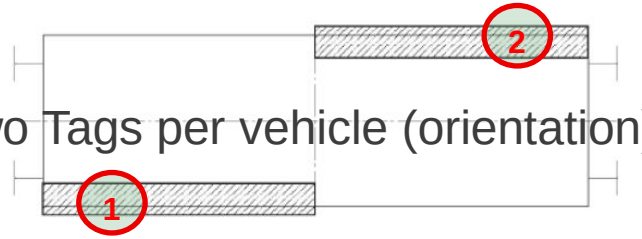
Vehicle capability to transmit information between ground and vehicle

Fig. F1

Tag position on wagon.



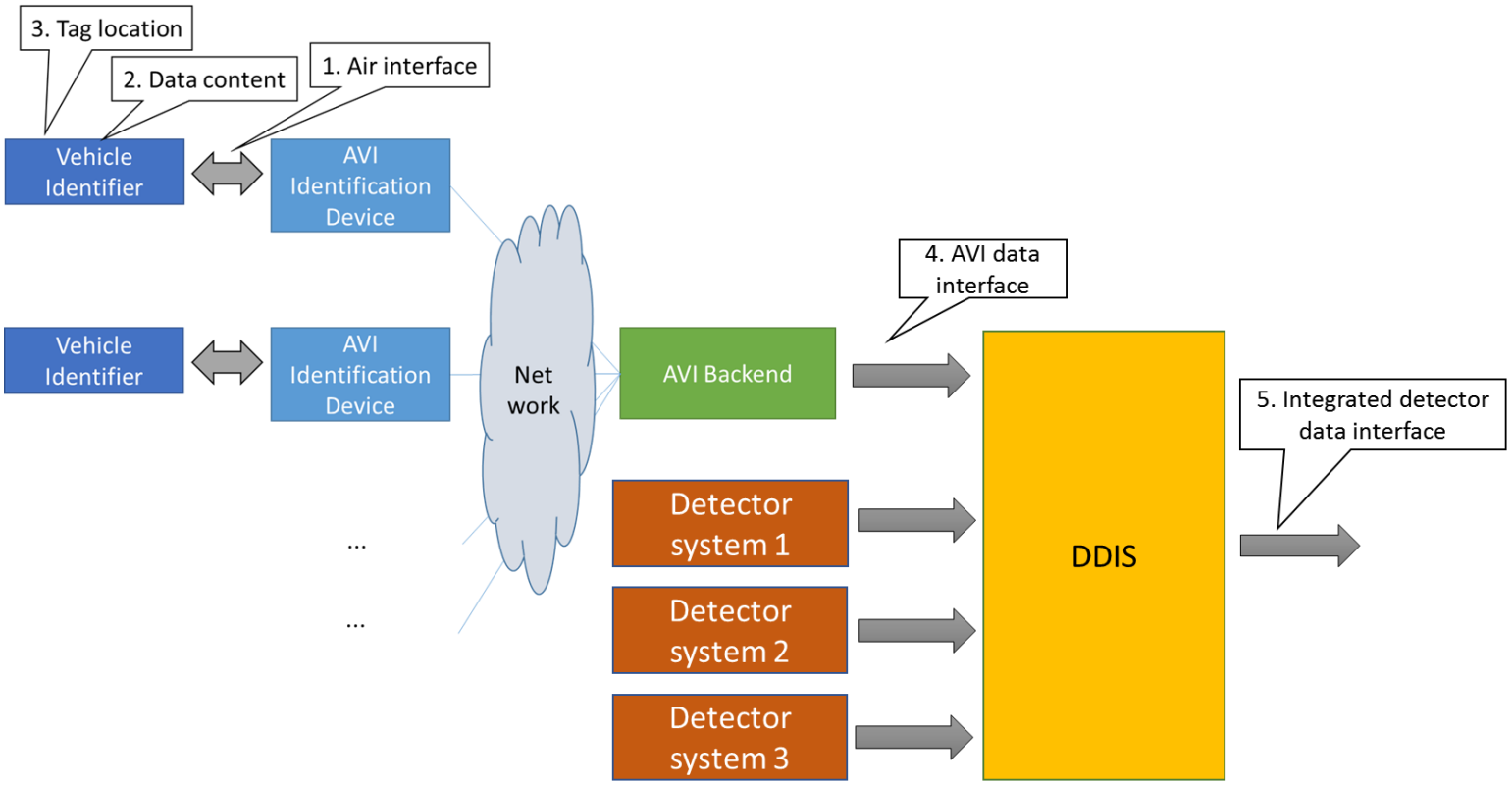
height 0.5-1.1m



Two Tags per vehicle (orientation)

WP4 Conclusion

AVI system architecture



We recommend a centralized server software for linking AVI (RFID) data to WTMS measurement results

WP4 Conclusion

HRMS WP4 specifications for RFID implementations

- **Every railway vehicle in Europe should be RFID tagged as soon as possible to meet future needs**
- **A common data format and data transfer protocol is recommended (for AVI data and integrated detector data)**
- **Regarding air-interface, tag location and tag data content, HRMS group endorses "GS1 Guideline for the Identification of Railway Assets using GS1 Standards", which already specifies details for these aspects**

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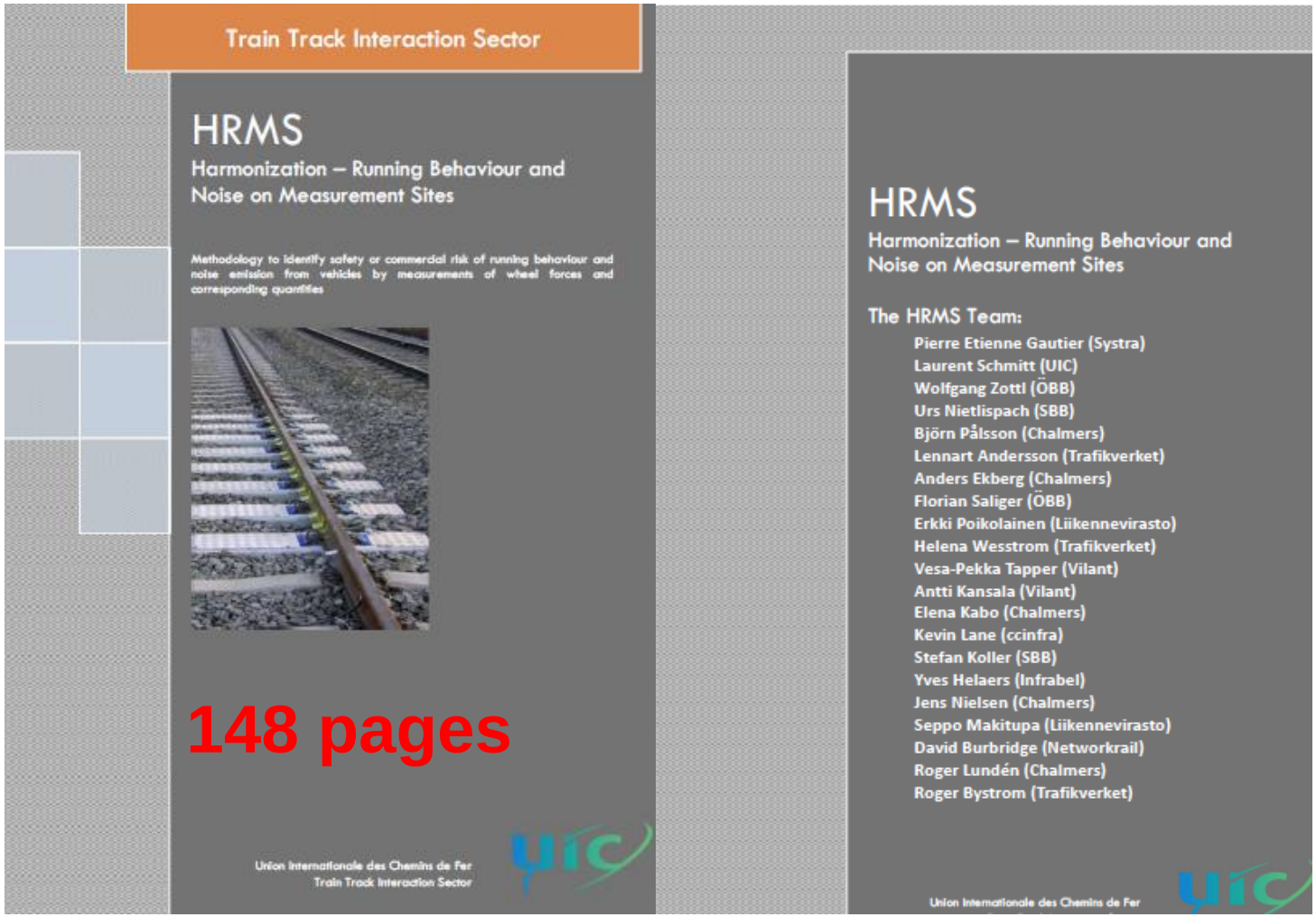
Train Track Interaction Sector
HRMS
Harmonization – Running Behaviour and Noise on Measurement Sites
Methodology to identify safety or commercial risk of running behaviour and noise emission from vehicles by measurements of wheel forces and corresponding quantities
148 pages
Union Internationale des Chemins de Fer
Train Track Interaction Sector
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Harmonization – Running Behaviour and Noise on Measurement Sites
The HRMS Team:
Pierre Etienne Gautier (Systra)
Laurent Schmitt (UIC)
Wolfgang Zottl (ÖBB)
Urs Nietlispach (SBB)
Björn Pålsson (Chalmers)
Lennart Andersson (Trafikverket)
Anders Ekberg (Chalmers)
Florian Saliger (ÖBB)
Erkki Poikolainen (Liikennevirasto)
Helena Wesstrom (Trafikverket)
Vesa-Pekka Tapper (Vilant)
Antti Kansala (Vilant)
Elena Kabo (Chalmers)
Kevin Lane (ccinfra)
Stefan Koller (SBB)
Yves Helaers (Infrabel)
Jens Nielsen (Chalmers)
Seppo Makitupa (Liikennevirasto)
David Burbridge (Networkrail)
Roger Lundén (Chalmers)
Roger Bystrom (Trafikverket)
Union Internationale des Chemins de Fer

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The geometric factor is for bending and uniform tensile loading of rail foot cracks approximated as that of an edge crack in a plate (see e.g. [14]):

$$f(a,b)=\frac{\sqrt{\frac{2b_f}{\pi a_f}\tan\left(\frac{\pi a_f}{2b_f}\right)}}{\cos\left(\frac{\pi a_f}{2b_f}\right)}\cdot\left\{0.752+2.02\left(\frac{a_f}{b_f}\right)+0.37\left(1-\sin\left(\frac{\pi a_f}{2b_f}\right)\right)^2\right\} \quad (9)$$

For rail head cracks, the geometry factor is approximated for bending (see [13]) as

$$f_b(a,b)=2.6\left(\frac{a_h}{b_h}\right)^2-0.97\left(\frac{a_h}{b_h}\right)+0.70 \quad (10)$$

and for uniform tension as

$$f_t(a,b)=1.4\left(\frac{a_h}{b_h}\right)^2-0.16\left(\frac{a_h}{b_h}\right)+0.72 \quad (11)$$

Fracture criterion

For railhead and rail foot cracks, the fracture criterion is expressed as

$$\max_t\{K_I\}\geq K_{Ic} \quad (12)$$

The maximum is taken over a load passage, and K_{Ic} is the rail fracture toughness. In the following, K_{Ic} = 40 MPa√m was employed. Note that linear elastic fracture mechanics (LEFM) is presumed to be valid, a presumption that is less strong due to the cyclic loading.

A fracture criterion for the combined bending and thermal loading (both loading the crack in mode I) can thus be expressed as

$$\max_t\{K_{Ib}+K_{It}\}\geq K_{Ic} \quad (13)$$

Since the thermal loading is presumed to be constant during a wheel passage, equation (13) can be reformulated as

$$\max_t\{K_{Ib}\}\geq K_{Ic}-K_{It} \quad (14)$$

In the current study, the influence of temperatures ΔT = 0°C, 20°C and 40°C were investigated. Examples of results are given in Figure 14 and Figure 15 for a foot crack of a_f = 5 mm, and a head crack of a_h = 25 mm, respectively. Here, vehicle types are indicated by colour:

- Vehicle type A (iron ore) – black
- Vehicle type B (high speed freight) – blue
- Vehicle type C (passenger) – red

and ballast stiffness by line types:

- k_b = 5MN/m – dotted
- k_b = 10 MN/m – dashed-dotted
- k_b = 30 MN/m – dashed
- k_b = 100MN/m – solid

Fracture according to the fracture criterion in equation (14) corresponding to crossing of the horizontal lines for the different temperatures considered.

The bad case scenarios for foot and head cracks, as defined by bending moments according to equations (1) and (2) (for foot and head cracks, respectively) is indicated by a thick black line.

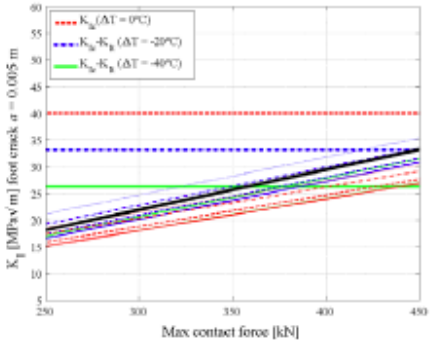

FIGURE 14 : STRESS INTENSITY FACTORS FOR A 5 MM FOOT CRACK IN A 60E1 RAIL DUE TO IMPACT LOADS OF VARYING MAGNITUDES. VEHICLE TYPE IS INDICATED BY COLOUR, AND BALLAST STIFFNESS BY LINE TYPE. THE HORIZONTAL LINES INDICATE FRACTURE TOUGHNESS REDUCED BY THERMAL STRESSES ACCORDING TO EQUATION (14). THE THICK BLACK LINE INDICATES THE "BAD CASE" SCENARIO.

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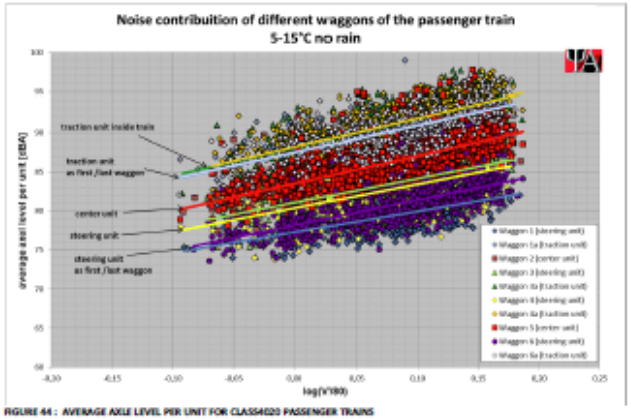

FIGURE 44 : AVERAGE AXLE LEVEL PER UNIT FOR CLASS4020 PASSENGER TRAINS

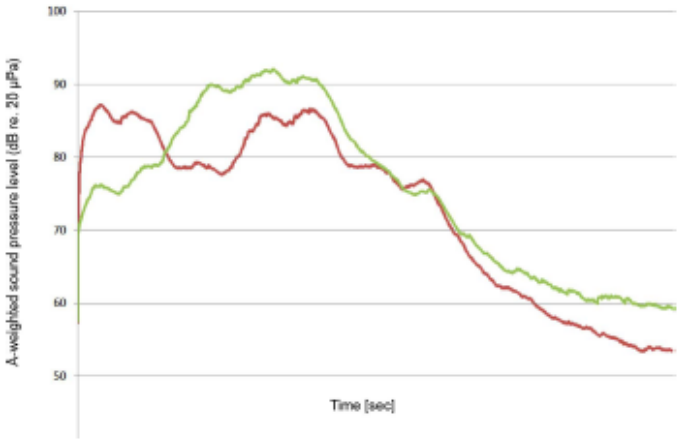

FIGURE 45 : A-WEIGHTED NOISE LEVEL VS. TIME FOR TWO PASSENGER TRAINS WITH DIFFERENT LOCATIONS OF THE TRACTION UNIT

3.4.4.3 Influence of temperature

Datasets are classified in three temperature ranges:

- T < 0°C
- 5°C < T < 15°C
- T > 20°C.

Figure 46 and Figure 47 illustrate the effect of temperature on pass by noise levels emitted by freight trains and passenger trains respectively.

Comments:

Broadly, these results reveal **a stability of average pass by noise levels vs. temperature**, the maximal deviation in average noise levels being only 1 dB.

At speeds higher than 80 km/h, and for freight trains, the average pass-by noise level for temperatures below 0 °C is about 1 dB below the noise level at higher temperatures.

For both train categories, noise levels measured for temperatures from 5 to 15°C are, as expected, slightly higher than at temperature lower than 0°C, but more surprisingly also higher than noise levels measured at temperatures higher than 20°C. The average deviation in noise levels after speed correction (applying the relation ($LpA_{eq,Tpv}$ -30lg(v/80)) from one temperature range to another is illustrated in Figure 48. The average noise level for temperatures between 5 and 15°C is 0.4 dB higher than at temperatures higher than 20°C and around 1 dB higher than at temperatures lower than 0°C.

These observations do not exactly match those from the analysis of deviation in rail vibration and track decay rates (derived from PBA tool calculations – see Appendix B for more details) when varying the temperature:

- Rail vibration levels which are analysed in terms of A-weighted particle velocity levels continuously increase as the temperature increases (see Figure 49);
- The vertical Track Decay Rate shown in Figure 50 globally decreases as the temperature increases (in the frequency range of interest, i.e. from 315 to 2000 Hz)

Note: the track decay rate is an index for noise performance of the track which quantifies the reduction in rail vibration per linear metre of rail [dB/m] in the individual 1/3-octave bands. The higher the track decay rate, the longer the effective rail radiation length.

The average 1/3-octave band pass-by noise spectra plotted for the different temperature ranges and for both train categories in Figure 52 and Figure 53, show that maximal noise levels (after A-weighting) appear between 400 Hz and 1600 Hz.

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Auswahl zu löschen.

As the centralized server software, DDIS, for linking measurement results and AVI data is the most common and has the most benefits this architecture has been taken as the basis for the UIC HRMS WP4 specifications. The other alternatives are discussed below to give a better understanding of the architecture issues.

3.5.5.1 Centralized server software

Centralized software for linking AVI data to detector data (DDIS system) means that all AVI data is collected to single server software, together with all detector measurement data. The linking of the detector measurement data to the right vehicle is done at the centralized server software after both data are received by the system.

This approach has several benefits

- The linking algorithm can be quite complex to implement. With centralized DDIS system, this needs to be implemented only once
- Updates and upgrades to the systems are typically needed every now and then. With a centralized system, updates and upgrades need to be implemented only once, and need to be installed to one location only
- AVI data interface integration needs to be implemented only once with one common interface
- Ease of operating in multi-vendor situations for detectors
- Needs only one instance of AVI backend system/software

This is the architecture used as the basis in the rest of this document, and it is the same architecture presented in Section 3.4.3.

FIGURE 67 : THE CENTRALIZED SERVER ARCHITECTURE

3.5.5.2 Local software at detector site

Local software at the detector site linking the measurement results directly to AVI data and then sending the information to a central system for further use might have some benefits in small scale implementations, where the number of vendors and detector sites is small and not expected to grow in the future. This requires separate implementation of the AVI system and its interface for each measurement site, either separately or integrated with the detector. This approach has the benefit of simplifying the managing of different software systems, in the case where e.g. only one detector type is used.

However, it has several drawbacks

- Need to implement a separate AVI interface for each detector type
- Need to implement and install the AVI system with a train composing algorithm for each instance separately. The system can be complex and implementing several systems increases the build and maintenance costs.
- More difficult to manage AVI system and detector system separately

Software changes, updates and upgrades need to designed, implemented and tested for several software and multiple instances separately each time

FIGURE 68 : LOCAL SOFTWARE INTEGRATION ARCHITECTURE

3.5.5.3 Existing implementations

The most wide scale implementations of the linking software use the centralized server software approach. These include ZKE by SBB in Switzerland, DPC III by Trafikverket in Sweden and VALTSU (planned 2014) by Finnish Transport Agency in Finland. Each implementation has gained most benefits out of the centralized approach.

3.5.6 Scope of the work

In the UIC HRMS group it was found important to give guidelines for interoperable use of AVI and detector systems throughout Europe and the World. The following issues are the most crucial in ensuring interoperable systems:

Next steps

Next Steps

- Implementation of approved proposed limit values/intervention thresholds in Europe
- Harmonized measuring results (axle loads, dynamic forces, noise, hot box detection, overall vehicle gauge measurement …)
- Cross border WTMS Data exchange
- RFID Tags on every railway vehicle
- UIC Leaflet about WTMS

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unity, solidarity, universality

Thanks for your attention!

More information:

Wolfgang Zottl
ÖBB-Infrastruktur AG, R&D
wolfgang.zottl@oebb.at
+431/93000-32604

Laurent Schmitt
UIC, Senior Advisor Infrastructure
lschmitt@uic.org
+33 1 44 49 21 10