Annex 1. Tender specifications
Data Science with Fibre Optic Acoustic Sensing

N.B.: This document contains the assignment description for the entire contract period.

From Responsible authority	ProRail
Model version	1.0
Model date	February 2024
Model status	Final

Contents

1 Introduction

1.1 General

The purpose of this tendering procedure is to conclude a lease agreement between ProRail and Contractor.

1.2 Structure of tender specifications

These tender specifications consist of:

Chapter 2 : General information contracting authority
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2 General information ProRail

2.1 As organisation

ProRail B.V. is responsible for the Dutch railway network: construction, maintenance, management and safety. As an independent party, it allocates rail space among many different transport operators, regulates all train traffic, builds and manages stations and lays new tracks. And finally, ProRail maintains existing tracks, switches, signals and level crossings, among other things. All this makes it possible for 15.2 billion passengers and 42 million tonnes of goods to be transported in the Netherlands every year.

Our mission
ProRail connects people, cities and companies by rail, now and in the future. ProRail makes pleasant travel and sustainable transport possible. Every day, we ensure that a million passengers and more than 100,000 tonnes of goods reach their destinations by train, over more than 7,000 kilometres of track. Successive generations have built this for us over the past 175 years, we are good at it and proud of it!

We are a leading international organisation where professionals play an essential role in the accessibility of the Netherlands.
This is reflected in the international comparison: the Netherlands is among the busiest and most punctually travelled railway networks in Europe.

Our task and ambitions:
In the Netherlands, we expect substantial growth in the number of passengers and goods wanting to be transported via all modes (road, water, rail and air) in the coming years. It is up to us to facilitate this growth on the railways and thus contribute to solving the Netherlands' mobility demand in a sustainable way. We do this by offering an increasingly reliable, sustainable and affordable railway that can be used more and more intensively. ProRail does so by focusing on three ambitions:

- **Connection** - ensuring that more people and freight can be transported by rail.
- **Improvement** - ensuring that people and freight arrive at their destinations at the expected time.
- **Sustainability** – ensuring that people and freight reach their destinations in a sustainable manner.

2.2 Asset Management and Innovation Department

Contractors supply products to the Datalab Department. The Datalab is a partnership between the Asset Management, Innovation, ICT and Traffic Management departments. The solutions developed are mainly of added value to the Asset Management Department.

Asset Management
The ambition of the Asset Management (AM) Department is to provide rail infrastructure for the mobility needs of today and tomorrow. We focus on what is needed at present but also, just as importantly, on future demands. AM is responsible for ensuring the optimum reliability and safety of the Netherlands' rail network. AM takes care of the management of the railways (the 'assets'), the optimal allocation of funds, having daily, small-scale maintenance carried out and the resolution of malfunctions. To achieve this, AM works to conclude and direct contracts with the process contract contractors (PCAs) that carry out the daily (process-based) maintenance. We also coordinate the replacement of existing infrastructure. Thanks to good day-to-day maintenance and management of the current infrastructure, and by looking ahead in a structured way (when is infrastructure due for replacement?), AM keeps the existing tracks in top condition, so that the timetable can be run without disruptions.

Innovation
Innovation is a must as the world of rail transport is changing faster than ever. We are using the railways more and more intensively and society has new needs and wishes. New technology and smart applications on and around the railways offer solutions to this, both for now and for the long term. We invest in innovation for future-proof, safe and comfortable rail transport. Together with colleagues and partners, we innovate within the logistics and asset value chain, to increase the safety, reliability and punctuality of the railways for passengers and shippers. This is to strengthen rail's lead as a sustainable form of mobility.

We explore new disruptive logistical and technological developments: a) From talking to testing; experimenting together and targeted innovation; b) Predicting and preventing disruptions; utilising new ICT possibilities in the asset chain; c) Making innovations production-ready; ready for implementation/rollout.

An integral part of the Innovation Department is contributing to the DataLab,
which is the innovative incubator for rail data. Here, data experts from ProRail and partners experiment with big data technology to better track the condition of the track and stay ahead of disruptions. By linking existing data sources, we create predictive models so that rail workers can take preventive measures and train nuisance is avoided.

3 Description of the service/product requested

3.1 Project context

ProRail wants to contribute to improving train punctuality by reducing disruptions or speed restrictions that have a major impact on train traffic. Overall, 26% of the total number of train delay minutes are caused by defective rolling stock (12%) or defective infrastructure (14%). In addition, the deteriorated quality of the track subsoil at some locations in the Netherlands is causing a speed limit at those locations. The desire is to be able to better monitor the deterioration of infrastructure, equipment and subsoil in order to see failures in advance and then prevent them (predictive maintenance).

In addition, delays caused by third parties are also a major problem. Think of track walkers, vandalists, copper thieves and suicidal people. If this activity on, or around the track can be spotted at the time it takes place, it could potentially contribute a lot to the safety and availability of train traffic.

Currently, the condition of the infrastructure is measured approximately twice a year through track inspection services. There is also increasing use of sensors in, on and around the tracks. By deploying "free fibres" in existing fibre-optic cables for data traffic as monitoring sensors, the condition of the infrastructure can be measured continuously, allowing potential defects to be identified and resolved much faster. Indeed, fibre-optic cables are already buried along practically every stretch of track. It is a durable, reliable, safe and low-cost addition or alternative to other monitoring tools currently available.

3.2 Studies to date

For this reason, about 3 projects have already been carried out using this method. In Culemborg, a study was carried out in 2020 on the composition of the subsoil and the critical track speed of the train and was conducted in cooperation with Deltares. In 2022 / 2023, an extensive trial was carried out together with Network Rail on a stretch of operational and test track in Great Britain, where use cases are being tested in the areas of track and wheel defects, track defects, level crossings and track walkers. Finally, in 2022, ProRail established a data science team supplemented by external data science capacity and leased an interrogator for a year and connected it to the fibre-optic cable along the operational section of track in the Netherlands to study a use case every 2 months. Seven use cases were studied for detection namely:

1. Trains
2. Wheel defects
3. Electrical separation (ES) welds
4. Loose spring clips
5. Track walkers
6. Level crossing traffic
7. Critical track section speed and subsoil structure.

This last use case was carried out together with Deltares to improve the earlier model of Culemborg.

We were successful on all use cases except the one involving loose clamp springs. For this reason, in the coming year (2024 - 2025), ProRail plans to further develop and test about five use cases using sensor data from a number of interrogator units to be leased, which will be linked to the free fibres in an existing fibre-optic cable. These interrogators will be deployed at locations selected for the specific use cases. This effectively creates a microphone/vibration sensor kilometres long along the track that can be used to "hear" track and rolling stock defects, as well as track walkers. The data collected by the interrogator is used to develop algorithms to recognise these defects and track walkers and then demonstrate whether ProRail can use the 'fibre-optic' data to fill the use cases. At the end of this period, all outcomes will be reviewed and a conclusion will be drawn on the deployment of interrogators and algorithms on the different use case in the operation.

3.3 Project objective

The objective of this project is:

- Study, demonstrate and further develop the extent to which acoustic sensing using a fibre optic cable can demonstrate the use cases listed below.
- Operationalise the use case 'critical train speed' using acoustic sensing.
- Testing realtime monitoring with alarm notification in case of track walkers, burrowing animals, hollow spaces in the track section and wheel defects.
- Testing edge computing where algorithms from 1 or more of the use cases are applied locally to the raw data and generates an 'alarm notification'.

The use cases are:

1) Track stability study (Deventer-German border section):
   a) Measurement of soil displacement in relation to the embankment of the Deventer to German border section (good comparison as measurements are also made there using conventional methods).
   b) Measurement of track subsidence (good comparison as measurements are also made there using conventional methods. The sensors on the sleepers).
   c) Measurement of subsoil structure (based on shear wave velocity) at Deventer - German border.
   d) Measurement and calculation of the critical track section speed (at Deventer plus a top 3 of other places in NL).
   e) Monitoring subsoil at critical locations
2) Further development of wheel defect detection
   a) Identification of a train / trainset / axle / wheel with a wheel defect
   b) An indicator of the severity of the wheel defect and which wheel it concerns
3) Further development of track walker detection
   a) The presence of persons alongside the tracks (range 2 to 10 metres)
   b) The presence of persons alongside and in the tracks (range 1 metre to the track)
   c) Exploring and developing the possibility of realtime monitoring
   d) Exploring and developing the possibility of applying edge computing during this use case
4) Vibration nuisance
   a) Insight into degree of vibration nuisance and the effect of mitigation measures (e.g. track maintenance) on vibration nuisance. (Hanzelijn seems suitable)
5) Detection of burrowing animals
   a) Detection of burrowing activities of animals (including badges and beavers)
   b) Detection of animal burrows (in relation to track subsidence)
   c) Realtime monitoring of a track section

4 The tender specifications

ProRail envisages the following tender specifications for the realisation of the assignment:

Scope of the assignment

- Supply of 2 interrogator systems:
  Requested is the leasing of a 2 interrogator system for a term of 1 year with an option to extend for 6 months. Included in the lease is per interrogator system one interrogator unit plus all peripherals required to functionally accomplish the following:
  - Using distributed acoustic sensing to be able to monitor a fiber optic link for vibrations (also-called interrogator that can send laser signals through a fiber optic and capture the reflection)
  - Local storage and processing of the data collected by Distributed acoustic sensing. As well on a local hard disk and to be copied to 2 mobile hard disks of at least 4 TB each.
  - A unit on which local algorithms can be put that can be applied to the collected data,
  - Local access to the data (e.g. with a computer with monitor)
  - Compact and protective housing for the entire system ,
  - Being able to monitor the system itself as well as being able to adjust settings of the system through remote access (e.g. with a modem);
  - Being able to terminate the fiber at the other end of the fiber connection (e.g. an attenuator)
  - For the technical specification of the system, please refer to the Annex 1a.
- Management of the system:
  In addition to the delivery of the system, this includes Remote -management, -changes of settings and -support. This includes:
  - Maintaining the system remotely by e.g. performing software updates.
  - Changes of settings means that the settings of the system are adjusted such as channel width or Gauge settings.Support means that the system can be viewed remotely to see if it is functioning properly and if that is not the case that a diagnosis is made of a possible omission.

  In case the remote management is not sufficient due to e.g. larger software updates or hardware problems, the contractor will organize the necessary updates of software and/or replacements of hardware. This can be done e.g. in cooperation with ProRail and/or the integrator. Additional costs shall be borne by the contractor.

Out of scope of the assignment

- Integration of the interrogator on ProRail fibre optic network (the actual installation of the system on the fiber optic network and on-site finishing);
- Provision of data science capacity for the purposes of the activities below:
  1. Data collection
  2. Analysis
  3. Data prepping
  4. Algorithm design per use case
  5. Application of algorithm to datasets
  6. Algorithm iteration and validation on other dataset

5 Assignment principles for tender specifications consisting of supply of 2 interrogator systems

Delivery of the interrogator systems takes place in coordination with ProRail project group FOAS and Integrator.

The supplier will provide expertise (on- or off premise; as required) to enable the integrator to install the system on the ProRail fibre-optic network.
The supplier will provide documentation such as (installation) manuals and regulations so that the integrator can install and disconnect the system correctly and safely.
During the calibration of the Interrogator, the supplier will (remotely) view the system for the purposes of the points to be calibrated on the track section to be monitored by the Interrogator.
During the operation of the Interrogator systems, the supplier will monitor the functioning of the systems on a daily basis. The possible failure of a system will be reported to the ProRail project group FOAS within 24 hours. Every month a report is delivered on the operation of the system.
The supplier is available to ProRail during working days in case of malfunctions, incidents or questions. Questions are dealt with on a weekly basis. Malfunctions and incidents within 24 hours.
In consultation, support is provided by the supplier for specific tests with, for example, edge computing and realtime monitoring.
During the project period, the supplier and ProRail will meet every three weeks in a 1-hour consultation to discuss the operation of the system and the progress of the use cases.

System specifications:

- The interrogator can detect vibrations caused by a walking adult near the fibre-optic cable (within 20 metres).
- The interrogator can be connected to the following fibre optic type with the following specifications: Single mode optical fibre (Single mode (SM) non-dispersion shifted (NDS) fibre in accordance with ITU-T G.652.D or ITU-T G.657.A1, as well as NEN-EN-IEC 60793 - 2-50, category B 1.1.)
- Remote adjustable gauge lengths (gauge length) that can be optimised for the cable length used. Minimum gauge length of 2 metres Minimum channel spacing of 1 metre for range of 15 km.
- ProRail allows equipment up to class 3R (equals 5 mW).
- GPS time synchronisation.
- Flat frequency response including up to DC (0 Hz).
- Capability of 100 km data output, with minimum 25,000 channels with a ping rate of 1 kHz, obtained in real time.
- 100% of data can be written to SSD or RAID0 HDD.
- Easily adjustable channel lengths (1 to 100 metres).
- The Contractor shall demonstrate that the equipment or fixed installation meets the EMC requirements set by ProRail by providing a Declaration of. Conformity. The associated test reports issued by a NEN-EN-ISO/IEC 17025 accredited test institute must also be supplied.
- The contractor shall demonstrate that the equipment or fixed installation complies with the electromagnetic emission standards as stated in the RLN00007-V007. This is the Dutch guideline, including additions (reinforcements), for the European NEN-EN 50121 (parts 1 to 5) (see Annex 1a).
- The equipment operates on 230V AC 50 Hz.
- Supply of attenuators for terminating the fibre-optic connection at the end.

Functional specifications:

- The system delivers raw data (with open source Python package to be read e.g. H5 format).Internal storage capacity for raw data for up to 2 weeks of data. The system generates local alerts. The system provides a place where algorithms can be placed locally and applied to the data. If the outcome exceeds the set thresholds, an alert is generated (edge computing). The system provides a solution for realtime data streaming displayed for a short period of time.

System delivery:

- The system will be delivered to a yet to be specified location in the Netherlands.
- The system will be delivered on a working day and not on weekends.
- Each DAS instrument is tested individually before shipment and meets strict test limits. This ensures that each DAS unit meets or exceeds the specifications mentioned in this list of criteria. The outcome of the test is included with the delivery of the system.