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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 is 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 government and by Infraspeed, a consortium consisting of Royal BAM Group, Fluor, Siemens and institutional companies Innesfree and HSBC Infrastructure. The contract has been awarded as a Design, Built, Finance and Maintenance contract (DBFM). The maintenance period is 25 years in which an availability >99% has to be achieved.

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 be not more than 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 $0.13/N^2$.

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).

$$N_{VA} = 2 \cdot \sqrt{\left(a_{YA95}^{W_d}\right)^2 + \left(a_{ZA95}^{W_b}\right)^2} + 4 \cdot \left(a_{ZP95}^{W_b}\right) + 4 \cdot \left(a_{XD95}^{W_c}\right)$$

where:

N	Ride comfort value (N < 1 very comfortable to N > 5 very uncomfortable)	
a	Acceleration, r.m.s – value over 5s,	[m/s^2]
w_b	Weighting filter for vertical accelerations, (ISO 2631-1 suggest w_k instead)	
w_c	Weighting filter for longitudinal accelerations (backrest seat)	
w_d	weighting filter 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)	
95	95^{th} - percentile of sampled 5 s r.m.s. – values under 5 min duration of constant and representative condition. At least four 5 min units shall be evaluated.	

[3]

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 derailments 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.

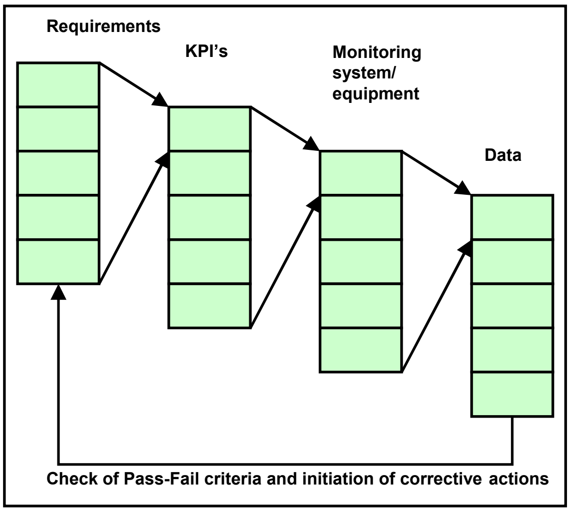

Figure 2. Relation Requirements to Data

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

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].

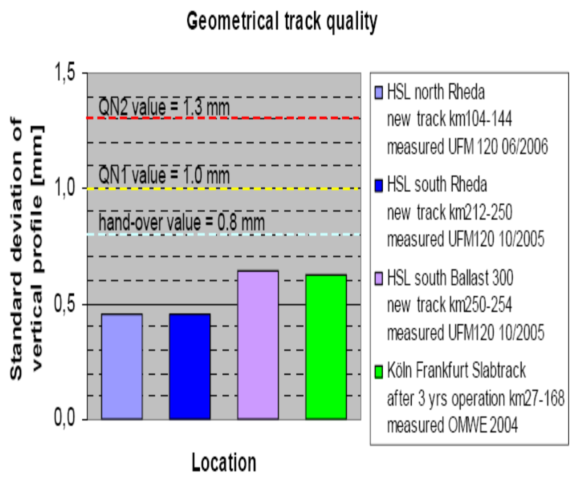

Figure 3. Geometrical track quality

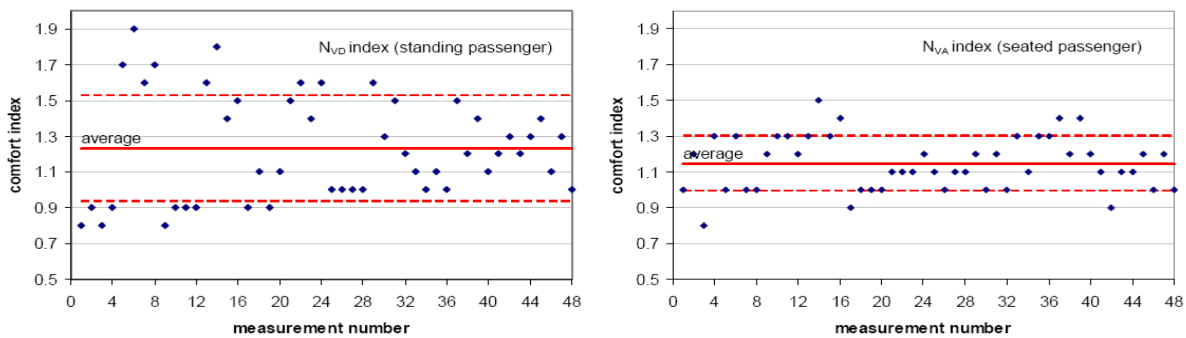

Figure 4. Comfort index of the HSL

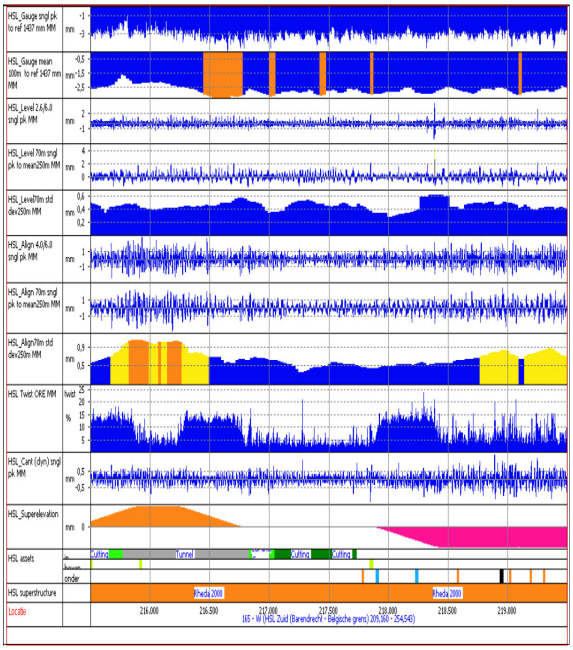

Figure 5. UFM 120 measurements on the HSL track

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.

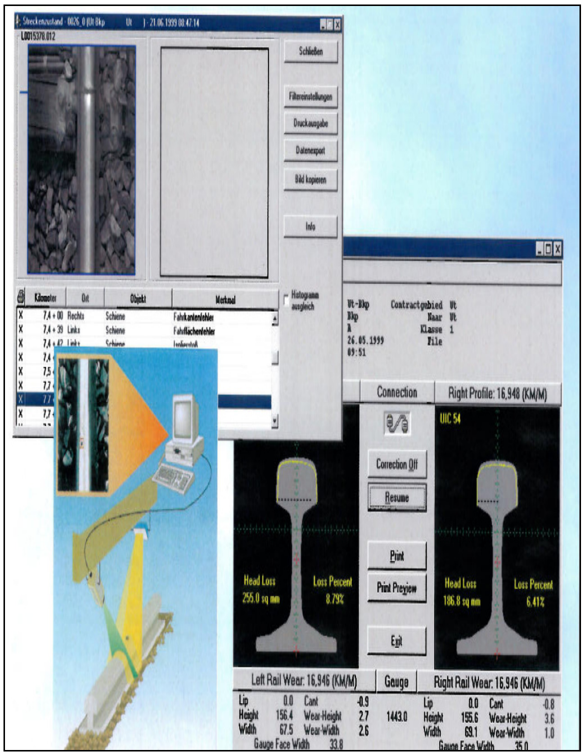

Figure 6. Eddy current testing

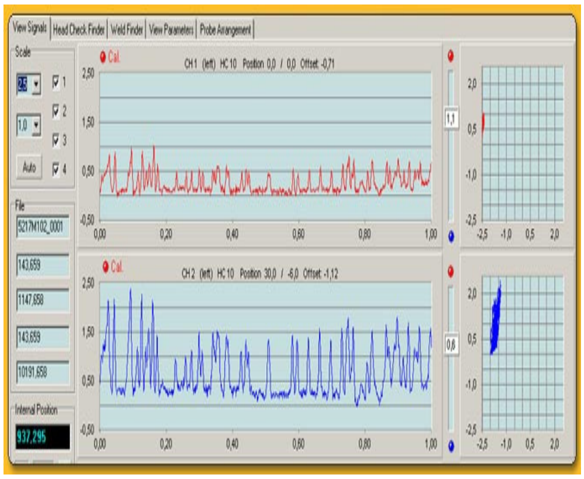

Figure 7. Eddy current testing

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 glasfiber sensors that can measure the vertical and horizontal displacement over a joint with an accuracy of 0,1mm. 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.

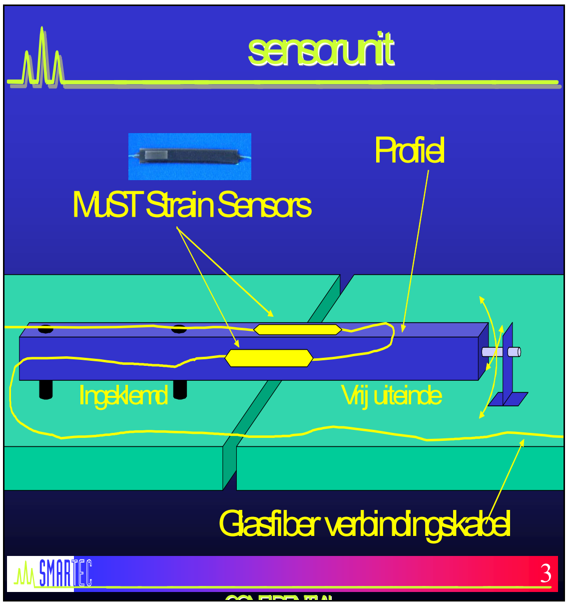

Figure 8. Sensor unit joint monitoring

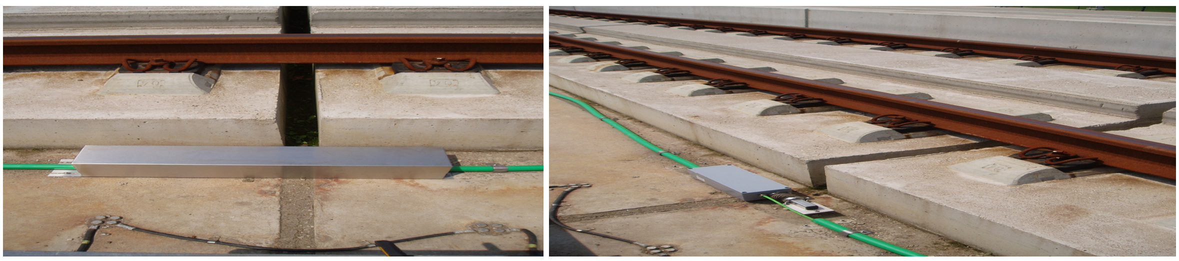

Figure 9. Sensor unit build over a joint

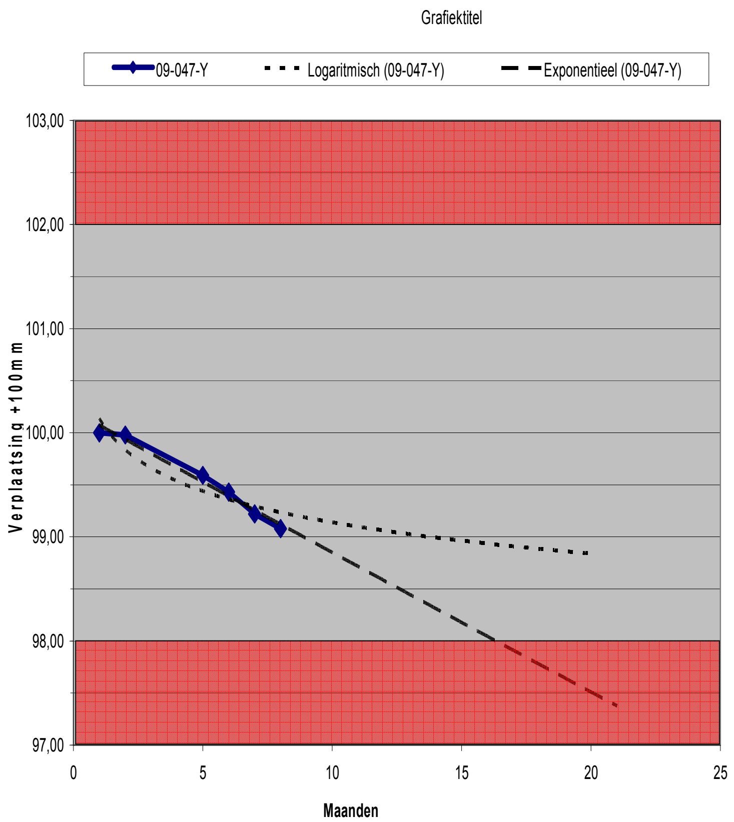

Figure 10. Vertical differential settlement over joint

Figure 11. Gotcha sensor [8]

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

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