Requirement specification

Pilot Wheel Profile Measuring System

Supply, installation and one year operation of a track bound wheel profile measuring system (lease with option to purchase)

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Definitions

Train: a single or group of rail vehicles that are coupled together.

Train length: distance between first and last axle of a train.

Train direction: direction in which the train passes the measuring site with respect to the defined standard operating direction.

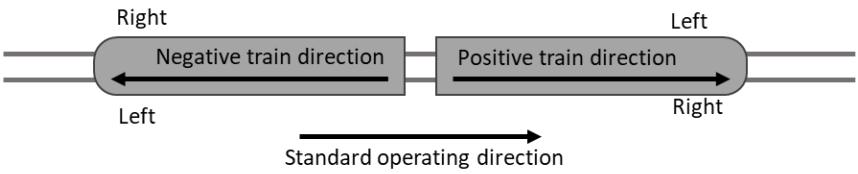


Figure 1: definition of train direction

1. Introduction

This document aims to describe the project, identify the involved parties, define the project scope, outline responsibilities, and specify our expectations for the wheel profile measuring system and the resulting data. Therefore, this document encompasses the requirements specification for supply, installation, operation and data.

The complete list of requirements can be found in *Annex 1 Requirements Specification Matrix*. In case of any inconsistencies, *Annex 1 Requirements Specification Matrix,* is leading.

ProRail will lease the wheel profile measuring system for this project, with the option to purchase.

2. Initial Situation & Goals

Involved Parties: NS & ProRail
This project is a cooperation between NS (passenger railway operator) and ProRail (rail infrastructure manager) in the Netherlands.

ProRail represents the interests of the other railway operators and freight railway operators in this project. They do not participate directly in this project.

Camino Rail development program
Within Camino Rail, a joint program of NS and ProRail, NS and ProRail are experimenting together with new data-driven solutions that improve the performance of infrastructure and trains. This includes collecting and enriching existing data and generating new data with sensors. As a possibility to generate additional information, ProRail and NS are preparing a pilot for a track-related wheel profile measuring system (WPMS).

Wheel measurement with WPMS
The wheelset is the part of the train which carries the weight of the load. Therefore, it is exposed to high forces which can lead to failures of the wheelset components. To reduce the risk of failure strict maintenance intervals and inspections must be executed. The wheelset inspection process is divided into different maintenance stages, that shall be supported with the WPMS data.

Intended purpose of a WPMS
The purpose of the WPMS is to support and improve safety, maintenance and operation. This means for example:

- Monitor and possibly warn or alarm on deviating wheel profile characteristics to enhance safety.
- Provide real-time information to the Entity in Charge of Maintenance (ECM) to enable condition-based wheel maintenance so that the ECM:
    - Can monitor wheel profile characteristics so that the current manual measurement effort in the workshop or at the shunting yard can be reduced.
    - Can optimize the wheel maintenance so that life cycle costs can be reduced.
    - Can reduce the inspection time so that the availability of trains can be improved.
- Monitor and detect sudden abnormal degradation of a train or fleet in an early state so that the operational impact can be minimized.
- Monitor and possibly warn or alarm on deviating wheel profile characteristics so that infrastructural damage can be prevented, and availability and safety can be increased.
- Can optimize the planning of periodic wheel maintenance in the overhaul and maintenance depots so that the train availability and the reliability of the planning can be improved and the amount of logistic movements can be reduced.
- Enable research and developments related to the (current) population and condition of wheel profiles and their interface with the infrastructure.

Wheel measurement today
Wheel measurements are currently carried out by operators by means of periodic inspection. In addition, tread defects are monitored by means of the Quo Vadis system, a wayside wheel force measurement system.

Within NS, wheel measurements are done manually every three months and the equivalent conicity is measured and determined every year in the workshop. In the case of sudden abnormal degradation, this will be investigated directly by means of time intensive research and measurements. Depending on the workshop, there could be different maintenance strategies for the three-monthly measurements:

- Preventive maintenance strategy: the train will go to the wheel lathe every three months.
- Corrective maintenance strategy: the train wheels will have a visual wheel tread inspection and will be measured with a digital wheel profile measurement device (Calipri) every three months. Depending on the results, the train will go to the wheel lathe.

For (freight) wagon owners, wheel measurements are carried out annually or during major maintenance.

Wheel measurement in the future
The desired process would be that ProRail, NS and other operators have real-time information about the wheel condition internally available, so that the information can be easily used for further automatic processing and continuous development of wheel maintenance optimization.

For NS, continuous and real-time wheel monitoring enables condition monitoring of the wheels. This would make the labor and time intensive manual measurements for the three-monthly inspection and the equivalent conicity unnecessary. Also, degradation of wheels could be monitored. This means that the planning in the workshop and for the wheel lathe can be optimized, since an indication can be given beforehand if the train must go to the wheel lathe. During peak hours, for example during autumn, it would be possible to prioritize the trains for the wheel lathe. Also, maintenance and spare part management can be optimized and research on wheel optimization can be done, since degradation of wheels will be clear and traceable. Since bogies have high life cycle costs, this could be of interest. Different alarming functionalities can be developed by the infrastructure manager or the operators by using automatic anomaly detection methods and by combining the information with other data sources.
In this way, abnormal degradation patterns can be detected at an early stage and damage on the infrastructure or unexpected standstill of trains can be prevented.

For ProRail, wheel monitoring gives insight into the current population and condition of the wheels of the trains of the different train operators that run on the Dutch railway infrastructure. With this insight, ProRail will be able to set norms and requirements for the wheel quality. For instance, hollow wheels can damage parts of the switches, floors of level crossings and rail dampers. With these requirements, ProRail will be able to warn or alarm on deviating wheel profile characteristics that can harm the infrastructure, so that additional maintenance of the wheels can be done and maintenance costs due to damaged infrastructure can be prevented.

For these purposes, a nationwide network of 5-10 wheel profile measurement systems would be required, so that train wheels can be measured frequently during operational train service. Also, all data shall be internally available for ProRail and NS, so that continuous research, developments and implementations can be easily done.

Goals of the pilot
The main goal is the verification and validation of the system and the added value. This will give input for a decision for a national roll out by ProRail and/or NS.

Based on the pilot, the following can be determined:

- Whether the measurements are accurate and reliable enough, so that the anticipated benefits are proven in practice and can be realized.
- The actual costs and effort of implementing and operating such a system in practice.

3. Delivery Items / Scope of Supply

The delivery of the complete wayside train monitoring system and the related services can be divided into different subitems:

- Wheel Profile Measurement System
- Tracking and triggering system
- Measurement data
- Service and support
- Documentation

Each subitem is explained in this document. See *Annex 1 Requirements Specification Matrix* for the specific requirements.

In general, the system will be activated based on the presence of a train. The system will measure the passing train and identify the train by using an RFID (Radio Frequency Identification) tag reader. After the train has passed, the measurements and the metadata will be sent in a single data packet to the ProRail system/server.

The supplier is responsible for developing, shipping, setting up and running/operating the described system within the timeframe provided.

Wheel Profile Measurement System
The Wheel Profile Measurement System will be an optical measuring system which scans the wheel profile of passing trains. The system uses (laser) sensors which are installed in the track. This position allows the sensors to capture all required measurements of the wheel profile.

For the project there will be a lease of one wheel profile measurement system for 12 months, with the option to purchase.

Tracking and triggering system
The system will be activated based on the presence of a train (e.g. through a triggering/wake-up mechanism). Train identification with an RFID reader is necessary to assign the data to the right wagon, the right axle and the right wheel position. All for the project relevant rail vehicles are equipped with two RFID tags (GS1 Standard). Each RFID tag has unique content. The RFID transponders are attached on the right external beam (Wagon end 1, seen from positive train direction) and on the left external beam (Wagon end 2, seen from positive train direction). The RFID tags on each side of the train are different.

Measurement data
A measurement from the wheel profile measurement system will result in a single data packet containing the measurements and metadata and will contain four sections with:

- Measurement on train level: General information about the train passage.
- Measurement on wheel level: General information about the wheel and measured and calculated quantities of the wheel profile.
- Measurement on wheelset level: General information about the wheelset and measured and calculated quantities of the wheelset.
- Measurement of wheel profile coordinates: General information about the wheel and measured raw data of the wheel profile.

The single data packet is provided to ProRail. ProRail and NS become owners of the data.

Services & Support
The scope of service & support is defined as:

- Providing the described system at the described location with the required components.
- Connecting the system and all components, such as connecting the wiring and linking it to the modem/computer and making the data accessible (infrastructure work to be completed by ProRail).
- Initial startup and calibrating the system/commissioning.
- Ensuring that the data corresponds to the described parameters and is correctly assigned to the axles, wheels and train side.
- Ensuring that the data is transferred and received correctly at the ProRail Azure Cloud environment.
- System monitoring, maintenance and troubleshooting during the pilot (the system is supposed to be maintenance free and free of additional maintenance cost during the pilot phase).
- Shipping to a secured location of the subcontractor of ProRail near the test site (ProRail will do the shipment from the site to the supplier).
- Decouple all systems, after the pilot, before de-installation of the system by the subcontractor of ProRail.

During the installation phase, the supplier will work closely with the client to accelerate the site preparation and installation process.

Documentation
ProRail regulations require certain documents for planning and installation of the system. A part of the documentation needs to be provided prior to installation and needs to be proven that during and after the set-up the railway safety and operations are not affected.

4. System Boundaries

The roles and responsibilities between the supplier and ProRail can be found in figure 2 and table 1. The services provided by ProRail are explained in chapter 5, “Service provided by ProRail”.

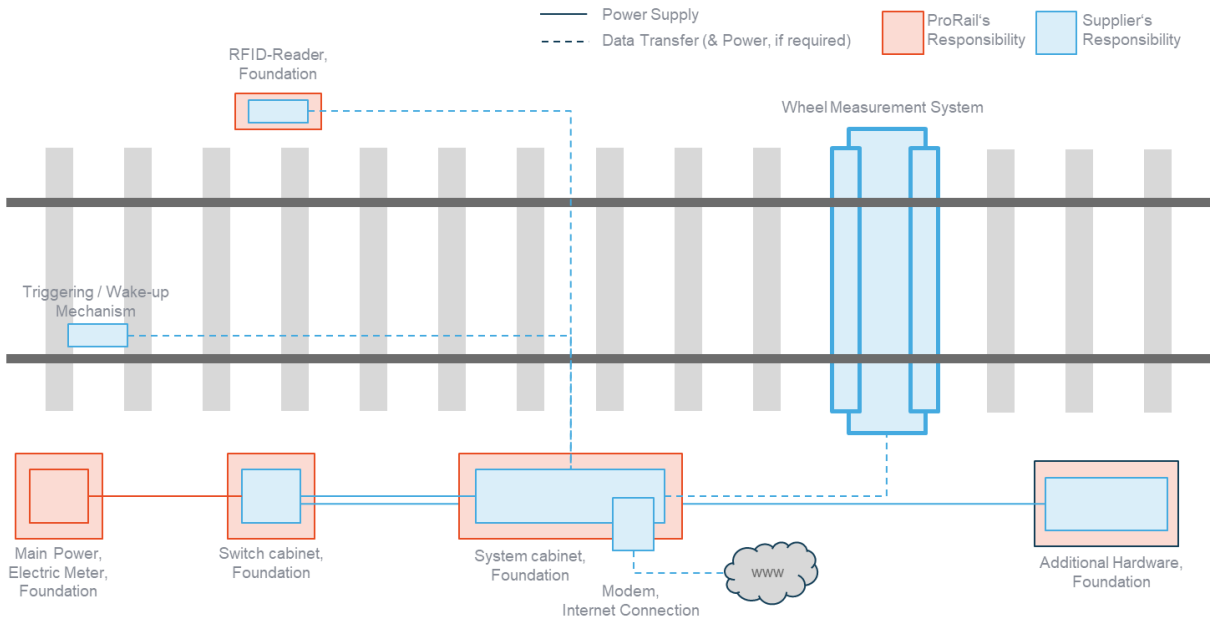


Figure 2 - System boundaries

Component	Procurement	Supply at site	Installation	Input
Main Power (230V AC, 16A and 400V AC) incl. Foundation, Cabinet & Cabling	ProRail	ProRail	ProRail	-
Electric Meter (if relevant)	ProRail	ProRail	ProRail	-
One or two cabinets (Switch/System cabinet incl. cabling)	ProRail	ProRail	ProRail	ProRail (allowed Standards)
One or two cabinet Foundations (Switch/System cabinet)	ProRail	ProRail	ProRail	Supplier (layout)
Components inside Switch/System cabinet (incl. cabling, computer, server racks)	Supplier	Supplier	Supplier	ProRail (allowed Standards)
Modem	Supplier	Supplier	Supplier	ProRail (allowed Standards)
Internet connection	Supplier	Supplier	Supplier	ProRail can provide a SIM card (costs will be on account of ProRail)
RFID Reader unit (incl. cabling)	Supplier	Supplier	Supplier	ProRail (RFID Standard)
RFID Reader Foundation/Stand	ProRail	ProRail	ProRail	Supplier (layout)
Triggering/Wake-up Mechanism (incl. cabling)	Supplier	Supplier	Supplier	ProRail (allowed Standards)
Wheel Measurement System (incl. cabling)	Supplier	Supplier	Supplier	
Additional Hardware (if needed, incl. cabling)	Supplier	Supplier	Supplier	
Additional Foundation (if needed)	ProRail	ProRail	ProRail	Supplier (layout)
Cable Conduits	ProRail	ProRail	ProRail	Supplier (layout)

Table 1 - Roles and responsibilities

5. Services provided by ProRail

For ProRail and NS, a successful pilot is of high importance. The companies will support the pilot, to ensure the successful conduction of the pilot.

Services
ProRail works with subcontractors for track maintenance and the installation of additional equipment. They have the right authorities to work in/on the track.

The following services will be explicitly provided by ProRail or by their subcontractors:

- Managing the internal approvals to set up the system (based on supplier's information and documentation).
- Preparation and conduction of the required underground works (e.g. track crossings, foundations, cable ducts / cable conduits) and heavy lifting (e.g. if a crane is required to place and move large items).
- The provision of one or two small cabinets within five meters of the measuring location. In the cabinet will be an electrical earth connection, which is obliged to be used by the supplier to earth the measuring device, and a switch with a 16A fuse and a 230V connection, see Figure 3. For the auxiliary equipment a 400 V AC power supply can be made available. The maximum power consumption shall be designed in consultation with ProRail. Preferably, the power consumption is as low as possible. Energy expenses will be covered by ProRail.
- Organizational support during the set-up.
- Needed construction approvals from external stakeholders.
- Development of the "approval to conduct work close to railroad" tracks during the installation.
- Safety personnel during installation, maintenance and de-installation.
- Requests for work at the track during train-free periods (all work at the track will take place during natural train breaks during the night, when no trains are driving, these breaks last 4 hours and are approximately monthly or bimonthly).
- All relevant details of all trains (incl. wheelset information) passing through the site and to be monitored by the system.

- Supervise the supplier with the installation of the system in the track.
- Removal of the system from the track and the cabinets and other additions next to the track, after the pilot (before removal the supplier must decouple all systems).
- Shipping of the system from the site to the supplier, in the case that the option to purchase is not used.

All specific needs concerning the services of ProRail or their subcontractors must be stated by the supplier as part of the offer process.

Figure 3, Cabinet: approximately 1500x1000x600 mm

6. Location pilot

Description of the measuring location

The foreseen location of the pilot is between Weesp and Bussum, south-east of Amsterdam (Geocoordinates 52.294765, 5.090124), see figure 4 and figure 5.

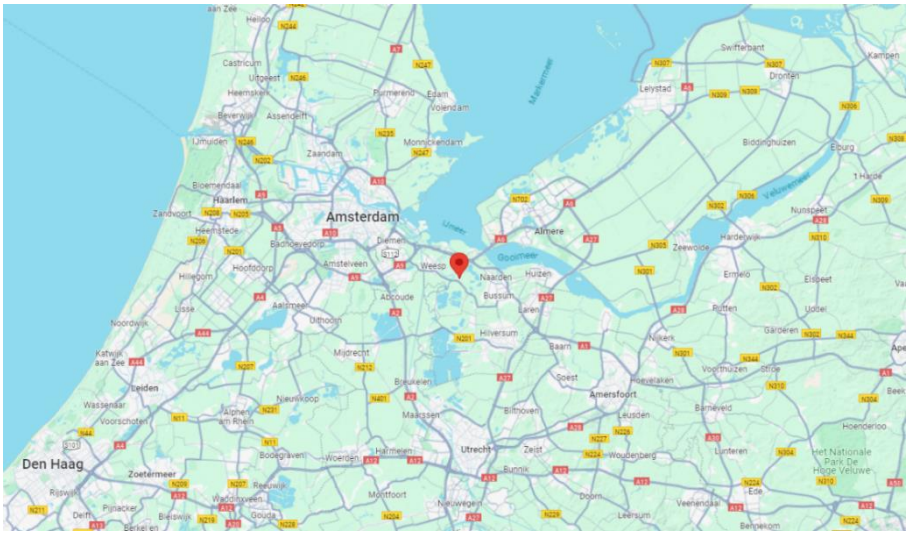


Figure 4: Location for the pilot installation

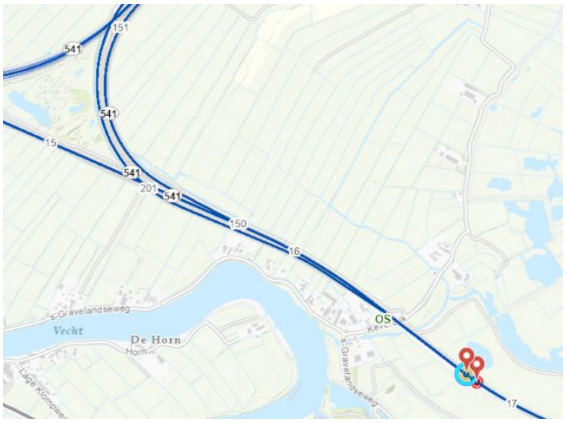


Figure 5 - Pilot location - nearby yellow and red spot (Railmaps)

The site can be described as follows:

- Two tracks, only one shall be measured.
- Both driving directions possible.
- Approximately 300-400 train passages per day, approximately 2350 per week.
- Several passenger train types pass this location as well as freight trains. Some of the most common passenger train types: SNG, ICM, DDZ, SLT, VIRM, TRAXX, ICNG.
- 24/7 operation possible without any interruption. The actual operating time of the track depends on the at a time applicable train schedule, but mostly this is between 05:00 hrs – 01:00 hrs on working days and between 05:00 hrs – 03:00 hrs during the weekend.
- The driving speed is up to 140 km/h for passenger trains and 100 km/h for freight trains, whereas most trains drive between 120-140 km/h, see figure 6. The trains and track are designed at a speed limit of 160 km/h.
- The track design is railhead UIC54E1 with 1/40 inclination and a 1435 gauge.

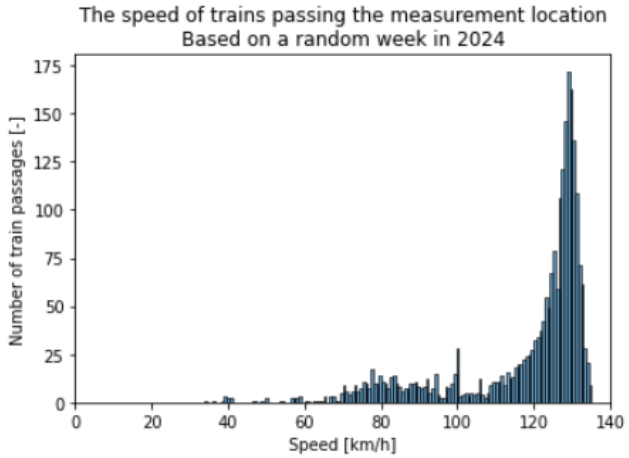


Figure 6 - Distribution of train speed at the measurement location

It will be close to a Quo Vadis wheel force measurement system and Hotbox detection location, so ProRail and NS can verify the reading of the RFID tags to this specific location. Also, it will be close to a power station for the energy supply of the WPMS.

7. Wheel Profile Measurement System requirements

The system is supposed to run during day and night (24 hours) and record/measure all types of wagons and wheels. The provided system must meet the required standards concerning material, processing and safety to be operated in ProRail railway environment. The system shall comply with the current technology standards and be according to all relevant safety guidelines. If demanded by ProRail, the supplier must prove that those standards are followed.

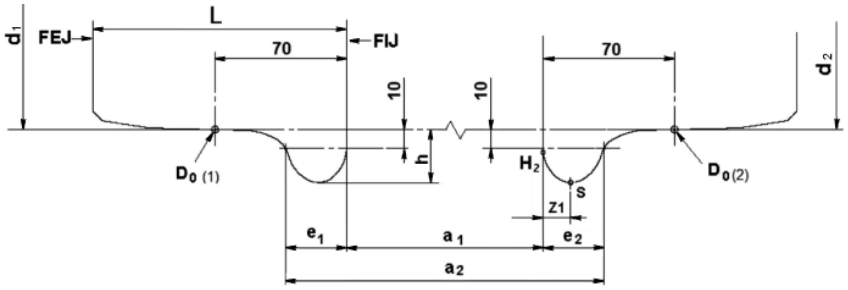
The detailed system requirements can be found in *Annex 1 Requirements Specification Matrix*. It consists of the following information:

Required Measurement Values
The required measurement values, including their range, accuracy and resolution, are specified in *Annex 1 Requirements Specification Matrix* as part of the functional requirements. A summary of the required quantities is given in the table below. In case of any inconsistencies, *Annex 1 Requirements Specification Matrix,* is leading.

Most quantities are defined in EN standards. The appropriate standards and naming are provided in table 2 under ‘Reference’ and *Annex 1 Requirements Specification Matrix.* Figures with definitions of the quantities are presented in Figure 7 through Figure 11.

Quantity description	Reference
Flange thickness	EN15313, e
Flange height	EN15313, h
Flange angle dimension	EN15313, qR
Wheel diameter measured at 70mm from the internal face	EN15313, D_0
Wheel tire thickness with respect to groove	EN15313, Rd, 3.2.1.7 wear groove
Wheel rim width	EN15313, L
Back to back dimension	EN15313, a1
Front to front dimension	EN15313, a2
Equivalent conicity	EN15302 and EN14363, $\tan\gamma_e$
Hollow wear of tread profile	EN15313, false flange
Material discharge horizontal	EN15313, roll-over, s1
Wheel profile coordinates (raw data from each measured wheel profile)	Chapter 7, coordinates

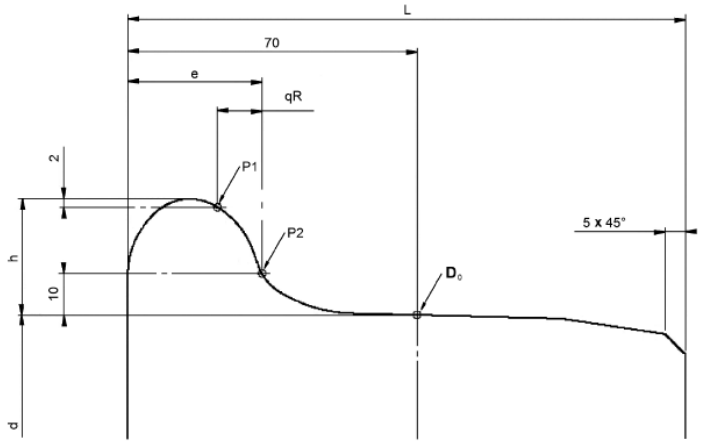
Table 2 - Measurement Quantities



Key

a_1	back-to-back dimension
a_2	front-to-front dimension ($a_1 + e_1 + e_2$)
D_0	location of the wheel tread, 70 mm from its internal face. (1) wheel 1, (2) wheel 2
e_1, e_2	flange thicknesses
h	flange height
L	rim nominal width

Figure 7 - Definition of interface dimensions - from EN15313, figure 8



Key

d	wheel diameter
D_0	location of the wheel tread, 70 mm from its internal face
h	flange height
L	rim nominal width
e	flange thickness
qR	flange angle dimension between P1 and P2

Figure 8 - Definition of wheel functional reference (from EN15313, figure 9)

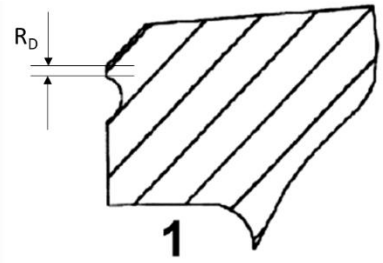


Figure 9 - Definition of wheel tire thickness R_D

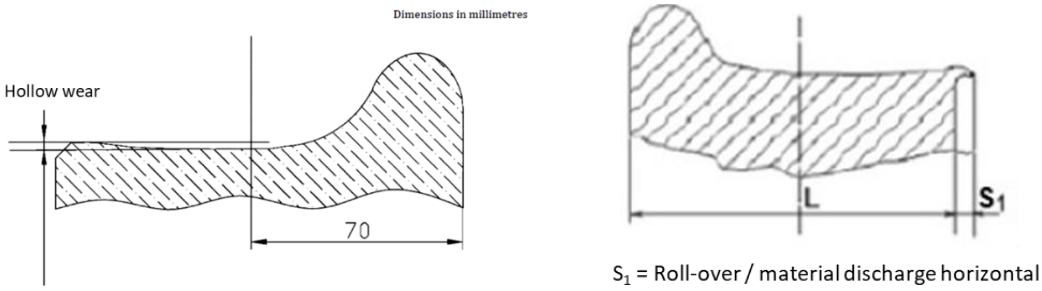


Figure 10 - Definition of hollow wear (false flange, left) and material discharge horizontal (roll-over, right) (from EN15313)

Equivalent Conicity
The equivalent conicity is a complex calculated parameter. It is described as 'tangent of the cone angle of a wheelset with coned wheels whose lateral movement has the same kinematic wavelength as the given wheelset'

The equivalent conicity is calculated from the wheel and rail profiles and their relative position. The general method for calculating the equivalent conicity is described in standard EN153202. The specific requirements for the pilot system are set in *Annex 1 Requirements Specification Matrix*.

Wheel profile coordinates
The quantity 'coordinates' is not defined in a standard. This is defined as follows:

- A list of x-, y- coordinates that defines the shape of the profile.
- Origin of the coordinate system at location of the wheel tread D_0.
- Sign convention as indicated in 1.
- Resolution and range as specified in Annex 1 Requirements Specification

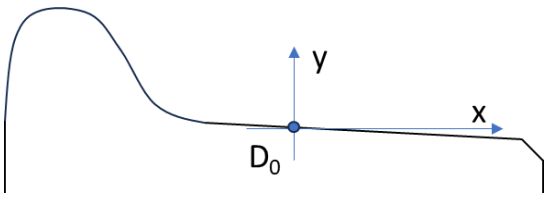


Figure 11 - Sign convention of wheel profile coordinates

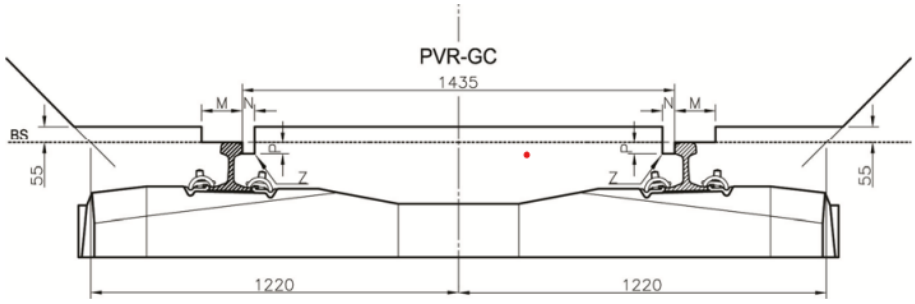
Definition of accuracy
The required accuracy of all measured and calculated quantities is defined with a confidence level of 95%. In addition, one and a half times the required accuracy must be within a confidence level of 99.7%. E.g. If the actual value is *x* mm and the accuracy is defined as *a* mm, 95% of the measurements shall be within *x* ± *a* mm, and 99.7% of the measurements shall be within x ± 1.5*a* mm.

The measurement error shall be normally distributed with 2σ better or equal to the specified accuracy, with σ being the standard deviation of the measurement error.

8. Hardware track

When designing and installing the WPMS, consideration must be given to the requirements set by ProRail for the various components within the track, while ensuring a safe track. In this chapter a brief description is given for each component. See *Annex 1 Requirements Specification Matrix* for the specific requirements.

Structure gauge: The structure gauge is an agreed-upon space around the track where fixed objects cannot be placed. The risk is that a train might collide with these objects as it passes by.



M	–	135 mm	voor vast aan de spoorstaaf verbonden voorwerpen;
		150 mm	voor andere niet bewegelijke voorwerpen.
N	–	41 mm	voor strijkregels en strijkspoorstaven over het gedeelte tegenover de punt-stukken van wissels en kruisingen;
		45 mm	voor strijkregels en strijkspoorstaven;
		70 mm	voor andere niet beweeglijke voorwerpen.
P	–	45 mm	voor nieuw werk;
		38 mm	minimale maat, ook bij slijtage van de spoorstaaf.
Z	–		afrondingsbogen tot met een maximale straal van 12 mm.

Figure 132 - Overview Structure gauge (from OVS00026-V006)

Ballast Bed: The ballast bed will be adjusted as necessary before installation. The WPMS installation must not compromise the stability of the track.

Sleeper: At the test location, sleeper type NS90 is used with a sleeper spacing of 60cm.

Hollow sleeper: A hollow sleeper may only be used if it does not serve a load-bearing function. For example, it can be used as a cable duct. ProRail has not approved any hollow sleeper as a replacement for the standard sleeper. When using a hollow sleeper, consideration must be given to the structure gauge (see figure 12).

Rail: In the Netherlands, rail type 54E1 is used. Drilling into the rail is not permitted; only clamping is allowed.

9. System acceptance and validation

The supplier shall validate the system after installation (the system acceptance). In addition to the supplier's system acceptance, ProRail and NS will validate the installed system as part of the pilot. Validation means assessing the validity and accuracy of the supplied measurement data.

System acceptance by the Supplier
The system acceptance after installation will be done in two phases:

1. Acceptance of installation: immediately after the installation the supplier shall prove that the system has been correctly installed and train operation can safely be resumed.
2. Acceptance of fit for use: within two weeks after installation, the supplier shall provide a statement to ProRail and NS that the system is fit for use:
    a. The supplier shall demonstrate that the system has been validated against and compliant with the requirements of *Annex 1 Requirements Specification Matrix*.
    b. The supplier shall demonstrate that the installed system corresponds to the validated system.

c. The supplier shall demonstrate that the installed system is fit to provide the required performance. This shall at least contain:
    i. Commissioning report.
    ii. Calibration report.

After the system acceptance by ProRail and NS the trial will formally start.

Validation by ProRail and NS

The exact scope of this validation and coverage of the requirements will be determined during the proof of concept/pilot phase. ProRail and NS will at least perform the following validation activities:

- Comparison of measurements from the WPMS system for the same wheel for succeeding measurements.
- Comparison of measurements from the WPMS system and measurements taken at the workshop (e.g. with a wheel lathe or Calipri).
- Validation of robustness of the system.

Validation of succeeding measurements

Passenger trains are fitted with tags. By combining the information underneath, measurements of passenger trains can be coupled to a unique wheel and followed over time:

- The measured tag
- The driving direction
- The tag reader location (left or right)
- The tag list, which is a configuration file that couples the tag to a rolling stock number

The accuracy of measurements will be validated by comparing the WPMS measurements over time for all WPMS measurements on wheel and wheelset level for all axles during the pilot period.

Validation of measurement quantities

Passenger trains are fitted with tags. The wheels of trains are manually measured by NS as part of the regular wheel maintenance process. Either by manual measurement or at the wheel lathe. These measurements will be used as a reference for validation of the measurement quantities.

The validation will be based on all axles of at least four SNG trainsets (with either 8 or 10 wheelsets), providing at least 64 to 80 validation cases.

Each reference measurement will be compared with prior and post measurements from the WPMS. The WPMS measurements will be compensated for wheel profile wear (linear over mileage). The accuracy of the reference measurement system will be accounted for as well.

Validation of measurement quantities (equivalent conicity)

The equivalent conicity is not measured as part of the regular maintenance process. It will be evaluated separately by comparing three quantities:

a) The equivalent conicity as provided by the WPMS.
b) The equivalent conicity calculated from the wheel profile coordinates as provided by the WMPS.
c) The equivalent conicity calculated from manually measured wheel profiles.

Comparison of a) and b) provides information on the correct implementation of the equivalent conicity calculation (according to EN 15302 and EN14363). Comparison of b) and c) provides information on the accuracy of the measured wheel profile coordinates and consequences for the equivalent conicity.

The comparison will be made for two selected SNG trainsets, resulting in 32 to 40 validation cases. The selected trainsets will be specifically measured for this purpose. Each validation case will be compared with prior and post measurements from the WMPS system.

Validation of robustness of the system

Since the WPMS system will be used in the maintenance process, the robustness of the WPMS system is important. Therefore, the robustness of the system will be validated by calculating the following quantities:

- Availability:
  - The available amount of WPMS measurements on train/wheel/wheelset level with respect to the total amount of train/wheel/wheelset passages.
- Completeness:
  - The available amount of WPMS measurements on train /wheel/wheelset level with a complete measurement with respect to the total amount of train /wheel/wheelset passages.
- Timeliness:
  - The amount of WPMS measurements with respect to the total amount of available WPMS measurements, where the time between the WPMS measurement and the availability on the ProRail cloud environment is within the specified number of minutes.

10. Defect Management

We do not expect any failure to occur in the system or any of its components during the pilot. During the pilot the supplier monitors the system to assure that the system is running and free of defects. Should any errors, failures or defects nevertheless occur, we expect the supplier to rectify these defects in the system that are either reported to the supplier by the customer, e.g. via e-mail, or which the supplier identifies independently of the customer. Regarding defects that are discovered by the supplier independently of the client, we expect that the supplier notifies the client of the defect immediately before it is corrected.

Defects are errors of any kind, including malfunctions and other impairments to the expected functioning of the system. Defects can occur on hardware, software or the data quality / data outcome. There are technical defects and functional defects. Both defects might have an impact on railway safety or the quality or provision of measured values so that the specified requirements are not met anymore or not. A defect may also exist as a defect in the documentation if a reasonable user with basic knowledge of the use of the system or programs/software is unable to understand the operation of individual functions with reasonable effort with the aid of the documentation or is unable to solve problems that arise with reasonable effort.

For the troubleshooting of defects, recovery and resolution times shall commence from the date of notification of the defect by the client or discovery by the supplier, whichever occurs first.

Downtime

We expect that the total downtime of the system does not exceed 10% of the lease period. Downtimes due to planned or corrective maintenance of the track by ProRail will be excluded from this calculation. If the downtime exceeds the above-mentioned value, we expect that the period of use shall be extended by the downtime period and that the extension of the period of use shall be free of charge for the client.

Defect Priorities
Defects are classified into different defect categories. Different response and recovery times apply depending on the defect category.

Defect priority 1

exists if the use of the system or parts thereof is impossible or severely restricted, for example due to malfunctions, incorrect work results or response times, or if data records/measurement data can no longer be restored. Appropriate, economically viable use is not possible or is unreasonably restricted.

Defect priority 2

exists if the use of the system or parts thereof is not impossible or is not severely restricted, for example due to malfunctions, incorrect work results or response times, and is still possible with

reasonable organizational or other economically reasonable means. Data records/measurement data are not affected by the defect or recoverable. Appropriate and economically reasonable use is only possible with restrictions.

Defect priority 3

exists if the use of the system or parts of the system is not directly and/or not significantly/substantially impaired by the defect, such as in the case of unfavorably defined basic settings or missing "nice-to-have functions". The system can be used for its intended purpose and in an economically viable manner despite the defect.

Response and resolution times
In the event of system failures that do not allow the measured values to be restored during the downtime (defect priority 1), a maximum recovery time of 1 working week applies.

In the event of system failures that do allow the measured values to be restored after the fault has been rectified (defect priority 2), a maximum recovery time of 2 workings weeks applies.

Defects that have no influence on the quality or provision of measured values (defect priority 3) are prioritized in consultation with the client.

See *Annex 1 Requirements Specification Matrix* for the specific requirements.