DATA COLLECTION TO MEET CONTRACT REQUIREMENTS

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ABSTRACT
Infrastructural projects under a Design, Build, Finance and Maintenance contract (DBFM) need a different approach for information management.

This paper gives an insight of Dutch initiatives in the HSL ZUID project (High speed rail track from Amsterdam to Antwerp). This contract is awarded in 2001 and delivered as a DBFM contract in 2007. Today the track is in operation and the maintenance contract started. One of the challenges is the stability of the rail track in relation to the soft soil in this part of The Netherlands. Tunnels and bridges are creating fixed points in the substructure of the rail track and the soil in between these fixed points is soft. An important issue for the operation of this rail track is the possible damage of the track caused by whether bad design and construction or by the different movements in the substructure. Glass fiber sensor systems are used to monitor deviations at the points where the fixed substructure transfers to soft soil. Some examples will show the relation between contract requirement, needed data and the use of sensors. The aim of the research is to show that monitoring the performance of a structure is conditionally for the execution of a DBFMO contract.

The following questions will be addressed: What are the contract requirements? How has the system been designed to show and approve that the supplier meets these requirements? Which data are needed in this quality system? How can new technology support the secure monitoring of the desired data? How can monitoring of the performance create the condition for DBFMO contracts?

KEYWORDS
Sensor, DBFMO, contract, data collection

1. INTRODUCTION
This paper discusses the transformation of the contract requirements for the track into measurable requirements and some of the measuring systems that are used to monitor the track condition.

The HSL-South is part of the Trans-European high-speed rail Network, connecting Amsterdam to Brussels and Paris with a speed of 300 km/h.

In 2001 the contract for the superstructure of the HSL-South line was signed between the Dutch
The requirements that were laid down in the contract covered the interface with existing infrastructure, functionality, rolling stock, environment, and safety and health.

2. EXAMPLES OF THE CONTRACT REQUIREMENTS

The passenger ride comfort index required a value of 2 as described in UIC 513 [1].

Track geometry compliance with UIC 518, QN1 had to be demonstrated [2].

Derailment should not exceed 10^-9 per train.km for the track on average.

The frequency (1/year) of derailments with more than N passengers and/or train staff being killed (N>=10) shall be no more than 0.13/N².

The track has to be maintained for a period of 25 years during which an availability of 99% is reached.

Ad 1+2

Dynamic calculations demonstrate that the UIC 513 passenger comfort level of 2 and track geometry compliance with UIC 518, QN1 are achieved provided that the geometrical track quality standards are maintained at the levels specified by engineering and passed on to the maintenance organization.

These levels have been extracted from a number of international standards for high-Speed track: UIC 518, TSI Infrastructure, Deutsche Bahn Richtlinie 821, Deutsche Bahn Anforderungs Katalog Feste Fahrbahn 4. Auflage, ProRail Specs and TUC Rail Specs.

Both the requirements are in general influenced by acceleration values in vertical-, longitudinal-, and lateral directions, rolling motion, the roughness of the track, the damping of the bogie and the track geometry-, and cant deviations (Figure 1).

\[ N_{VA} = 2 \cdot \sqrt{\left( a_{x 0.65}^{W} \right)^2 + \left( a_{z 0.65}^{W} \right)^2 + 4 \cdot \left( a_{z 0.65}^{M} \right)^2 + 4 \cdot (a_{w 0.65})^2} \]

where:

- N: Ride comfort value (N < 1 very comfortable to N > 5 very uncomfortable)
- a: Acceleration, r.m.s. value over 5s. [m/s²]
- N1: Weighting factor for vertical acceleration (ISO 2631-1 suggests ν1 instead)
- N2: Weighting factor for longitudinal accelerations (backed seat)
- ν0: Weighting factor for lateral accelerations
- X, Y, Z: Direction of measurement (longitudinal, lateral and vertical, respectively)
- P, A, D: Position of measurement (floor, seat interface, backrest interface, respectively)
- R: Rolling radius - a percentile of samples 5 s r.m.s. - values under 5 min duration of constant and representative condition. At least four 5 min units shall be evaluated.

Figure 1. Formula for passenger ride comfort value [3]

Ad 3+4

Derailment requirements are met when the rolling stock will meet the wheel unloading characteristics of ERRI C138 Rp9 Permissible maximum values for the Y-and Q forces and derailment criteria' and DSRV ERR1 B55 Rp8 (geometric track design and maintenance to prevent derailment due to track twist).

The lateral force (Y) and the wheel load (Q) and the friction of the wheel flange against the railhead influence the occurrence of flange climb whereby the flange of the wheel climbs up to the railhead.

Once derailment has occurred passenger safety is mainly controlled by the provision of derailment plinths on critical locations in order to guide the train, and keep it in an upright position.

Ad 5

With respect to maintenance the critical factors effecting rail renewal are wear, fatigue and operational requirements. The wear characteristics are a function of the cumulative traffic load and form the basis of the calculation determining rail renewal for optimum life cycles. Particular impacts that can change the optimum rail life selection are:

- Rail grinding
• Operational changes (e.g., timetable, tonnage, axle load)

• Unplanned isolated impacts (e.g., wheel burns, flat wheels)

The use of rail grinding will extend rail life by removing surface defects, shifting the point of maximum stress and optimizing the wheel/rail contact band on wear and fatigue levels. As wear levels generally are very predictive in repetitive operational systems the computation of effective projective rail life and optimum rail renewal can be computed.

3. FROM REQUIREMENTS TO KPI’S AND DATA COLLECTION

The translation of the requirements to measurable values for the track to be reached and maintained during construction and maintenance period were done through dynamic analysis. The main values were set to be 2.0 mm/15 m (short waves) and 7.5 mm/150 m (long waves) while the design roughness should be 0.66 mm. To prevent fatigue of the rail over the joints of the concrete base plates a value of 2 mm was set to be the maximum allowable differential settlement between the plates on either side of the joint.

To assure compliance with the contract requirements and the resulting KPI’s the HSL assets are continuously monitored by means of visual inspections and regular train based and non train based measuring systems (Figure 2). There are several measuring systems used and the results are combined in order to be able to analyse the results.

Once the measured values reach the preset intervention levels a preventive correction will be carried out. When the measured values reach their safety level the use of the HSL will be influenced, for instance by decreasing the allowable speed on the track, until corrective maintenance has corrected the condition of the track to within the required KPI’s.

Inspections and measurements that are carried out on a regular basis are;

**Visual inspections**
- Loose parts
- Cracks, holes
- Depressions
- Water
- Strange objects
- Irregularities
- Graffiti, rubbish

**Train measurements**
- Geometry – track position
  - UFM 120 or EM 130
- Ultrasonic – eddy current
  - UST 96
- Video monitoring
  - VST
- Acceleration measurement
  - Thalys, Ansaldo, Traxx
- Sound measurement
  - BAM rail measurement wagon
- IRIS sys
  - Combination of measurements

**Non Train measurements**
- Joint movement
  - Inventec

![Figure 2. Relation Requirements to Data](image-url)
4. TECHNOLOGY TO MONITOR THE KPI’S
UNIVERSAL FAHRWEG MESSWAGEN 120

In order to measure the required values according to
UIC 518 Dynamic track geometry tests have been
done by the Eurailscout UFM-120. The test speeds of
the UFM-120 have been 40, 80 and 120 km/h.

The measurements according to UIC 513 have been
carried out in High-speed tests by the Thalys; for the
Thalys speeds of 160, 200, 230, 270, 300 and 330
km/h have been used.

An example of the measured vertical geometry and
the PSD (Power Spectral Density) measured by the
UFM-120 is shown in Figure 3 for the East track of
the section between Amsterdam and Rotterdam. It
shows the measured standard deviations on the
HSL-South compared to the measurement of 0.63 mm
of 2004 on the German Köln-Frankfurt high-speed
line (slab track), taken over a length of 141 km, after 3
years of operation [4].

The bogie and coach accelerations during high-speed
test-rides of the Thalys have been processed
according to UIC 513 for Nvd (standing passenger)
and Nva (seated passenger). The test results for both
the northern and the southern section are summarized
in the graphs of Figure 4, the average value of the
comfort index is 1.2 which indicates a very good
comfort level.

The measurements of the UFM 120 are presented in
the form of a combination figure in which deviations
down to 0.1 mm to the theoretical geometry of the
track are presented. See Figure 5. [5]

4.1. Ultrasonic Inspection vehicle (UST 96)

Rail defects close to the surface got more and more
important during recent past. Because of new high
quality rail materials with a high resistance to wear the
material abrasion from usual operations is no longer
sufficient to wear out cracks that grow from natural
wear and tear. These types of defects can hardly be
detected with ultrasonic testing equipment. Therefore
only combined rail testing with ultrasonic and eddy
current methods can provide enough information
about the rail status [6].

![Figure 3. Geometrical track quality](image)

![Figure 4. Comfort index of the HSL](image)
The UST 96 is used for the detection of rail defects like hair cracks, broken rails and welding quality. Measurements are carried out at speeds up to 100 kph. The rail is inspected at different angles with the help of 16 special ultrasonic detection heads. The control electronics ensure permanent optimisation of the signal levels, the rail profile type is automatically taken into account in the optimisation.

During eddy current testing (see Figure 6 and 7) the measured data from the EC probes are sent to the control computer, where they are combined with other data such as GPS and path cycle information. By means of special evaluation software, detected surface damages are sorted out at once. A more detailed evaluation and analysis can be done off-line. The results are presented on the screen as track charts (amplitudes v. mileage) and stored digitally.
4.2. Ground Penetration Radar by UFM 120

Railway track substructure maintenance management is the process of utilizing railroad resources to maintain and upgrade the track substructure. The process begins with a measure of the track condition to evaluate the substructure performance, determine locations along the track that require maintenance, and identify appropriate solutions. Ground penetrating radar (GPR) has been proposed as a potentially valuable tool for this purpose.

The principle of GPR operation is the transmission of short electromagnetic waves into the subsurface and recording the resulting signal of the reflected waves. Electromagnetic waves are influenced most significantly by the dielectric constant of the soil. The dielectric constant is most affected by moisture content making GPR a valuable tool for locating trapped water that will cause increased track deterioration rates. GPR has the potential to evaluate the thicknesses and properties of the substructure layers on a continuous, non-destructive basis to improve the process of diagnosing substructure causes of track performance deterioration [7].

4.3. Inventec joint monitoring

Differential settlement of the concrete base plates on which the Rheda Track system was build can result in peak stresses in the rail and lead to fatigue problems and cracks. Because the intervention level of the differential settlement was only 2 mm a very accurate monitoring system was developed by Inventec consisting of two MuSt glassfiber sensors that can measure the vertical and horizontal displacement over a joint with an accuracy of 0.1 mm. See Figure 8 and 9.

In figure 10 it can be seen that the measured differential settlement over a joint is almost 1 mm. in a period of 8 months.

4.4. Gotcha Weighing in motion

Gotcha is a measurement system for Weighing In Motion (WIM) and Wheel Defect Detection (WDD) of trains.

See Figure 11.

![Figure 8. Sensor unit joint monitoring](image1)

![Figure 9. Sensor unit build over a joint](image2)
The WIM-module determines the wheel load for every wheel based on the maximum vertical bending of the rail due to the weight. Based on the individual wheel loads calculated the axle load, vehicle weight and total train weight are determined by the WIM algorithms based on the information recorded by all the sensors.

The WDD-module determines the dynamic peak force generated by every wheel. The sophisticated analysis software determines real-time which wheel caused each impact, ensuring quick and reliable remote reporting to the central server, typically within 60 seconds of each train’s passage.
5. ACTUAL PROBLEMS WITH RESPECT TO MEASUREMENTS AND MONITORING

Improvement of the performance of technology can stimulate the wider use of DBFMO contracts. Next aspects should have special attention:

- GPS positioning is not accurate enough to align different measurements and correlate their results
- GPS positioning in tunnels is not working
- Data files are 5 to 6 Gigabyte and can not be handled in normal computers
- Computers are too slow to analyse the data
- Image recognition of defects in track is not accurate enough and therefore not reliable
- Typical defects are available by means of photo’s but can not be converted to information for a computer to check on these defects
- Intrusion detection for line objects (intrusion by people through fences)
- Very accurate absolute elevation measurements (1 mm) on the track is not possible over long stretches
- Theft of earthen cables can not be detected

REFERENCES AND LITERATURE


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