Horizon 2020
European Union Funding
for Research & Innovation

In2Rail

In2Rail

Project Title:	**INNOVATIVE INTELLIGENT RAIL**
Starting date:	01/05/2015
Duration in months:	36
Call (part) identifier:	H2020-MG-2014
Grant agreement no:	635900

Deliverable D6.1
Prioritised Relevant Input

Due date of deliverable	Month 06 (GA) – Month 26 (EC review)
Actual submission date	28-06-2017
Organization name of lead contractor for this deliverable	SR
Dissemination level	PU
Revision	FINAL – Updated after EC review

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Review Comments

Following the In2Rail midterm review on Tuesday 28th February 2017, this deliverable was requested for revision by the European Commission in the assessment report #Ref. Ares(2017)1734456 - 31/03/2017, In2Rail can confirm that the review comments have been duly considered and this modified report contains revisions to address these specific points.

The below table provides an index to Sections of the revised document that contain the responses to the review comments.

Revision Requested from EC	Revision in document
The report needs to elaborate more in depth on the *deterioration and root causes* leading to maintenance issues and failure in accordance with the DoA.	see Section 3.1.3, 3.2.3, 3.3.3, 3.4.3 & 3.5.3
The report shall consider existing studies, but also "*partners knowledge*" which was a requirement for this report and is considered key background information before engaging into the next WP6 phases with a thorough analysis of optimised maintenance methodologies	see Section 3.1.2, 3.2.2, 3.3.2, 3.4.2 & 3.5.2

Executive Summary

This report provides an overview of the identification and categorisation of relevant inputs from previous research projects and the knowledge of partners involved. It focuses on deterioration models and root causes of failures, and has been carried out in conjunction with WP3, WP4 and WP5.

The report is structured according to the tasks requirements in this work package to identify the relevant input material from previous projects. For each WP6 task there is a brief analysis of the research project examined and the specific relevancy to the individual WP tasks.

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Abbreviations and acronyms

Abbreviation / Acronyms	Description
AUTOMAIN	Augmented usage of track by optimisation of maintenance, allocation and inspection of railway networks. FP7 project. www.automain.eu
CAPACITY4Rail	Increasing Capacity 4 Rail networks through enhanced infrastructure and optimised. FP7 project. www.capacity4rail.eu
CSM	Common Safety Method
DB	Deutsche Bahn
EN	European Standard
ERA	European Railway Agency
EU	European Union
FMECA	Failure Mode, Effects and Criticality Analysis
H2020	Horizon 2020. The EU Framework Programme for Research and Innovation
ICT	Information and Communication Technology
Im2Rail	Innovative Intelligent Rail a H2020 project proposal
INTEGRAIL	Intelligent Integration of Railway Systems. FP6 project. www.integrail.info
ISO	International Organization for Standardization
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
NDT	Non-Destructive Testing
R&D	Research and Development
R&I	Research and Innovation
RailML	RailML is the XML-Interface for railway applications
RAMS	Reliability, Availability, Maintainability and Safety
RAM4S	Reliability, Availability, Maintainability, Safety, Security, Supportability, Sustainability
RFID	Radio Frequency Identification
S&C	Switches and Crossings
SME	Small and Medium Enterprise
SNCF	Société Nationale des Chemins de Fer Français (French National Railway Company)
TMS	Traffic Management System
TRL	Technology Readiness Level
TSI	Technical Specification for Interoperability
UIC	Union Internationale des Chemins de Fer (International Union of Railways)
UNIFE	Association of the European Rail Industry
WP	Work Package

1. Background

The present document constitutes the second issue of Deliverable D6.1 "Prioritised Relevant Input" in the framework of the Project titled "Innovative Intelligent Rail" (Project Acronym: In2Rail; Grant Agreement No 635900) and reflects the changes required following the EU deliverables review contained in Project Officer (PO) report Ref Ares(2017)1734456-31/03/2017.

1.1. Work Package 6

This document is the deliverable of the first step in WP6: the identification and categorisation of relevant inputs from previous research projects. This report reflects the first analysis and gives guidance to integrate the input from those projects in the respective tasks of WP6. During the execution of those tasks, a more detailed look at the results of the identified projects will take place. It is expected that this will give more detailed insights of how the results are being used within this project. It is foreseen that later in the project there will be an update in which the actual use and relevance will be described.

1.2. Objective / Aim

The aim of Deliverable 6.1 is to identify relevant input from previous research and to categorise it. Relevant input can be the results of previous research projects and knowledge of the partners involved.

The results of this deliverable are at the level of concrete links to other document. The results are the starting point for further research and development in WP6 "Smart Infrastructure - Maintenance Strategies & Execution".

2. Projects reviewed

2.1. In2Rail projects

The In2Rail project proposal has mentioned explicitly the following projects:

Name	Input to In2Rail	Relevance for task
AUTOMAIN	Research results on mechanised track maintenance and inspection (tamping and grinding); LEAN analysis of working methods and processes to reduce possession times; demonstration of advanced switch monitoring; decision support tool for maintenance planning and scheduling	6.2, 6.3, 6.4, 6.5, 6.6
CAPACITY4RAIL	Research work on infrastructure, train dispatching and timetable planning and monitoring. Recommendations for Open-Source and Open-Interface for advanced railway monitoring applications	6.2, 6.3, 6.4, 6.5
D-RAIL	Cost efficient measures to reduce derailments	6.5
INNOTRACK	Analysis of major track cost drivers to reduce maintenance costs for sub-structure, track, S&C including LCC and logistics aspects	6.2, 6.3, 6.4
INTEGRAIL	Proposed approaches and demonstrators for intelligent communication infrastructure, including information system architecture and semantic data structure	6.3
INTERAIL	Integrated high speed inspection system based on a modular design	*Not relevant for this WP*
MAINLINE	Life cycle assessment tool and findings regarding modern technologies for track, tunnels and bridges	6.2, 6.3
MERLIN	Optimisation concepts and proposals for minimising energy demand	*Not relevant for this WP*
ON-TIME	Open and common communication and data models based on open standards (e.g. railML developments) Common components and data flows between TMS building blocks and services.	*Not relevant for this WP*
PM'n'IDEA	Predictive maintenance methods for Metro and Light Rail Transport systems	*Not relevant for this WP*
RAILENERGY	Calculation methods and simulation models for rail power supply systems	*Not relevant for this WP*
SAFTInspect	Developing intelligent track self inspecting equipment; capable of mechanically and electronically compensating for wear, automatically reducing inspection and maintenance time and costs	*Not relevant for this WP*
SMART RAIL	Complimentary to MAINLINE with a life cycle assessment tool for other structures	6.2
SUSTAINABLE	Bridge inspection, assessment, monitoring and	*Not relevant*

Name	Input to In2Rail	Relevance for task
BRIDGES	measurement methods	*for this WP*
SUSTRAIL	Optimised track and substrate design and component selection to increase sustainable freight traffic as part of mixed traffic operations	6.3, 3 6.4, 6.5
National research projects	Results from various national projects from participant member states will be drawn upon e.g. VTISM and T-SPAR in the UK	*Not at the moment: review during project*

Table 2.1: Relevant Projects

2.2. Other projects

Besides the projects as presented in the previous table and mentioned in the proposal of In2Rail, 2 other relevant projects are identified:

Name	Project description	Relevance for task
DYNO Train	Promote interoperable rail traffic in Europe by reducing costs of certification and closing “open points” in the TSI’s	6.3, 6.4
OptiRail	Development of a smart framework based on knowledge to support infrastructure maintenance decisions in railway corridor	6.5

Table 2.2: Relevant other projects

In this document, these 2 projects are integrated in the list of projects as mentioned in the proposal of In2Rail and listed by alphabet in the attachment.

2.3. Review criteria

Results of previous research in terms of first analysis, gaps between state of the art and vision, sets of requirements, best practices, guidelines, recommendations for further research about:

- A systematic approach across all assets part of the rail infrastructure;
- Decision support framework;
- Dynamic models of track and switches and crossings;
- Real-time diagnosis of asset conditions, prognosis of future condition from predictive models and probabilistic risk assessments;
- Information regarding asset physical state;
- Improved tamping methods for predictive maintenance of track geometry and operational processes.

3. Relevant input In2Rail

In chapter 2 previous projects with a possible relevance for WP6 are identified. These projects are summarised and analyzed for relevant input for WP6 in Appendices I toXVll. In this chapter, the concrete relevant results in terms of Deliverables or Work Packages are summarised per task and per project to create a useful structure for future activities in WP6.

3.1. Task 6.2: Specification of Asset Management framework

3.1.1. Relevant previous projects

3.1.1.1. AUTOMAIN

Deliverable 3.1 algorithms are derived which inform and support decision makers to manage usage of maintenance resources and budget more efficiently.

The input is relevant for the specification of a decision support framework in In2Rail.

Deliverable 4.2 presents a performance measurement model, i.e. an operational reliability assessment model, called *Link and Effect Model*; Section 2.4 in D4.2. The link and effect model is a method for developing performance measurements systems, by combining performance measurement and engineering principles for proactive management of physical assets (Stenström et al., 2013)[1], i.e. integral of asset management. The model is built on the components of strategic planning (Table 4 of D4.2). In short: strategic planning involves collecting information, setting goals, translating goals to specific objectives, setting up activities to achieve the objectives, and measure the outcome with use of indicators.

3.1.1.2. CAPACITY4RAIL

Subproject "Advanced Monitoring" emphasises that, to keep the infrastructure available and to release time to operation, Infrastructure Managers need to get maintenance done in a timely manner by optimising the construction and maintenance process (development of modular plug-and-play systems, predictive maintenance, self monitoring systems, non-intrusive inspection, coordination of maintenance activities), by reducing maintenance requirements, and need to limit traffic unplanned disruption by improving the reliability of the infrastructure and its resilience to higher duty and to extreme climatic hazards.

The objective of Infrastructure management are defined as follow:

- reliability of Infrastructure thanks to early pre-failure detection;
- availability of Infrastructure thanks to less failure and non-intrusive monitoring;

[1] Stenström C., A. Parida, D. Galar, and U. Kumar, 2013, 'Link and effect model for performance improvement of railway infrastructure', Proceedings of the Institution of mechanical engineers. Part F, journal of rail and rapid transit, vol. 227, no. 4, pp. 392–402

- higher maintainability of Infrastructure thanks to earlier and more accurate diagnoses.

The input is relevant for a common approach for predicting performance of each asset type.

3.1.1.3. INNOTRACK

The objectives were dread by performing research on four key topics:

- Track support structure;
- Switches and Crossings;
- Rails and welding;
- Duty and requirements;
- Logistics for track maintenance and renewal;
- LCC and RAMS.

Note: The three first Subprojects have technical relevance to In2Rail while the three transversal can ensure that cost reductions can be consistently evaluated across Europe, INNOTRACK did also devise an innovative generic methodology for LCC calculation, based on best LCC practices at EU level, to be used by all IMs across Europe.

3.1.1.4. MAINLINE

The overall aim of WP5 is to create a Life Cycle Assessment Tool (LCAT) that can compare different maintenance and replacement strategies for track and infrastructure based on a life cycle evaluation. The life cycle evaluation shall quantify direct economic costs, availability costs (e.g. delay costs, user cost/benefit from upgrade etc.) and environmental impact costs. Moreover, the tool should also take into account target user safety levels in the optimisation process.

In deliverable 5.3 a gap analysis study revealed, at general level, the LCC and LCA process of carrying out analyses is quite similar. However, there are significant differences in terms of their model concepts and evaluation process involved. Moreover, there are principles and parameters in the LCC approach that are not considered in LCA and these are considered as the 'gaps'.

Moreover, the relevant parameters for the LCAT are identified by the gap analysis and these are the common parameters used by the currently available LCC and LCA tools to evaluate life cycle cost, carbon emission and waste impacts. In deliverable 5.3 the most relevant parameters for LCAT are provided in chapter 5.3. The results can be used identify factors and a common approach for predicting the performance of each asset type.

In deliverable 5.7 the LCAT is presented. The LCATS have been developed using the data and information made available to the project team. From the research completed in other

MAINLINE Work Packages, it is clear that the LCAT models presented here improve on previous modelling practice in two key areas, in that they:

- incorporate mechanisms to estimate deterioration of assets;
- assess the environmental impact of interventions alongside their financial and operational impacts.

The method of modelling within each of these LCATs is innovative, detailed and they have been individually developed based on the specific engineering characteristics of the asset types.

The models are provided as Microsoft Excel workbooks for each asset type. This is a medium widely used by partners in the MAINLINE project and in the industry in general. The models are extensively annotated with all the calculations explicitly shown and do not include any obscure programming code. This is intended to allow the workings of the models to be examined and reviewed by other partners and keep the models as transparent as possible.

The Life-Cycle Assessment Tools are prototypes; they are meant to prove a concept.

The input can be used to specify a procedure by which all included assets models for each sub-system could be assembled to form the whole system model at the desired level of resolution.

3.1.1.5. SMARTRAIL

Deliverable 4.2 specified the design for the life cycle costing tool. The tool was constructed in accordance with this specification and is available. Deliverable 4.3 are case studies to determine the environmental and economic credentials of the remedial engineering solutions employed, and compare them to alternative remedial solutions or ‘do-nothing’ alternatives. In the course of conducting the environmental and economic analyses, bespoke LCA and LCC tools were created.

The tools are concrete deliverables of the project and can be used as input for the development of a system level asset model.

3.1.1.6. Additional inputs and EU-projects

Performance measurement, benchmarking, and thus KPIs, is an essential part of asset management. Several EU-projects have studied KPIs and benchmarking in the railway sector considering transportation, i.e. rolling stock. See EQUIP (2000)[2], IMPROVERAIL (2001)[3], UTBI

[2] EQUIP, 2000. Extending the Quality of Public Transport: Final Report. www.transport-research.info: TRKC (Transport Research Knowledge Centre)

[3] IMPROVERAIL, 2001. Improved Tools for Railway Capacity and Access Management: D2 Benchmarking Methodologies and Harmonisation of Concepts in the Railway Sector. Competitive and Sustainable Growth Programme

(2004)[4] and SuperGreen (2010)[5] for reviews. However, such studies are lacking when it comes to rail infrastructure. Nevertheless, a review of rail infrastructure KPIs are found in Stenström et al. (2012)[6].

3.1.2. Specific partner knowledge

Several partners of In2Rail WP6 (Deutsche Bahn, Luleå University of Technology, Network Rail, Strukton Rail, Trafikverket) were involved in AUTOMAIN deliverables 4.1[7] and 4.2[8]. The link and effect model knowledge and case studies regarding the simulation of maintenance work were contained within these deliverables. Specifically the considered models are the means to optimise tamping, grinding and maintenance possessions.

DLR contributes knowledge on the handling of uncertainties in data analysis and modelling for In2Rail.

During the last decades, SNCF participated in most of the major European Research Projects dedicated to Railways, including Innotrack, AUTOMAIN, Dyno-Train. These projects contributed to extend xxpertise and scientific knowledge. This work particularly focussed on modelling for Asset Management decision-making.

Past and current Asset Management practices, and Research activities, make SNCF familiar with the existing approaches (benefits and limits) and enable specifying requirements for innovative modelling. Internal SNCF databases provide access to data sets that enable testing and improvements to these new models using realistic information.

Ansaldo STS participated in the project Capacity4Rail which is relevant for this task. Ansaldo STS have relevant knowledge about how to use and process measuring data from monitoring systems and TMS. In particular, Ansaldo STS is familiar with the new techniques of Nowcasting and Forecasting and can translate these into relevant inputs and requirements for the Asset Management Framework.

In addition they have experience as a developer, manager and maintenance service provider of rail technological systems, Ansaldo STS provides important knowledge about how the Asset Management framework should be formulated as a decision-making process, defining

[4] UTBI, 2004. The Urban Transport Benchmarking Initiative: Year One Final Report. www.transport-research.info: Transport Research Knowledge Centre (TRKC)

[5] SuperGreen, 2010. Deliverable D2.2: Definition of Benchmark Indicators and Methodology. Seventh Framework Programme ed. www.supergreenproject.eu

[6] Stenström C., A. Parida, and D. Galar, 2012, 'Performance indicators of railway infrastructure', The international journal of railway technology, vol. 1, no. 3, pp. 1–18

[7] AUTOMAIN, 2013, 'D4.1 Improvement analysis for high performance maintenance and modular infrastructure', Tech. report, FP 7 EU-project, automain.eu

[8] AUTOMAIN, 2013, 'D4.2 Optimised maintenance activities like, grinding, tamping and other maintenance processes', Tech. report, FP 7 EU-project, automain.eu

the relevant KPIs and objectives for improving maintenance operations efficiency and effectiveness.

Strukton Rail operates as a service provider in asset management systems and can provide a specific view on the specification of the asset management framework. Most research on asset management systems is performed from the view of the asset owner or asset manager, the role of service provider is often under-represented. Strukton Rail has significant experience in this role, both from delivering performance based contracts, and from theoretical studies on how to operate in an asset management system environment.

Acciona have been involved in the Capacity4Rail project and have worked on the Advanced Monitoring sub-project. They are technical capable and familiar with the economical assessment of monitoring and system diagnosis.

The following boundary conditions describe the initial point :

- Target group of the questionnaire are asset manager and strategists of the railway systems;
- Identification of the needs regarding diagnostic and monitoring respectively for short-term, mid-term and long-term perspective;
- Create a decision support for diagnostic/monitoring demand based on technical and operational analysis;
- Systems and components of assets for the trades of track, civil engineering structure and control & safety technologies as summarized above;
- Target group of questionnaire.

Steps :

- Clustering of assets;
- Key indicator matrix;
- Representation of the cause and effect relationship;
- Identification of the operationally components;
- Decision support / Priority list.

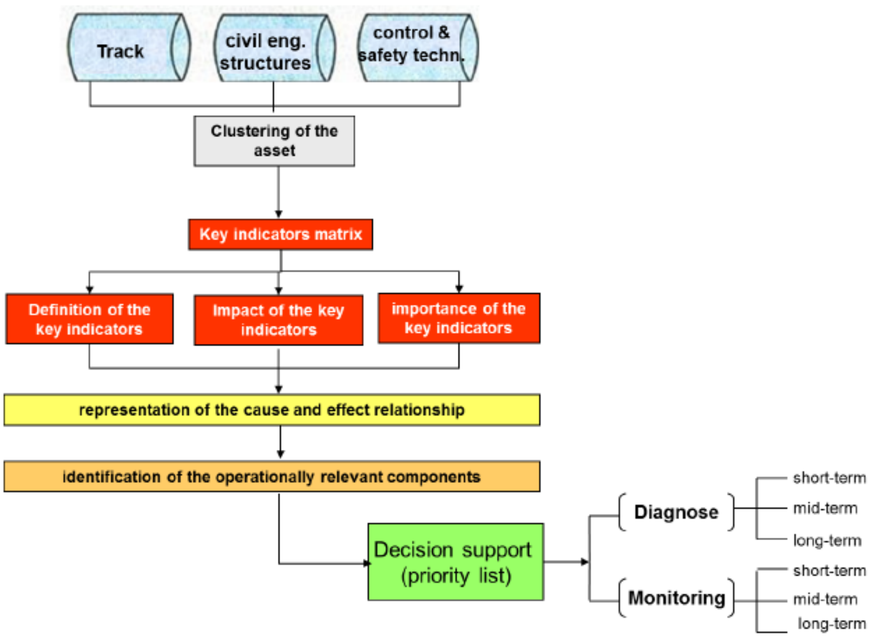


Figure 3.1: Description of the flow chart with the necessary steps [Capacity4Rail]

3.1.3. Relevant input deterioration and root causes

A specific root cause which has been derived from the AUTOMAIN project which identifies a performance measurement capability that needs to be improved is, the lack of mutually agreed key performance indicators (KPIs) within organisations.

A root cause which can be derived from additional inputs and other EU-projects besides those projects specifically focused on KPIs have addressed on the rolling stock issues rather than infrastructure. A root cause besides that projects on KPIs have focused on the rolling stock rather than the infrastructure is the semi-continuous operation; trains pass infrastructure spatial positions in a stochastic manner. Hence, KPIs from manufacturing and process industry, as examples, are not always intuitively depict into railways.

It should also be considered that KPIs originating from manufacturing and process industry are not always applicable into railway scenerios.

3.2. Task 6.3: Dynamic model for track maintenance

3.2.1. Relevant previous projects

3.2.1.1. AUTOMAIN

Deliverable 3.1: the additional effort needed for data processing increases the track maintenance efficiency substantially. For instance, the gathered data enable a continuous track monitoring, i.e., potential track failures become detectable at an early stage. Here, acceleration data gathered by low-cost units on in-service freight locomotives are used to recalculate the vertical track geometry. In addition, also fault tracing, i.e. the identification of the same fault in subsequent data records, is considered to analyse the fault progression reliably. Moreover, due to the increased number of data sets even a failure prediction can be put into operation. That is, the precursors of a track failure (tiny peaks in the displacement data) are evaluated to predict the remaining time until the expected track failure becomes critically. By knowing the remaining time until a track failure is expected an optimised maintenance can be scheduled.

The input can be used to develop prediction models for optimised maintenance scenario's.

Deliverable 6.1 is a demonstration of in-service inspection (by freight locomotive). The output includes a maintenance assessment, based on failure prediction algorithms, an optimised maintenance date and plan, which is displayed by the software.

The input is relevant for asset condition data and actual and forecast usage information.

3.2.1.2. CAPACITY4RAIL

New monitoring systems may be able to deliver important information that is needed for the optimisation of maintenance and prevention of breakdowns. But implementation of monitoring systems on the whole network needs also analysis of financial return of investments. CAPACITY4RAIL (C4R) therefore not only looks for the technical performance and advantages but also for the economic performance of monitoring systems.

Important in this regard are the tow work packages of SP4 of C4R, i. e. WP 4.3 “Implementation in new structures” and WP 4.4 “Migration of innovative technologies to existing structures”.

The objective of WP4.3 is the design of an Advanced Monitoring System (AMS) able to gather the most relevant information on infrastructure state and on the rail services for the new concepts of infrastructure developed in C4R. The developed technologies should be low cost, easy and rapid to implement during the construction of the infrastructure and oriented towards a cost-effective, easy and rapid sensor (including batteries) replacement/maintenance.

The result can be used as input for “improved sets of inputs: asset condition data and actual and forecasting usage information.

The aim WP4.4 is to provide retrofit kits for existing railway infrastructure. In a first step, the present fault and cost drivers has to be identified. Then it is to investigate whether a retrofit of a monitoring system is technically possible and economical meaningful. Relevant results will be available in spring 2016.

The results can be used as input for the Research into new concepts for track (geometry) maintenance based on risk assessment.

More general: In SP1 there is a deliverable D1.1.4 and D1.1.5 dealing with upgrading of infrastructure in order to meet new operation and market demands. Since upgrading is a question for existing lines there is a chapter 4.3 where there is an approach about different resolution analysis. This could be used in In2Rail since most models are too low resolutions to steer maintenance. In WP6 it has to be discussed and decided what resolution is needed. When that is done some of the work can be useful.

3.2.1.3. DYNO TRAIN

The DYNO TRAIN project involved a test campaign that toured Europe, and visited:- Germany, Italy, Switzerland and France. As far as the project is concerned this is the largest test campaign ever undertaken anywhere in the world. The test covered 7500km of track and recorded 4.7 terabytes of data. The train incorporated four types of test vehicles (locomotive, coach and two freight wagons (that were tested in both tare and laden conditions) and included in the train was a track recording car so synchronised data of track input and vehicle reactions could be recorded simultaneously. In addition static tests were undertaken on all the test vehicles. Relevant WP's are:

- WP 1 – Measurements of Track Geometry, Contact Geometry and Vehicle Reactions;
- WP 2 – Track Quality Geometry;
- WP 3 – Contact Geometry;
- WP 4 – Track Loading Limits Related to Network Access;
- WP 5 – Model Building and Validation.

The enormous database accumulated during the project and the build model and validation is relevant for the development of prediction models for optimised maintenance scenarios.

3.2.1.4. INNOTRACK

In WP2.1, a guideline regarding methodologies of geophysical investigation of railway track defects shows the latest improvements in this area. Geophysical methods have been used for a long time, but have been questioned due to difficulties in drawing precise conclusions. This report is a significant improvement in this context. A guideline on methods for track stiffness measurements has been derived. The results from INNOTRACK are a key factor in the increasing use of track stiffness for track substructure assessment. The work in INNOTRACK also paves the way for future standardisation and inclusion in TSIs. Measuring techniques for assessing track stiffness have been compared for the first time. Furthermore, results from all in-situ measurements of subgrade quality covering a very wide range of investigative methods.

Deliverable D2.1.12 GL - Modelling of the track subgrade Part 1: Final report on the modelling of poor quality sites Part 2: Variability accounting in numerical modelling of the track subgrade gives input for modelling of track. Part 1 is orientated towards physical and numerical modelling of poor quality sites and the aim of part 2 is to quantify the uncertainties and variability's of mechanical properties.

The results of this project are relevant for the development of prediction models for optimised maintenance scenarios.

3.2.1.5. INTEGRAIL

Delivered in Demonstration Scenario 2 software for Monitoring and diagnostics:

- The Event Analyser is a semantically enabled application using InteGRail intelligent monitoring (IMON) distributed reasoning service which enables the registration of queries from applications to remote reasoning nodes;
- The Wheel Trend Analyser is a software application that receives wheel status data from multiple monitoring systems;
- The Track Trend Analyser is a software application that receives data from multiple monitoring systems such as Wheel Impact Load Measurement (WILM) systems and on vehicle track data recorders.

The results of this project are relevant for an improved sets of input for asset condition data.

3.2.1.6. MAINLINE

Deliverables 2.1, 2.3 & 2.4 are focused on degradation and structural models to develop realistic life cycle cost and safety models. Deliverable 2.1 chapter 9.3 shows a study about track behaviour based on time rows of recording car data and status date (traffic volume, type and age of track and turnouts and maintenance actions executed).

In deliverable 2.2 the track deterioration is modelled with an exponential function. Once a deterioration model is calibrated, it is possible to predict when tamping and other maintenance actions will be necessary by forecasts based on recent track quality measurements. Several economically proven proposals for shared corridors are presented. The chapter aims to describe the background of a track quality prediction model, its necessary differences due to the varying reaction of track to different boundary conditions.

In deliverable 2.3 and 2.4 the most relevant parameters for decision making are described and the LCAT model is developed and validated. The main target of the whole validation process was to compare the calculated service life out of the LCAT model with the resulting service life of the three different described data sources. Although the validation sample should cover the most commonly applied combinations and demonstrate the logical and technical consistency of the whole model, it is necessary to evaluate the sample and the methodology followed for this validation process.

The results are input for the development of prediction models.

3.2.1.7. SUSTRAIL

Deliverable 4.1 (“Performance Based Design Principles for Resilient Track”) utilises performance based design principles and complementary monitoring tools to determine:

- The factors that influence the resistance of track to the different loads imposed on it by trains, and
- The means by which this resistance can be improved.

The main sub-packages of this deliverable which have relevance to the task 6.3 are:

- 4.1.1 - Determine Dynamic Loading of Wagons on Track and Key Components;
- 4.1.2 - Influence of Track Stiffness on the Dynamic Loads caused by Wagons on track and Key Components;
- 4.1.4 - Mechanical Testing of Track Components;
- 4.1.5a - Risk Analysis in the Design and Operation Phase;
- 4.1.5b - From Safety Limits to Maintenance Limits.

As the main priority of the Task 6.3 is track geometry, SUSTRAIL Deliverable 4.3 (“Track Degradation Models") can also be taken into account. The useful subtasks of this deliverable are as follows:

- Subtask 4.3.2 is dedicated to the analysis of track geometry degradation to find out requirements for maintenance towards the project “zero” maintenance ideal;
- Subtask 4.3.3 “Analysis of track global resistance, failure modes, and risk” has the objective to analyse the track global resistance, failure modes, and related risk in order to identify, on a risk basis, incoming and futuristic innovations that can lead to a more resilient track;
- Subtask 4.3.4 “Track Detection Methods” had the objective of analysing sensing methods for comparing the loading condition of optimised vs. standard track;
- Subtask 4.3.5 “Modelling tools” had the objectives of:
    - Mathematical modelling and simulation of train-track interaction for novel track forms (POLIMI);
    - Modelling the accumulation of rail damage for maintenance planning (USFD);
    - Analysis of novel track systems to predict maintenance requirements under mixed traffic;
    - Setup conventional ballasted track – vehicle interaction models;
    - Run several cases to investigate reaction forces of components.

The results are input for the improved sets of inputs: asset condition data (including train-born monitoring systems and actual (way-side monitoring systems) and forecasted usage information.

3.2.2. Specific partner knowledge

DLR participated in the project AUTOMAIN and worked on WP 3 "High-Speed Inspection" on the development of failure detection and prediction algorithms for track geometry based on measurement data from in-line service trains. DLR have significant experience in failure detection, data analysis, system modelling and fault diagnosis for switches gained from collaboration with other industry partners engaged in research projects.

During the last decades, SNCF participated in most of the major European Research projects dedicated to Railways, including Innotrack, AUTOMAIN, Dyno-Train. These projects contributed to extending SNCF expertise and scientific knowledge, required for normal asset management responsibilities. This particularly concerns track geometry modelling.

SNCF are familiar with the existing approaches (benefits and limits) that enable the specifying of requirements for innovative modelling. Internal SNCF databases also make available realistic data sets to to test and improve these new models.

The purpose of the functional model is gaining new insights in relation to the usage, maintenance activities, performances and costs. The functional model describes the "main" functions of a system and its components. By defining these functions, the model can be used as a key integrator for different data inputs and are linked with functions of the model. By doing this new insights will be gained that could be used in a decision support tool.

Domain knowledge and the availability of data is the key for bringing the theory into a practical model which can be used in daily operation. Strukton Rail has knowledge and experience on maintenance and reliability engineering (FMECA and RCA) , and has access to data from various maintenance contracts. Strukton is familiar with the functional breakdown of systems and can analyse the failure data/ costs, maintenance activities and maintenance costs to determine cost and performance drivers. To verify the model Strukton Rail proposes to develop a particular "use case" as a proof of concept.

FCCCo has contractor based experience and bringss knowledge in tamping process, measurement and track auscultation, maintenance modelling for track and switches in high speed rail, as well as cost estimations and appropriate mechanised maintenance technologies. FCCCo also has knowledge about current practices and has databases of information gathered from its operational experience.

MerMec brings expertise on Decision Support System for assets maintenance (Experience as Ramsys developer), with a focus on data measurements and the (re)localization and validation for exact positioning purposes. The RAMSYS platform enables proactive management of a diverse set of railway assets through enhanced analysis of volumes of data (measurements, current and historic asset data. This Decision Support System fully supports condition based and predictive maintenance. Data analysis has to be done in order to make an evaluation with the defined acceptance threshold.

ACCIONA has been involved in Capactiy4Rail with respect to SP1 Infrastructure. The main goal has been the design, development and testing of new concepts for railway track, adapted to mixed traffic and eventual adaption to very high speed. In SP4, advanced monitoring, the main goal has been the design of an Advance Monitoring System (AMS) able to gather together the most relevant information on infrastructure state and on the rail services. Besides the knowledge based on this specific project, ACCIONA can also contribute based on the Spanish railway maintenance use case knowledge.

Luleå University of Technology participated in the projects AUTOMAIN and Optirail. Within the AUTOMAIN project, Luleå University of Technology was the work package leader for WP4 “High Performance Maintenance” and contributed in the high performance grinding and high speed tamping tasks. In the Optirail project, Luleå University of Technology was the work package leader for WP6 “Pilot tests” and worked with development and validation of the track geometry analysis tool.

These are relevant to task 6.3 of In2Rail. Taking into account the knowledge and experiences obtained from the involvement not only in the aforementioned European projects but also in several National projects, that can contribute in the development and validation of dynamic maintenance model for track geometry as well as application of maintenance decision support tools RAMS and LCC.

3.2.3. Relevant input deterioration and root causes

In deliverable 4.1 of the Sustrail project the "Ishikawa" diagram is mentioned (see Figure 2). In this diagram, several parameters that affect the deterioration of geometry are defined. These parameters can be used as inputs for the proposed dynamic track maintenance model .

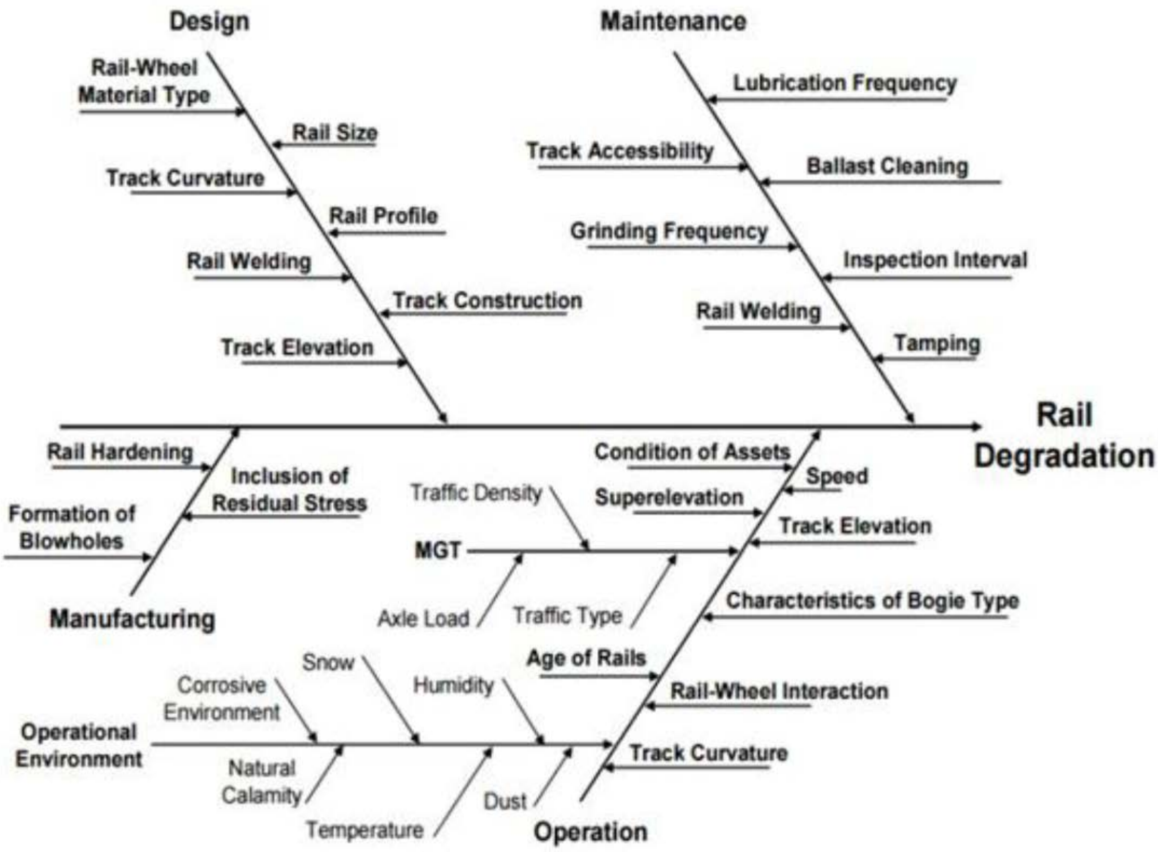


Figure 3.2: Ishikawa diagram of Track Geometry degradation influencing factors [SUSTRAIL D4.1]

3.3. Task 6.4: Dynamic model for switch maintenance

3.3.1. Relevant previous projects

3.3.1.1. AUTOMAIN

Deliverable 3.2 seeks for and promotes the development of technologies that will enable S&C to be inspected automatically and remotely. The report describes the evaluation of inspection requirements, and then the development and evaluation of five specific inspection technologies. The report includes a concept design for a self-inspecting switch and supporting systems that would be effective in supporting the goals of the AUTOMAIN project.

The input is relevant for data gathering/mining techniques supporting efforts in S&C diagnosis as well as prognosis.

Deliverable 6.2 demonstrates the research and test trials carried out for the development of a "Modular, self inspecting switch" different parts of the solution have been demonstrated in different countries under laboratory and/or test track conditions. The objective is to reduce the inspection time of S&C as much as possible by moving towards condition based inspection and remote / automatic inspection.

The input is relevant for data mining techniques supporting efforts in S&C diagnosis as well as prognosis.

3.3.1.2. CAPACITY4RAIL

New monitoring systems may be able to deliver important information that is needed for the optimisation of maintenance and prevention of breakdowns. But implementation of monitoring systems on the whole network needs also analysis of financial return of investments. CAPACITY4RAIL (C4R) therefore not only looks for the technical performance and advantages but also for the economic performance of monitoring systems.

Important in this regard are the tow work packages of SP4 of C4R, i. e. WP 4.3 "Implementation in new structures" and WP 4.4 "Migration of innovative technologies to existing structures".

The objective of WP4.3 is the design of an Advanced Monitoring System (AMS) able to gather the most relevant information on infrastructure state and on the rail services for the new concepts of infrastructure developed in C4R. The developed technologies should be low cost, easy and rapid to implement during the construction of the infrastructure and oriented towards a cost-effective, easy and rapid sensor (including batteries) replacement/maintenance.

The input is relevant for data mining techniques supporting efforts in S&C.

The aim WP4.4 is to provide retrofit kits for existing railway infrastructure. In a first step, the present fault and cost drivers has to be identified. Then it is to investigate whether a retrofit of a monitoring system is technically possible and economical meaningful. Relevant results will be available in spring 2016.

The input is relevant for data mining techniques supporting efforts in S&C.

3.3.1.3. DYNO TRAIN

The DYNO TRAIN project involved a test campaign that toured Europe, and visited:- Germany, Italy, Switzerland and France. As far as the project is concerned this is the largest test campaign ever undertaken anywhere in the world. The test covered 7500km of track and recorded 4.7 terabytes of data. The train incorporated four types of test vehicles (locomotive, coach and two freight wagons (that were tested in both tare and laden conditions) and included in the train was a track recording car so synchronised data of track input and vehicle reactions could be recorded simultaneously. In addition static tests were undertaken on all the test vehicles. The project accumulated an enormous database that could be used for In2Rail task 6.3. Relevant WP's are:

- WP 1 – Measurements of Track Geometry, Contact Geometry and Vehicle Reactions;
- WP 2 – Track Quality Geometry;
- WP 3 – Contact Geometry;
- WP 4 – Track Loading Limits Related to Network Access;
- WP 5 – Model Building and Validation.

The results can be a one of the sources that will be combined, analysed and processed with data mining techniques.

3.3.1.4. INNOTRACK

WP3.1 has been a real breakthrough in reducing impact of lateral and vertical dynamic forces in the switch and the crossing when trains are passing. The work has also presented a full chain of computer-aided optimisation of switches: simulations of train–track interaction have been connected to numerical simulations of plastic deformation and wear. The results have been validated by full-scale field measurements of forces, wear and plastic deformation.

In WP3.2 technical and RAMS requirements/recommendations for the actuation system have been defined for locking and the detection devices for a UIC 60-300/1200 switch. This is important to promote future European standardisation. Especially Deliverable D3.2.5 - Technical and RAMS requirements/recommendations for the actuation system, the locking and the detection device for UIC 60-300/1200 switches is relevant.

In WP3.3 the deliverables specify requirements for IMs regarding switch monitoring. A report that quantifies the benefits that is available from switch and crossing monitoring has been produced. Most relevant input from this WP are the deliverables D3.3.1 - List of key parameters for switch and crossing monitoring and D3.3.4- Algorithms for detection and diagnosis of faults on S&C.

The results of these WP's can be input for the development of switch behavioural models.

3.3.1.5. SUSTRAIL

Subtask 4.4.3 deliverable 4.4 ("Optimised S&C Systems") presented an innovative and simplified approach to model the dynamic interactions between vehicle and railway crossings capable of taking into account stochastic data, for example the wheel geometry and the relative lateral positioning of wheel and rail, in order to estimate the vertical damage on different layers of the track system.

The results can be input for the development of switch behavioural models.

In addition, subtask 4.4.4 focused on the benefit of adding resilient layers to improve the support conditions in turnouts and the question of track stiffness, both measurement of and how it affects the system performance. There was a specific focus on the application of Under Sleeper Pads (USPs) in turnout and more specifically in the crossing panel with supporting information coming from a test site by Network Rail. PoliMi performed detailed dynamics simulation using a complete 3D Finite Element model to prove the benefit of USP in lowering forces in different layers of the track system. University of Huddersfield also supported this work by modelling vertical dynamics in the presence of voids and the mitigation effect of USP. Lulea University of Technology proposed a new system for the measurement of track stiffness in turnouts.

The results are relevant for the development of switch behavioural models with input from WP2 to predictive maintenance concepts for switches

3.3.2. Specific partner knowledge

In2Rail members (for instance Deutsche Bahn and Trafikverket) possessing the relavant knowledge for this task due to their active participation in INNOTRACK WP3.1.

DLR participated in the project AUTOMAIN and worked in work package WP 3 High-Speed Inspection on the development of failure detection and prediction algorithms for track geometry based on measurement data from in-line service trains. They have extensive experience in failure detection and diagnosis for switches.

During the last decades, SNCF participated in most of the major European Research projects dedicated to Railway, including Innotrack, AUTOMAIN, Dyno-Train. These projects contributed to extend existing SNCF Expertise and Scientific knowledge, required for its own activities and responsibilities. This particularly concerns Track (and Switch) geometry modelling.

Past and current Asset Management practices, and Research activities, make SNCF familiar with the existing approaches (benefits and limits) and enable specifying requirements for innovative modelling. Internal SNCF databases enable to test and improve these new modelling on realistic cases.

The purpose of the functional model is gaining new insights in relation to usage, maintenance activities, performances and costs. The functional model describes the "main" functions of a system and associated components. By defining these functions, the model can be used as a key integrator for different data inputs and are linked with functions of the model. In this way new insights will be gained that can be used as a decision support tool. Domain knowledge and the availability of data is the key for combining technical theory into a practical model which can be used in daily operations.

Strukton Rail contributes knowledge and experience on maintenance and reliability engineering (FMECA and RCA), and has access to data from numerous maintenance contracts. Strukton is familiar with the functional breakdown of systems and can analyse the failure data/ costs, maintenance activities and maintenance costs to determine cost- and performance drivers. To verify the model Strukton Rail proposes to develop a “use case” as a proof of concept.

Luleå University of Technology was involved in the European project Sustrail. In the Sustrail project, it contributed in WP4 “SUSTAINABLE TRACK” and WP5 “BUSINESS CASE”. They have has also performed measurements of track stiffness at S&C in Sweden within this project and have a comprehensive knowledge of measurement data processing, degradation maintenance modeling and developing decision support tools, for both railway track and S&Cs. This knowledge and experience can be used in task 6.4 of In2Rail to analyse and model geometrical degradation of S&C units.

3.3.3. Relevant input deterioration and root causes

The investigations performed in WP3.1 of INNOTRACK confirmed that the root-cause for the degradation (severe wear and plastic deformation) of railway crossings is the high dynamic loads caused by an inadequate transition geometry. Therefore, the optimisation of the transition geometry in crossings is aimed at providing a smooth transition of the wheel transfer between the crossing wing rail and nose which leads to lower dynamic impacts and hence reduced contact/internal stresses.. As a consequence of this insight a monitoring of the transition geometry should be established in order to be able to take preventive maintenance actions in time before serious damages occurs that results in expensive remedial maintenance work. A reliable predicition model for the degradation of the transition geometry in crossings could help to keep the effort for this monitoring as low as possible.

3.4. Task 6.5: Condition and Risk-based Maintenance planning

3.4.1. Relevant previous projects

3.4.1.1. AUTOMAIN

Deliverable 3.1 algorithms are derived which inform and support decision makers to manage usage of maintenance resources and budget more efficiently.

This information can be input for the decision support tool.

Deliverable 4.1: the purpose of this deliverable is to study, identify and assess innovations that can improve the effectiveness and efficiency of large scale maintenance activities (such as; rail grinding, tamping and maintenance of switches and crossings) with a view to reduce the maintenance track possession time.

This contribution can be input for the decision support tool

Deliverable 5.1: Methods and tools for operations research are introduced. To provide an optimal maintenance strategy, planning (macroscopic view; long-term behaviour) as well as scheduling (microscopic view; short-term behaviour) are considered. By setting up a hierarchical scheduling framework the problem is split into several sub-problems which, in principle, have to be solved sequentially. This final merging step is still missing due to interoperability problems.

These conclusions are relevant for the decision support tool.

3.4.1.2. CAPACITY4RAIL

In fact, Monitoring systems provide essential input for a reliable condition and risk-based maintenance planning. Implementation and use of monitoring systems therefore has a strong impact on this task. C4R will demonstrate monitoring systems at least for existing infrastructure. The information gathered by these systems could be of interest for In2Rail.

The results are input for the Design of a concept for a new approach of CRMP, based on an analysis of challenges and requirements for using real-time diagnosis of asset conditions.

3.4.1.3. D-RAIL

In WP 7 of D-Rail LCC and RAMS assessments were performed for the concerned inspection and monitoring systems.

However, Work package 7 provided a technical and economical assessment of derailment prevention measures, including inspection and monitoring systems based on RAMS- and LCC-analyses. The evaluation includes a developed conceptual framework on RAMS and LCC, recommendations of analysis methods, risk assessment and risk analysis with reference to the Common Safety Method on Risk Evaluation and Assessment (CSM-RA) and implementation.

The results can be used to Design a concept for a new approach of CRMP, based on an analysis of challenges and requirements for using real-time diagnosis of asset conditions, prognosis of future condition from predictive models and probabilistic risk assessments.

General note: The findings in D-RAIL was clear and showed that it was possible to reduce the occurrences of freight train derailments within Europe by between 8 - 12% and reduce derailment related costs 20%. This could be done by using existing technologies. More than half of all derailments 55% and f 75% of the costs was addressed by three types of interventions. This was proofed by RAMS and LCC analysis. It also showed that a good maintenance level is the base to reduce derailments.

3.4.1.4. OPTIRAIL

WP 2 gives a good base of the state of the art in other domains, and outlines the procedures to follow on the way to the implementation of a working system. The OPTIRAIL tool is based on Computational Intelligence (CI) and fuzzy techniques and these ones are based on data and expert knowledge, WP1 contributed towards establishing the foundations for the conceptual design of the smart framework, WP3, and the development of the different degradation models, WP4, mainly, through the description of the relevant elements, aspects and operations of the railway maintenance areas as the description of the main ICT systems, and the data stored in them, used by different railway managers, highlighting the difference between them in order to improve the corridors interoperability.

The results can be integrated in the track geometry modelling.

3.4.1.5. SUSTRAIL

Subtask 4.1.5a ("Risk Analysis in the Design and Operation Phase") focused on risk assessment techniques and tools. Risk assessment provides evidence-based information to make informed decisions. The information helps to understand risks, their causes, consequences and their probabilities and gives input into decisions such as:

- whether a design, operation or maintenance action should be undertaken;
- how to maximise opportunities; whether risks need to be treated;
- choosing between options with different risks;
- prioritising risk treatment options;
- the most appropriate selection of risk treatment strategies that will bring adverse risks to a tolerable level.

The task presented the application of risk matrix as an assessment tool. It is a frequency - consequence visualisation and evaluation tool used for the classification of events into risk categories to facilitate improvement decisions in terms of risk reduction or elimination. Basically, risk matrix gives the opportunity to combine qualitative ratings and quantitative estimates (even semi-quantitative ratings) of consequence and probability to produce risk rating.

The results are input for dynamic and real-time maintenance planning with the integration of maintenance logistics into the CRMP concept to enable efficient work site management, including dynamic planning and adaption of maintenance schedules to real-time information or unforeseen events and situations, supporting a risk-based approach.

Deliverable 4.5 ("Track Safety Criteria") have also a relevance to task 6.5 of In2Rail. The most useful part of this deliverable are:

- Wayside Sensors and Monitoring Systems:
- This part describes current and innovative wayside monitoring technologies. A focus is put on the monitoring systems able to provide data on forces and loads. The means by which the data collected from these technologies are used to define limits are also explained.
- Proposition of Condition Data use for Preventive Maintenance

- The wayside monitoring systems can produce statistics on the track utilisation which is an essential input to track maintenance planning and the prediction of track degradation.

The results can be used as input for the use of real-time diagnosis of asset conditions.

In addition, deliverable 5.1 (“Holistic RAMS and LCC analysis”) can provide some inputs for application of decision support tools RAMS & LCC in the maintenance planning. The RAMS and LCC model was developed to assess the innovations from a holistic approach. The holistic approach in the modelling work aims to reflect how the track and the wagons interact from a RAMS and LCC perspective. The developed RAMS and LCC model can simulate a vast number of different scenarios and can be adapted to other line sections and vehicle types.

The results are relevant for the design of concept for a new approach of Condition and Risk-based Maintenance Planning.

3.4.2. Specific partner knowledge

During the last decades, SNCF participated in most of the major European Research projects dedicated to Railway, including Innotrack, AUTOMAIN, Dyno-Train. These projects contributed. particularly to track geometry modelling and for asset management decision-making.

Past and current asset management practices, and research activities, make SNCF familiar with the existing approaches (benefits and limits) and enable specifying requirements for innovative modelling. Internal SNCF databases enable data sets to be available for testing and improving these new modelling on realistic use cases.

Ansaldo STS participated in the project Capacity4Rail which is relevant for this task. and have relevant knowledge in In2Rail about how to use process measuring data from infrastructure monitoring and TMS systems. With respect to this particular In2Rail task they have experience in risk-based maintenance planning, diagnostics automatic anomaly detection techniques and the associated alerts used to update maintenance planning decisions and evaluate adjustment actions .

Therefore this experience contributes to designing the maintenance planning process as an automated and digitalised process cycle able to receive continuous feedback from the field and to make decisions accordingly.

Strukton Rail as a maintenance contractor in the Netherlands has specific expertise in the field of performance based maintenance contracts. The Dutch railway market is the first European maintenance market to introduce this commercial approach, as a result maintenance practices have been optimised in a rapid way and the quest for optimum maintenance intervals is an ongoing priority.

FCCCo has detailed knowledge of the tamping process, measurement and track maintenance modelling for track and switches in High Speed Rail.

MerMec brings knowledge about how to make best use of asset condition data as one of the main purposes of decision support systems.

3.4.3. Relevant input deterioration and root causes

The AUTOMAIN project refers to root causes as "performance killers". The low production utilisation of possession time is stated as being attributable to low levels of confidence in activities being completed, which generates unnecessary contingency time being added to maintenance plans.

3.5. Task 6.6: High performance tamping

3.5.1. Relevant previous projects

3.5.1.1. AUTOMAIN

Deliverable 1.3: One of the results from the work packages in terms of their effect on the objectives is about the tamping process and is described in "2.2.1. Objective 1: Adopting best practices in/outside rail industry, lean approach (50% reduction possession time for maintenance4)".

The input can be used to identify the activities to eliminate pre-run track alignment activity.

Deliverable 2.2: There are a number of technological developments that could further enhance productivity such as multi-functional high output machines capable of recording and working in either direction minimising set up times on site.

The input can be use to eliminate pre-run track alignment activity.

Deliverable 4.1 Tamping design could be improved in the following areas: increased flexibility (e.g. for both high output plain lines and switches), reduced time and human intervention to set up, ability to warm up during transit, record work in either direction, and potentially drive on and off the tracks at suitable locations.

(The input can be use to eliminate pre-run track alignment activity)

3.5.2. Specific partner knowledge

DB participated in the project AUTOMAIN with specific engagement in the following tasks which are related to In2Rail:

- Lean analysis of maintenance processes;
- High speed tamping and;
- Optimisation of tamping parameters.

They also have knowledge in the area of maintenance procedures and strategies which are relevant for task 6.6 in In2Rail. DB therefore bring expertise regarding current best practice, and new approaches for improved and lean maintenance of track geometry.

Strukton Rail also participated in the project AUTOMAIN and worked on the work package High Speed Tamping. Strukton Rail have particulatly good knowledge of tamping techniques and how to use and process measuring data from the measurement train. They have particular skills to produce system requirements for defining new working methods. Strukton Rail can also perform tests for a Proof of Concept.

3.5.3. Relevant input deterioration and root causes

The root cause identified in AUTOMAIN was associated with the premeasurements of track geometry. (e.g. EM-Sat takes more time to perform than the actual tamping time). Therefore the recommendations was to reduce this premeasurement possession time or develop new measurement techniques that may possibly use measurements from the track recording car directly on the tamping machine.

4. Conclusions

It is concluded that the deliverables reviewed from previous projects are diverse, ranging from databases of measurements to academic models simulating the behaviour of systems within the railway industry.

A large number of projects have been analysed with respect to the the task objectives of In2Rail WP6 and a significant volume of material has been positively identified.

Although the material is considered useful it is also considered important that the onward inclusion of it as a foundation for In2Rail further work needs to remain mindful of the original source project remits and assumptions.

It is therefore intended that additional checks will be applied to validate all inputs into the WP.

The summary findings concerning relevant previous project work outputs are listed in the table below.

Task	Relevant input	Identified Task / Deliverable
6.2 Specification of Asset Management framework	AUTOMAIN	Deliverable 3.1
	CAPACITY4RAIL	Subproject "Advanced monitoring"
	INNOTRACK	Various sub projects
	MAINLINE	Deliverable 5.3
		Deliverable 5.7
	SMARTRAIL	Deliverable 4.2
		Deliverable 4.3
6.3 Dynamic model for track maintenance	AUTOMAIN	Deliverable 3.1
		Deliverable 6.1
	CAPACITY4RAIL	Deliverable 4.3
		Deliverable 4.4
	DYNO Train	Work Package 1
		Work Package 2
		Work Package 3
		Work Package 4
		Work Package 5
	INNOTRACK	Deliverable D2.1.12 GL
	INTEGRAIL	Demonstration Scenario 2
	MAINLINE	Deliverable 2.1
		Deliverable 2.2
		Deliverable 2.3
	SUSTRAIL	Deliverable 4.1 (4.1.1; 4.1.2; 4.1.4; 4.1.5a; 4.1.5b)
		Deliverable 4.3 (4.3.2; 4.3.3; 4.3.4; 4.3.5)

Task	Relevant input	Identified Task / Deliverable
6.4 Dynamic model for switch maintenance	AUTOMAIN	Deliverable 3.2
		Deliverable 6.2
	CAPACITY4RAIL	Work Package 4.3
		Work Package 4.4
	DYNO Train	Work Package 1
		Work Package 2
		Work Package 3
		Work Package 4
		Work Package 5
	INNOTRACK	Work Package 3.1
		Work Package 3.2
		Work Package 3.3
	SUSTRAIL	Subtask 4.4.3 deliverable 4.4
		Subtask 4.4.4
6.5 Condition and Risk-based Maintenance planning	AUTOMAIN	Deliverable 3.1
		Deliverable 4.1
		Deliverable 5.1
	CAPACITY4RAIL	Subproject “Advanced monitoring”
	D-RAIL	Work Package 7
	OPTIRAIL	Work Package 2
		Work Package 3
	SUSTRAIL	Deliverable 4.1.5a
		Deliverable 4.5
		Deliverable 5.1
6.6 High performance tamping	AUTOMAIN	Deliverable 1.3
		Deliverable 2.2
		Deliverable 4.1
6.7 Technical Validation	None	None

Table 4.1: Identified relevant input

Appendix I. **AUTOMAIN**

Research results on mechanised track maintenance and inspection (tamping and grinding); LEAN analysis of working methods and processes to reduce possession times; demonstration of advanced switch and track monitoring; decision support tool for maintenance planning and scheduling

I.1 Project details

Full title: AUTOMAIN is the acronym for the EU Framework 7 collaborative research project: "Augmented Usage of Track by Optimisation of Maintenance, Allocation and Inspection of Railway Networks".

Started in 2011 – ended in 2014

I.2 Partners

The project is executed by the following partners:

- ProRail
- Damill AB
- Deutsche Bahn
- DLR
- EFRTC
- Eurodecision
- KM&T
- Luleå University of Technology
- MER MEC group
- Network Rail
- SNCF
- Strukton Rail
- Technische Universität Braunsweig
- Trafikverket
- UIC
- Unife – The European Rail Industry
- University of Birmingham
- Vossloh

I.3 Objective and description

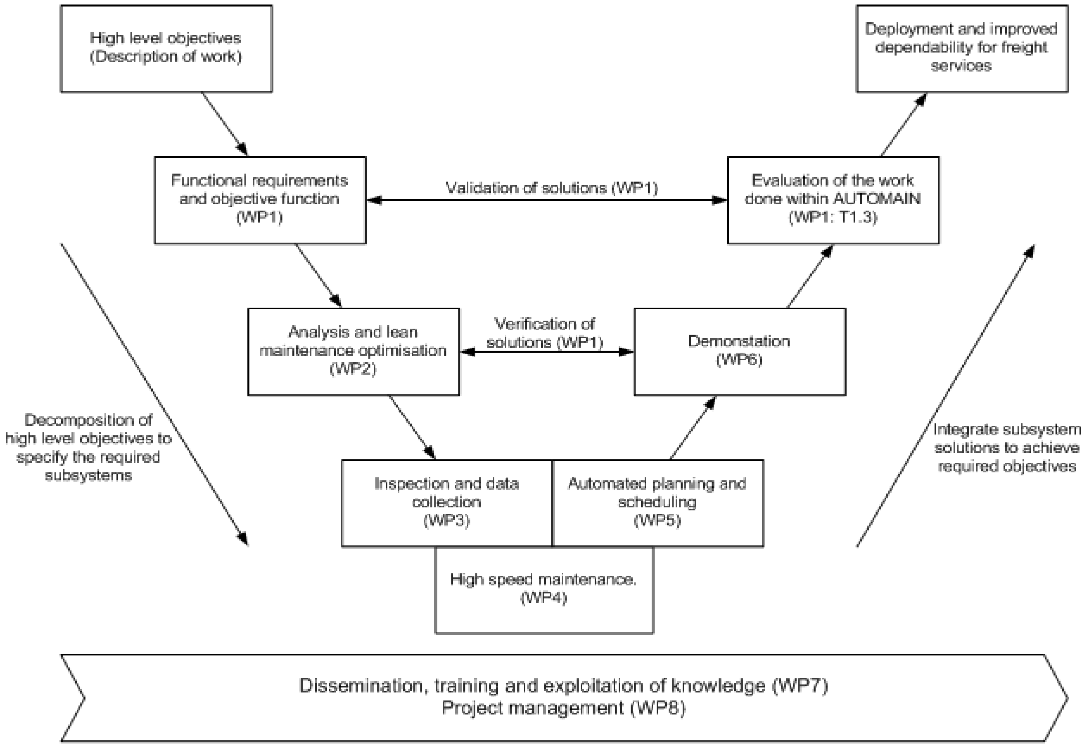
The high level aim of the AUTOMAIN project was to make the movement of freight by rail more dependable (reliable, available, maintainable and safe) through the generation of additional capacity on the existing network. Through the widespread introduction of automation and improvement of railway infrastructure equipment and systems, modular infrastructure design, and far-reaching optimisation of maintenance, required possession time (downtime for inspection, maintenance and/or installation) of the railway can be reduced.

Improvements are achieved through:

- Increased reliability;
- Increased availability;
- Increased maintainability;
- Improved worker safety.

I.4 Possible relevance

The research areas range from a new methodology for analysing and optimising maintenance processes, new (high speed) inspection and maintenance methods to improvement of automatic maintenance scheduling and planning systems.



Source: www.automain.eu

I.5 Project results relevant for In2Rail

The deliverables of AUTOMAIN are very useful for In2Rail WP6. But caution is recommended: most of the results showed “academic” examples under idealised conditions (they might be tuned manually to get the desired results). The results of AUTOMAIN have to be developed and validated for instance in WP6.

Appendix II. **CAPACITY4RAIL**

The objective of CAPACITY4RAIL is to increase capacity, availability and performance of the railway system through major step changes in:

- Infrastructure design;
- Construction and maintenance (including advanced monitoring);
- Operations management;
- Incident recovering through real-time data management;
- Freight operations, with a particular focus on transhipment and improved specifications for rolling stock.

II.1 Project details

CAPACITY4RAIL is the acronym for the EU Framework 7 collaborative research project:

"Increasing Capacity 4 Rail networks through enhanced infrastructure and optimised operations".

Started in 2013 – will end 2017

II.2 Partners

The project is executed by the following partners:

- UIC (Union Internationale des Chemins de Fer) – Coordinator
- ARTTIC
- Trafikverket
- Systra SA
- Deutsche Bahn
- Network Rail Infrastructure LTD
- Administrador de Infraestructuras Ferroviarias
- Fundación Ferrocarriles Españoles
- Instytut Kolejnictwa
- Voestalpine VAE
- ACCIONA Infraestructuras S.A,
- Instituto Superior Tecnico
- Universita Degli Studi di Roma La Sapienza
- Ansaldo STS S.p.A.
- Union Des Industries Ferroviaires Europeennes - UNIFE
- University of Newcastle Upon Tyne
- Ingenieria Y Economia Del Transporte S.A.
- Centro de Estudios Materiales y Control de Obras S.A.
- NEWOPERA Aisbl
- Oltis Group AS
- Kungliga Tekniska Högskolan
- Chalmers Tekniska Högskola AB
- The University of Birmingham
- TRL Limited
- Vossloh Fastening Systems
- The University of Huddersfield
- Technische Universitaet Dresden
- Uppsala Universitet
- Turkiye Cumhuriyeti Devlet Demir Yollari Isletmesi Genel Mudurlugu
- Rede Ferroviaria Nacional
- Universidade do Porto
- Kockums Industrier AB
- Van Dieren Sweden AB

- Centro De Estudios Y Experimentacion De Obras Publicas
- Societe Nationale des Chemins de Fer Francais
- Adevice Solutions S.L.
- Linköpings Universitet
- European Federation of Railway Trackworks Contractors
- Vossloh COGIFER SA
- Fundacion de la Comunidad Valenciana Para la Investigacion, Promocion Y Estudios Comerciales de Valenciaport
- CargoSped
- The University of Sheffield
- COMSA SAU
- STVA
- Knorr-Bremse Systeme fur Schienenfahrzeuge GMBH
- Réseau Ferré de France EPIC
- IFFSTAR

II.3 Objective and description

To face the future challenge of increasing traffic and to make the railway system more attractive and competitive, a step change is needed to guarantee an adaptable system, offering a high operational capacity with high reliability and resilience to hazards.

In order to make rail an attractive option to freight and passengers and to increase the capacity, operations, reliability, resilience and affordability of European rail networks, an overall coherent system approach is adopted in the Capacity4Rail project, where research and development on infrastructure, operation, rolling stock and freight systems are done with a rational system approach.

To tackle this vast challenge, Capacity4Rail has been put in place by not less than 47 partners from all over Europe representing a well-balanced group of rail operators, infrastructure managers, academia, suppliers and SMEs. Its overall objectives are to deliver innovative research and to prepare rail for the future while taking into account results from previous research projects and programs.

The Capacity4Rail project aims at bringing today's railway system to a future vision for 2030/2050 where enhanced capacity and performances will make it able to successfully face the challenge of the growing demand for goods and passengers transportation. In particular, it will define a comprehensive roadmap to describe the necessary steps to develop and implement innovation and to progress from the current state-of-the-art to a shared global vision of the 2050 railway along realistic scenarios.

The project is developing a vision and identifies the requirements of the railway system in 2030/2050. Identifying the technologies and their development/implementation steps necessary to move towards the targeted vision, the project is developing in an system approach, innovative concepts of infrastructure design, construction and maintenance, as well as operation management, incident recovering and freight operations, with a particular focus on transshipment and improved specifications for rolling stock. In particular, it includes:

- new concepts for railway track of the future, in view of potential application for mixed traffic, that encompassed cost savings, rapid construction, resilience and enhanced maintainability;
- design guidelines for very high speed with identification of limiting factors, especially in terms of admissible track irregularities and transition zones;
- conceptual design for the rail freight vehicles (wagons and trains) of the future;
- design of transhipment technologies and interchanges of the future (rail yards, intermodal terminals, shunting facilities, rail-sea ports, etc.);
- design of modern fully integrated rail freight systems for seamless logistics and network-based performance;
- modeling simulation tools for high volume traffic management;
- concepts for railway structural and operational monitoring, to enhance the availability of the track.

Five major requirements have been defined for all the developments within this project: The future railway system should be affordable, adaptable, automated, resilient and high capacity.

II.4 Possible relevance

CAPACITY4RAIL mainly focus on new track designs, freight vehicles operation and monitoring of infrastructure and weather conditions. The main topics addressed in the tasks of WP6 are not directly covered in CAPACITY4RAIL. Possible relevance may have the results from SP4 “Monitoring” as this subproject develops monitoring systems for new and existing infrastructure.

Appendix III. **D-RAIL**

The focus was on research work on infrastructure, train dispatching and timetable planning and monitoring as well as on recommendations for Open-Source and Open-Interface for advanced railway monitoring applications.

It has been established that many derailments occur due to a combination of causes. For this reason D-Rail focuses on identifying root causes of derailment and studying how a combination of several contributing factors may cause a derailment.

The main objective of the D-Rail project is to obtain a significant future reduction in freight derailments through an increased understanding of derailment causes, and improve methods of predicting derailment critical conditions through measurement of appropriate system parameters. That is to say it the aim was to come up with cost-efficient measures to reduce derailments.

III.1 Project details

Full title: D-RAILis the acronym for the EU Framework 7 collaborative research project: Development of the Future Rail Freight System to Reduce the Occurrences and Impact of Derailment

Started in 2011 – ended in 2014

III.2 Partners

The project is executed by the following partners:

- University of Newcastle Upon Tyne - coordinator together with UIC
- UIC (Union Internationale des Chemins de fer) - coordinator together with Unew
- Rail Safety and Standards Board Limited
- Technische Universitaet Wien
- Panteia Bv
- Chalmers Tekniska Hoegskola Ab
- Politecnico di Milano
- The Manchester Metropolitan University
- Lucchini Rs Spa
- Mer mec Spa
- Faiveley Transport Italia
- Telsys Gmbh
- Oltis Group AS
- Vyzkumny ustav zeleznicni
- Deutsche Bahn AG
- Harsco Rail Limited
- Schweizerische bundesbahnen SBB
- Obb-infrastruktur ag OBB
- Societe Nationale des Chemins de Fer
- Trafikverket - TRV

III.3 Objective and description

The main objective of the D-Rail project was reduce derailments in a cost efficient way by using modern monitoring equipment, To do so recommendations to reduce derailments by 8-12% and an associated cost reduction of 10-20% within Europe was produce. Selecting the right measures to obtain the maximum safety benefits requires an unbiased and objective process.

D-RAIL was focused on freight traffic, identifying root causes of derailment of particular significance to freight vehicles, which have a wider range of operating parameters (as a result of the huge range in loads, speeds and maintenance quality) than passenger vehicles. One key question that has been studied was how independent minor faults (e.g., a slight track twist and a failing bearing) could combine to cause a derailment. D-RAIL extended this study to include the expected demands on the rail freight system forecast for 2050, such as heavier axle loads, faster freight vehicle speeds for time-sensitive – low volume high value high speed services (LVHVHS) – goods, radically new vehicle designs, or longer train consists. A set of alarm limits has been specified which can be selected as appropriate by infrastructure managers, depending on local conditions.

In tandem with the above analysis, current monitoring systems (both wayside and vehicle-mounted) and developing technologies have been assessed with respect to their ability to identify developing faults and potential dangers. Where current systems are shown to be deficient, the requirements for future monitoring systems have been specified. D-RAIL has also examined vehicle identification technologies, such as the standards- and interoperability-focussed RFID system being implemented by GS1 and Trafikverket.

Integration of alarm limits, monitoring systems and vehicles across national borders and network boundaries have been examined and a deployment plan set out based on RAMS and LCC analyses. Procedures for applying speed limits to faulty vehicles, or taking them out of service, have been set out; this included communication with the parties responsible for the transport of the freight and for maintenance of the vehicle. This will input to standards, regulations and international contracts.

For field testing and validation, D-RAIL have had access to VUZ's (Vyzkumny Ustav Zeleznicni) test track in the Czech Republic.

III.4 Possible relevance

The findings in D-RAIL was clear and showed it was possible to reduce the occurrences of freight train derailments within Europe by between 8 - 12% and reduce derailment related costs 20%. This could be done by using existing technologies. 55% of all derailments and 75% of the costs was addressed by three types of interventions. This was proofed by RAMS and LCC analysis. It also showed that a good maintenance level is the base to reduce derailments.

The risk assessment approach, using different methodologies concerning risk analysis and their corresponding values could be of interest for task 6.5 of WP6, even if it was focused on derailment issues

Appendix IV. **DYNO Train**

The DynoTRAIN project aims to promote interoperable rail traffic in Europe by reducing costs of certification and closing “open points” in the TSI’s. On the basis of requirements for the new CR TSI and revision of HS TSI, opportunities to reduce certification costs and where virtual certification could be introduced it is decided to focus the study on the main aspects of rolling stock dynamics that are or need to be subject to certification[9].

IV.1 Project details

Full title: DYNO Train is the acronym for the EU Framework 7 collaborative research project: Railway Vehicle Dynamics and Track Interactions Total Regulatory Acceptance for the Interoperable Network.

Started in 2009 – ended in 2013

[9] Source: DYNO Train project, www.triotrain.eu

IV.2 Partners

The project is executed by the following partners:

- Union Des Industries Ferroviaires Europeennes - Unife
- Alstom Transport S.A.
- Bombardier Transportation Gmbh
- Ansaldobreda S.P.A.
- Siemens Aktiengesellschaft
- Rail Safety And Standards Board Limited
- Deutsche Bahn Ag
- Societe Nationale Des Chemins De Fer Francais
- Trenitalia Spa
- Union Internationale Des Chemins De Fer
- Universita Degli Studi Di Roma La Sapienza
- Centro De Estudios E Investigaciones Tecnicas
- The Manchester Metropolitan University
- Politecnico Di Milano
- Kungliga Tekniska Hoegskolan
- Technische Universitaet Berlin
- Reseau Ferre De France Epic
- Network Rail Infrastructure Ltd
- Alma Consulting Group Sas
- "Construcciones Y Auxiliar De Ferrocarriles, S.A."
- Ingenieria Y Economia Del Transporte S.A.
- "Institut Francais Des Sciences Et Technologies Des Transports, De L'amenagement Et Des Reseaux"
- The University Of Huddersfield

IV.3 Objective and description

DynoTRAIN is part of the TrioTRAIN cluster of projects. TrioTRAIN, an acronym for Total Regulatory Acceptance for the Interoperable Network, is the common title given to a cluster of projects (three hence "Trio") dealing with key railway interoperability issues. The objective of these projects is to propose an innovative methodology that will allow multi-system network and route approval in Europe to become a faster, cheaper and better process for all involved stakeholders. Therefore the successful implementation of the TrioTRAIN cluster results will lead to:

- A time reduction for relevant parts of the certification process from 2 years to 6 months;
- An 80 % saving in effort for the acceptance of a new vehicle that has already been accepted in a previous country;
- An estimated potential financial saving of € 20- 50 Million per year.

Accordingly, the high level objectives of the DynoTRAIN project include:

- To improve cross-acceptance of track tests;
- To introduce Virtual Certification;
- To define track loading limits related to network access;
- To gain regulatory acceptance.

IV.4 Possible relevance

The expected main innovation shall be a new description of track geometry quality with a good correlation to the vehicle's response.

Appendix V. **INNOTRACK**

Analysis of major track cost drivers to reduce maintenance costs for sub-structure, track, S&C including LCC and logistics aspects.

V.1 Project details

Full title: INNOTRACK is the acronym for the EU Framework 6 collaborative research project: Innovative Track Systems

Started in 2006– ended in 2009

V.2 Partners

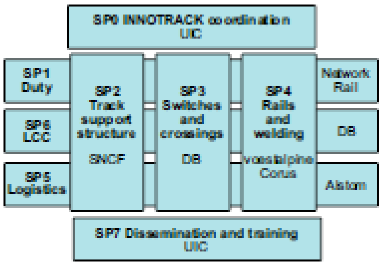
The project is executed by the following partners:

- Union Internationale Des Chemins De Fer UIC
- Banverket BV
- Administrador De Infraestructuras Ferroviarias ADIF
- Network Rail Infrastructure Limited NR
- Österreichische Bundesbahnen – Infrastruktur Bau AG OBB
- Reseau Ferre De France RFF
- Ceské Dráhy, A.S. CD Czech
- Association Of The European Railway Industries UNIFE
- European Federation Of Railway Track Work Contractors EFRTC
- Carillion Construction Ltd Carillion
- Voestalpine Schienen Gmbh VAS
- ALSTOM Transport SA ALSTOM
- Balfour Beatty Rail Projects Limited BBRP
- Goldschmidt Thermit Gmbh Goldschmidt
- Chalmers University Of Technology Chalmers
- Laboratoire Central Des Ponts Et Chaussées LCPC
- VOSSLOH COGIFER VCSA
- DB Netz AG DB
- SPENO INTERNATIONAL SA SPENO
- Railways Safety And Standards Board RSSB
- Delft University Of Technology (Technische Universiteit Delft) Tudelft
- PRORAIL BV PRORAIL
- Czech Technical University In Prague CTU
- Správa Železnicní Dopravní Cesty SZDC Czech
- Corus Corus United
- Société Nationale Des Chemins De Fer Français SNCF
- Damill AB Damill
- University Of Newcastle NCL
- University Of Southampton ISVR
- University Of Birmingham Uni Bham
- Manchester Metropolitan University MMU
- Universitaet Karlsruhe (TH) Unikarl
- G-Impuls Praha G-Impuls Praha
- VAE VAE Gmbh
- Contraffic GMBH Contraffic
- ARTTIC SA ARTTIC
- Tencate Geosynthetics

V.3 Objective and description

The INNOTRACK project has been a joint response of the major stakeholders in the rail sector – infrastructure managers (IM), railway supply industry and research bodies – to further develop a cost effective high performance track infrastructure by providing innovative solutions towards significant reduction of both investments and maintenance related infrastructure Life Cycle Costs Costs (LCC).

INNOTRACK was a unique opportunity and brought together rail IM's and industry suppliers and to concentrate on the research issues that has a strong influence on the reduction of rail infrastructure Life Cycle Cost (LCC).



The picture above shows the structure of INNOTRACK with three technical The three technical (vertical) sub-projects are:

- Track support structure;
- Switches and crossings;
- Rails and welding.

These sub-projects could be described as traditional technical projects. They are supported by three cross-disciplinary (horizontal) sub-projects:

- Duty and requirements

The aim of this subproject was first to identify current problems and cost drivers for the existing infrastructure. After the root causes had been identified, the project would propose innovative solutions in order to mitigate the problems. In the end of the project a technical

verification of technical solutions that had not been validated in the technical sub-projects was carried out. The aim was to deliver innovative solutions that were both technically and economically verified (see “Life cycle cost assessment”

below).This sub-project also had the responsibility to assess the overall potential cost reduction derived from the INNOTRACK solutions.

- Life cycle cost assessment

There were two ideas with this subproject. The first was to economically verify the innovative solutions to the technical problems. This was carried out with LCC and RAMS analyses. The second was to an Europe-wide accepted evaluation/develop process.

- Logistics

Here the potential for logistic improvements where identified and proposals for promising areas of improvement brought forward. Furthermore, the sub-project was responsible for a logistics assessment of derived technical solutions. Logistics should here be understood in a broad sense that incorporates aspects such as sourcing and contracting.

The INNOTRACK project is a joint response of the major stakeholders in the rail sector – IMs and the railway supply industry – for the development of cost effective high performance track infrastructure, aiming at providing innovative solutions towards significant reduction of both investments and maintenance of infrastructure costs.

INNOTRACK is a unique opportunity to bring together rail infrastructure managers (IM) and industry suppliers, the two major players in the rail industry, and to concentrate on the research issues that will contribute to the reduction of rail infrastructure Life Cycle Cost (LCC).

The EC White paper on Sustainable Transport called for rail operators to double passenger traffic & triple freight traffic by 2020 and reduce LCC by 30%.

The Railway Business Scenario 2020 also calls for railways to capture 15% of freight & 12% of the passenger market.

To achieve these objectives, investment alone was not sufficient, significant innovation and technology transfer was essential. This can only be achieved with very close cooperation between IMs and industry suppliers. It was essential that the IMs, as the end users, set out their priorities and needs, at a European Level, to solve the necessary problems for achieving the white paper objectives.

V.4 Possible relevance

The objectives were dread by performing research on four key topics:

- Track support structure;
- Switches and Crossings;
- Rails and welding;
- Duty and requirements;
- Logistics for track maintenance and renewal;
- LCC and RAMS.

To ensure that cost reductions can be consistently evaluated across Europe, INNOTRACK will also devise an innovative generic methodology for LCC calculation, based on best LCC practices at EU level, to be used by all IMs across Europe. For each of the research topics, INNOTRACK did:

- Analyse the root causes of identified issues on a European scale taking into account the effect of different duty conditions whilst providing product and service solutions for cheaper and longer lasting tracks;
- Provide innovative solutions to reduce failure rates and decrease LCC of material, equipment, machinery and systems;
- Draw together common European specifications regarding Reliability, Availability, Maintainability and Safety (RAMS) combined with LCC.

Finally, INNOTRACK has assurer a wide dissemination through UIC and UNIFE: two organisations representing Infrastructure Managers and industry.

Appendix VI. **INTEGRAIL**

Proposed approaches and demonstrators for intelligent communication infrastructure, including information system architecture and semantic data structure.

VI.1 Project details

Full title: INTEGRAIL is the acronym for the EU Framework 6 collaborative research project: INTElligent inteGration of RAILway systems

Started in 2005– ended in 2009

VI.2 Partners

The project is executed by the following partners:

- Unife
- Alstom
- Ansaldobreda
- Bombardier
- Siemens Ag
- D'appolonia
- Fav
- Deltarail
- Ansaldo Sts
- Caf
- Nortel Networks
- Laboratori G. Marconi
- Atos Origin
- Mermec
- Trenitalia
- Rfi
- Atoc
- Ceské Dráhy, A.S.
- Mav
- Unicontrols
- Strukton Railinfra
- Deuta-Werke Gmbh
- Heriot-Watt University
- Imec
- Offis, University Of Oldenburg
- Televic Nv
- Seebyte Ltd.
- Kontron Nv
- University Of Chile - Centro De Modeliamento Matematico
- Inrets
- Wireless Future
- University Of Birmingham
- Adif
- Corridor X
- Network Rail
- Prorail
- Sncf
- Uic
- Réseau Ferré De France
- Far Systems

VI.3 Objective and description

The European Rail Research Advisory Council (ERRAC) has proposed as a target for the year 2020 to double passenger traffic and triple freight traffic by rail. Such a goal should be achieved reducing costs and enhancing environmental sustainability, while at the same time keeping the present good safety level, compared to other modalities. InteGRail is part of the answer of railway research to ERRAC's challenge.

InteGRail is an Integrated Project, that is a research project addressing a wide number of coordinated objectives in a specific domain. The InteGRail project aims to create a holistic, coherent information system, integrating the major railway sub-systems, in order to achieve higher levels of performance of the railway system in terms of capacity, average speed and punctuality, safety and the optimised usage of resources. Building on results achieved by previous projects, InteGRail will propose new intelligent procedures and will contribute to the definition of new standards, in accord with EC directives and TSI's

VI.4 Possible relevance

Targets of INTEGRAIL are:

- Improve reliability by up to 50% for targeted systems by optimised maintenance;
- 30% availability improvement and irregularities reductions;
- Reducing maintenance costs by 10%;
- InteGRail could bring up to 5% increase in punctuality;
- Contribute to increased capacity in line with ERRAC objectives.

This targets are meeting the objectives of In2Rail.

Appendix VII. **INTERAIL**

Integrated high speed inspection system based on a modular design.

VII.1 Project details

Full Title: INTERAIL is the acronym for the EU Framework 7 collaborative research project: Development of a novel integrated system for the accurate evaluation of the structural integrity of rail tracks.

Started in 2009 – Ended in 2013

VII.2 Partners

The project is executed by the following partners:

- Instituto de Soldadura e Qualidade
- Technical Software Consultants Ltd
- MER MEC France
- Envirocoustics ABEE
- Société des Transports Intercommunaux de Bruxelles
- TWI Ltd
- National and Kapodistrian University of Athens
- Alfa Products and Technologies
- Tecnogamma Spa.
- Rede Ferroviária Nacional – REFER E.P.
- Feldman Enterprises Ltd.
- University of Birmingham
- Commissariat à l'Energie Atomique

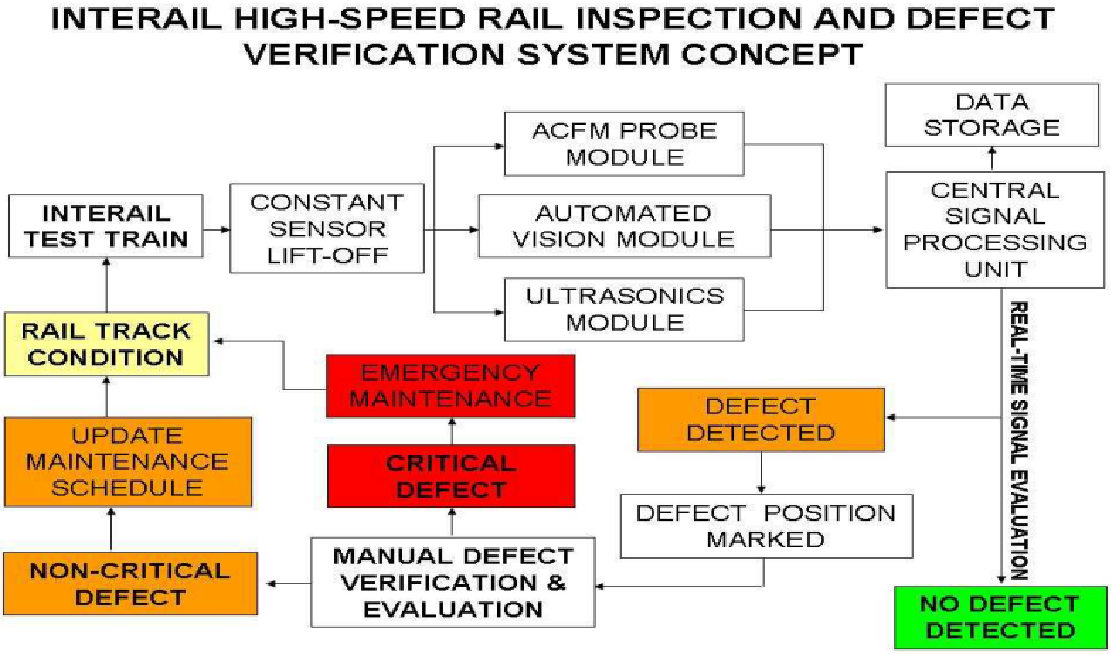
VII.3 Objective and description

INTERAIL aims at practically eliminating rail failures by developing and successfully implementing an integrated high-speed system for the fast and reliable inspection of rail tracks.

INTERAIL presents the following major objectives:

- To overcome the limitations of current inspection procedures of rail tracks through the successful implementation of an integrated high-speed inspection system based on automated visual, Alternated Current Field Measurement (ACFM) and ultrasonics techniques, combined in a single architecture;
- To develop advanced verification and evaluation procedures of the defects detectable by the high-speed system based on ACFM, ultrasonic phased arrays, and high-frequency vibration analysis equipment;
- To decrease inspection times and associated costs by up to 75% through the integration of three different rail track evaluation techniques that will complement each other as part of a functional single high-speed NDE;

- To develop the required software and intelligent control unit to enable automatic and real-time analysis of the defects detected and minimise human subjectivity during the interpretation and analysis of results;
- To contribute to the harmonisation of inspection procedures and network reliability across Europe.



Source: www.interailproject.eu

The major results from the project are:

- High speed Automated Inspection equipment integrating several NDT techniques;
- Intelligent software and control unit;
- Manual equipment for faster and efficient inspections;
- Reduction of costs, time and accident probability;
- Increase of POD and reduction of POF.

Training of operators and certification procedures.

VII.4 Possible relevance

This project has been identified as not relevant. Project overview included just for information and perhaps a second review later in the project.

Appendix VIII. **MAINLINE**

Life cycle assessment tool and findings regarding modern technologies for track, tunnels and bridges.

VIII.1 Project details

Full Title: MAINLINE is the acronym for the EU Framework 7 collaborative research project: MAINtenance, renewaL and improvement of rail transport INfrastructure to reduce Economic and environmental impacts.

Started in 2011 – Ended in 2014

VIII.2 Partners

The project is executed by the following partners:

- The International Union Of Railways (UIC)
- Network Rail Infrastructure Limited
- Deutsche Bahn
- MÁV Magyar Államvasutak
- TCDD
- TRAFIKVERKET
- COWI
- TWI
- COMSA
- SKANSKA
- Sinclair Knight Merz (SKM)
- University Of Surrey
- University Of Minho
- University Of Luleå
- Polytechnic University Of Catalonia
- Graz University Of Technology
- ARTTIC
- DAMILL
- SETRA

VIII.3 Objective and description

The objective of MAINLINE was to develop methods and tools contributing to an improved railway system by taking into consideration the whole life of specific infrastructure – tunnels, bridges, track, switches, earthworks and retaining walls.

The objectives were to:

- Apply new technologies to extend the life of elderly infrastructure;
- Improve degradation and structural models to develop more realistic life cycle cost and safety models;
- Investigate new construction methods for the replacement of obsolete infrastructure;
- Investigate monitoring techniques to complement or replace existing examination techniques;
- Develop management tools to assess whole life environmental and economic impact.

VIII.4 Possible relevance

The results of the project will enable a more effective planning of maintenance by the railway Infrastructure Managers (IMs). IMs will have access to new and improved renewal/strengthening/refurbishment solutions. MAINLINE will provide them also with an evaluation tool capable of accurately comparing cost-efficiency on a whole life basis, taking into account traffic situation, environmental criteria and economic criteria. In addition, the project will quantify the needs arising from emerging freight and passenger demands.

Appendix IX. **MERLIN**

Optimisation concepts and proposals for minimising energy demand.

IX.1 Project details

Full Title: MERLIN is the acronym for the EU Framework 7 collaborative research project: Sustainable and intelligent management of energy for smarter railway systems in Europe: an integrated optimisation approach

Started in 2012 – Ended in 2015

IX.2 Partners

The project is executed by the following partners:

- Unife
- CAF
- Adif
- ALSTOM
- Ansaldo Breda
- Ansaldo STS
- D'Appolonia
- FUNDACIÓN De Los FERROCARRILES ESPAÑOLES
- MERMEC Group
- Network Rail
- Altis Group
- Renfe
- Réseau Ferré De France
- RWTH AACHEN UNIVERSITY
- SIEMENS
- TRAFIKVERKET
- UIC
- Newcastle University

IX.3 Objective and description

MERLIN's main aim and purpose is to investigate and demonstrate the viability of an integrated management system to achieve a more sustainable and optimised energy usage in European electric mainline railway systems.

MERLIN will provide an integrated and optimised approach to support operational decisions leading to a cost-effective intelligent management of energy and resources through:

- Improved design of railway distribution networks and electrical systems and their interfaces;
- Better understanding of the influence of railway operations and procedures on energy demand;
- Identification of energy usage optimising technologies;
- Improved traction energy supply;
- Understanding of the cross-dependencies between technological solutions;
- Improving cost effectiveness of the overall railway system;
- Contribution to European standardisation (TecRec).

MERLIN outcomes will also be developed through the application of solutions to realistic scenarios.

Where MERLIN's results will be implemented, an overall reduction of the energy consumption of 10% is expected. MERLIN will contribute to the EU's aim of a more sustainable rail system and a reduction in CO2 via a more efficient use of energy resources.

IX.4 Possible relevance

This project has been identified as not relevant. Project overview included just for information and perhaps a second review later in the project.

Appendix X. **ON-TIME**

Open and common communication and data models based on open standards (e.g. railML developments) Common components and data flows between TMS building blocks and services.

X.1 Project details

Full Title: ON-TIME is the acronym for the EU Framework 7 collaborative research project: Optimal Networks for Train Integration Management across Europe

Started in 2011 – Ended in 2014

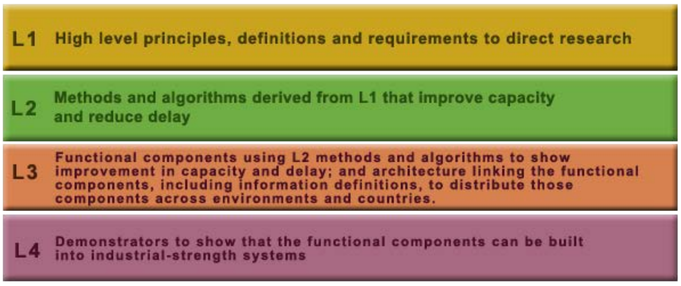
X.2 Partners

The project is executed by the following partners:

- D'appolonia Spa
- Network Rail Infrastructure Ltd
- Rete Ferroviaria Italiana
- Deutsche Bahn Ag
- Societe Nationale Des Chemins De Fer Francais
- Trafikverket – Trv
- Ansaldo Sts
- Ntt Data Italia S.P.A. (Formerly Value Team)
- University Of Birmingham
- Ecole Polytechnique Federale De Lausanne
- Erasmus Universiteit Rotterdam
- Institut Francais Des Sciences Et Technologies Des Transports, De L'amenagement Et Des Reseaux
- The University Of Nottingham
- Technische Universitaet Dresden
- Technische Universiteit Delft
- Alma Mater Studiorum-Universita Di Bologna
- Uppsala Universitet
- Graffica Ltd
- Transrail Sweden Aktiebolag

X.3 Objective and description

The ON-TIME project will develop new methods and processes to help maximise the available capacity on the European railway network and to decrease overall delays in order to both increase customer satisfaction and ensure that the railway network can continue to provide a dependable, resilient and green alternative to other modes of transport.



Source: www.ontime-project.eu

In the project, specific emphasis will be placed on approaches for alleviating congestion at bottlenecks. Case studies to be considered will include passenger and freight services along European corridors and on long distance main-line networks and urban commuter railways. The ON-TIME project envisages 4 levels of work:

The ON-TIME project formulated the next objectives:

- Objective 1: Improved management of the flow of traffic through bottlenecks to minimise track occupancy times. This will be addressed through improved timetabling techniques and real-time traffic management;
- Objective 2: To reduce overall delays through improved planning techniques that provide robust and resilient timetables capable of coping with normal statistical variations in operations and minor perturbations;
- Objective 3: To reduce overall delays and thus service dependability through improved traffic management techniques that can recover operations following minor perturbations as well as major disturbances;
- Objective 4: To improve the traffic flow throughout the entire system by providing effective, real-time information to traffic controllers and drivers, thus enhancing system performance;
- Objective 5: To provide customers of passenger and freight services with reliable and accurate information that is updated as new traffic management decisions are taken, particularly in the event of disruptions;
- Objective 6: To improve and move towards the standardisation of the information provided to drivers to allow improved real-time train management on international corridors and system interoperability; whilst also increasing the energy efficiency of railway operations;
- Objective 7: To better understand, manage and optimise the dependencies between train paths by considering connections, turn-around, passenger transit, shunting, etc. in order to allocate more appropriate recovery allowances, at the locations they are needed, during timetable generation;
- Objective 8: To provide a means of updating and notifying actors of changes to the timetable in a manner and to timescales that allows them to use the information effectively;

- Objective 9: To increase overall transport capacity by demonstrating the benefits of integrating, planning and real-time operations, as detailed in Objectives 1-8.

The overall aim of the proposed project is to improve railway customer satisfaction through increased capacity and decreased delays for passenger and freight. The ON-TIME project will develop new methods, processes and algorithms that will enable railway undertakings to significantly increase the available capacity.

X.4 Possible relevance

This project has been identified as not relevant. Project overview included just for information and perhaps a second review later in the project.

Appendix XI. **OptiRail**

XI.1 Project details

Full title: OptiRail is the acronym for the EU Framework 7 collaborative research project: Development of a smart framework based on knowledge to support infrastructure maintenance decisions in railway corridor.

Started in 2012 – will end in 2015

XI.2 Partners

The project is executed by the following partners:

- Vias,
- Cartif,
- Ltu,
- Ugr,
- Ostfalia,
- Sintef,
- Mermec,
- Evoleo,
- Adif

XI.3 Objective and description

The main objective targeted by the OPTIRAIL project aims at developing a new tool, based on Fuzzy and Computational Intelligence techniques and validated through two case studies (Sweden and Spain), that will enable the better cross-border coordination for decision making of railway infrastructure maintenance across the European railway corridors.

The developed smart maintenance management framework is based on SOA, open to any other ICT system, company or client. This Service Oriented Architecture is composed of:

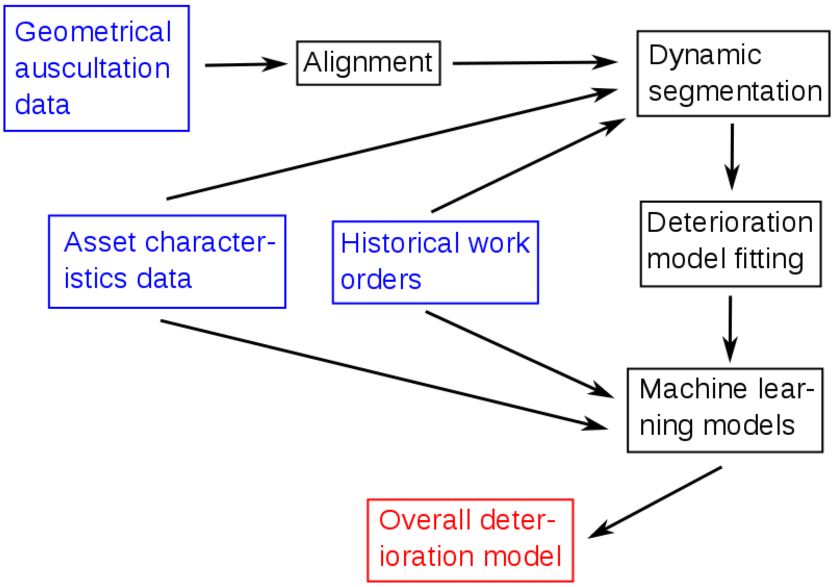
- Data service: Load/store, monitor and manage data from/to the database;
- Business service: Realise tasks based on tools with data gathered in data service;
- User service: Show the user the recommendations achieved in business service.

The possible inputs for the OPTIRAIL tool are:

- Historical geometrical condition data;
- Infrastructure data (asset characteristics), such as sleeper type and curvature;
- Available work order data.

The possible outputs are:

- Predictions of geometrical condition data (min, max, mean, sd);
- Thresholded predictions → prediction of need for interventions;
- Prediction of work orders.



Deterioration models processing steps

XI.4 Possible relevance

The main results relevant for In2Rail are:

- An open framework;
- Proposition of an OPTIRAIL index for Track quality (Time to next critical fault in the railway section);
- Dynamic segmentation of homogeneous sections based on curvature;
- Deterioration models based on geometrical auscultations;
- Methodology for modelling maintenance decisions from current auscultations was developed - Maintenance actions concern only tamping and renewal, based on auscultation data;
- Planning horizon of 3 years;
- Multi-objective optimisation for safety/quality of the track minimising cost and train delays, using the degradation model and the tamping effect model – No scheduling performed.

Appendix XII. **PM'n'IDEA**

Predictive maintenance methods for Metro and Light Rail Transport systems.

XII.1 Project details

Full Title: is the acronym for the EU Framework 7 collaborative research project: Predictive Maintenance employing Non-intrusive inspection and data analysis.

Started in 2009 – Ended in 2012

XII.2 Partners

The Project Is Executed By The Following Partners:

- Unife – The European Rail Industry
- Tata Steel
- Alstom Transport Sa
- Mer Mec S.P.A
- Tstg Schienen Technik Gmbh & Co. Kg
- D2s International
- Bytronic Automation Limited
- Manchester Metropolitan University
- Cranfield University
- Technische Universiteit Delft
- Politecnico Di Milano
- Stagecoach Light Rail
- Stib-Mivb
- Atac S.P.A
- Warsaw Tramways Ltd.
- D'appolonia S.P.A

XII.3 Objective and description

The project has two key drivers; firstly to contribute towards the realisation of a 24 x 7 railway by minimising the disruption caused by activities such as inspection, remedial and reactive maintenance, and track renewal. Secondly, the introduction of novel sensor and inspection technologies that focuses more on the monitoring of degradation through the measurement of deviation from identified benchmark data henceforth known as a "signature tune". Both these drivers promote the use of urban transport, and tramways in particular, which contributes to lowering congestion and the impact on the environment.

6 "Key Innovations" have been developed in the project, aiming at improving the integrity of urban rail transport networks through the deployment of intelligent design and sensor technologies into cost effective products and targeted non-intrusive monitoring processes

- Intelligent image acquisition & analysis techniques for undertaking objective track inspection;
- Laser sensors dimensional measuring system with on-board diagnostics;
- Assessment of internal integrity of embedded rails;

- Inspection technologies for the assessment of track quality,
- A scientifically validated methodology for establishing actionable boundary limits for the wear of rails;
- Automatic assessment of degradation and the integrity of intelligent track components.

The major results from the project are:

- Application of intelligent image acquisition and analysis techniques for as much of the track system and its environment currently inspected by manual means;
- Development of an inspection system for the assessment of internal integrity of street running grooved rail sections;
- Development of methodologies to measure the deviation of track quality from identified “signature tune” of the segments;
- Establishing the criteria for assessing the structural integrity of grooved rail sections embedded in street running sections of tramway networks;
- Development of techniques for the automatic assessment of the degradation and integrity of track sub-components.

XII.4 Possible relevance

This project has been identified as not relevant. Project overview included just for information and perhaps a second review later in the project.

Appendix XIII. **RAILENERGY**

Calculation methods and simulation models for rail power supply systems.

XIII.1Project details

Full Title: RAILENERGY is the acronym for the EU Framework 6 collaborative research project: Innovative integrated energy efficiency solutions for railway rolling stock, rail infrastructure and train operation

Started in 2006 – Ended in 2010

XIII.2Partners

The project is executed by the following partners:

- Alstom
- Ansaldo-Breda
- Bombardier
- Siemens
- Unife
- Corys G
- Faiveley
- Saft
- Rca
- Rfi
- Trafikverket
- Trenitalia
- Uic
- D'appolonia
- Emkamatik
- Enotrac
- Izt
- Sciroidea
- Tfk
- Transrail
- Fav
- Ist
- Kth
- Nitel
- Veri
- Výzkumný Ústav Železniční
- Adif
- Atoc
- Cd
- Deutsche Bahn Ag
- Dsb
- Ns
- Nsb
- Pkp
- Renfe
- Sbb
- Sncb
- Sncf

XIII.3Objective and description

Railenergy is bringing awareness and understanding of the implications of railway energy issues. A toolkit is developed for railway professionals dealing with energy efficiency – whether from a technical, operational, economic, or strategic point of view.

Railenergy serves as a platform for an integrated development of new methodologies, techniques and technologies. Within this system framework approach the outputs of the Railenergy project are:

- Relevant baseline energy consumption figures and scenarios for selected reference systems;
- System-based concept for modelling energy consumption;
- Common and standardised methodology to determine energy consumption by rail sub-systems and components in the development and procurement phases (TecRec 100_001);
- Integrated railway energy efficiency Calculator & decision support tool;
- Strategic energy efficiency recommendations for rolling stock, infrastructure and traffic management;
- New validated energy efficiency-oriented railway technologies for trackside and on-board sub-systems and equipment, developed in compliance with the new integrated approach;
- Refined best practices for Railway Operators and Infrastructure Managers;
- Incentives framework.

XIII.4Possible relevance

This project has been identified as not relevant. Project overview included just for information and perhaps a second review later in the project.

Appendix XIV. **SAFTInspect**

Developing intelligent track self inspecting equipment; capable of mechanically and electronically compensating for wear, automatically reducing inspection and maintenance time and costs.

XIV.1 Project details

Full Title: SAFTInspect is the acronym for the EU Framework 7 collaborative research project: Ultrasonic Synthetic Aperture Focusing Technique for Inspection of Railway Crossings (Frogs)

Started in 2012 – Ended in 2014

XIV.2 Partners

The project is executed by the following partners:

- Twi
- Precision Acoustics
- Microtest, S.L
- Airtren, S.L.
- Performance In Cold
- Trafikverket
- Luleå University of Technology

XIV.3 Objective and description

SAFTInspect aims to develop an affordable and reliable ultrasonic inspection solution for sections of high manganese steel rail crossing points, which are used in the European railways. A non-destructive testing (NDT) inspection solution will be developed in the project to facilitate early defect detection of crack defects at safety critical locations.

Within the project a novel array transducer working in a synthetic aperture focusing technique (SAFT) inspection mode will be developed. This novel design will enable efficient acquisition of data for SAFT processing. SAFT post-processing will generate 2 and 3D reconstructions of the ultrasonic volumetric image to produce a simple pass or fail indication for the user. If defects such as cracks are detected at an early stage in their growth, their structural integrity can be monitored and assessed, resulting in less stringent speed restrictions, increased asset lifecycle and improved levels of track safety and reliability.

The project results will increase industrial confidence in NDT by achieving better quality levels in the identification, classification and sizing of defects compared to existing techniques. The automated output will increase efficiency and reduce scanning mistakes associated with manual methods. The rapid, automated solution will reduce time required for personnel to be located in potentially hazardous environments. This will provide NDT workers with safer, healthier and better working conditions in European industry related inspection and maintenance activities.

XIV.4 Possible relevance

This project has been identified as not relevant. Project overview included just for information and perhaps a second review later in the project.

Appendix XV. **SMART RAIL**

Complimentary to MAINLINE with a life cycle assessment tool for other structures.

XV.1 Project details

Full Title: SMART RAIL is the acronym for the EU Framework 7 collaborative research project: Smart Maintenance and Analysis of Transport Infrastructure.

Started in 2011 – Ended in 2014

XV.2 Partners

The project is executed by the following partners:

- University College Dublin, National University of Ireland
- Slovenske Zeleznice DOO
- Forum of European Highway Research Laboratories (FEHRL)
- EURNEX e.V.
- Institut IGH DD
- Zavod Za Gradbenistvo Slovenije (ZAG)
- Roughnan & O'Donovan Limited
- Adaptronica ZOO SP
- Technische Universitaet Muenchen
- Instytut Kolejnictwa
- The University of Nottingham
- HZ Infrastruktura D.O.O.
- Iarnrod Eireann
- De Montfort University
- University of Twente
- Austrian Institute of Technology
- National Technical University of Athens
- Ecole Polytechnique Fédérale de Lausanne
- Centrum Dopravniho Vyzkumu
- Transport Research Laboratory
- Swedish National Road and Transport Research Institute
- Riga Technical University
- Moscow State University of Railway Engineering

XV.3 Objective and description

This SMARTRAIL project aims to bring together experts in the fields of rail and road transport infrastructure to develop state of the art inspection; monitoring and assessment techniques which will allow rail operators manage ageing infrastructure networks in a cost-effective and environmentally friendly manner.

XV.4 Possible relevance

In order to achieve its stated objectives the SMARTRAIL project is clearly structured in four content-orientated work packages (WP1-4), two work packages for project management, (one for administrative and one for scientific management, termed WP6 and WP7, respectively) and one for dissemination and exploitation (WP5). WP’s 1-4 address the core issues of measuring the current state of infrastructure (WP1), quantifying its safety (WP2), implementing remediation strategies where required (WP3) and assessing the economic and environmental costs (WP4).

Appendix XVI. **SUSTAINABLE BRIDGES**

Bridge inspection, assessment, monitoring and measurement methods.

XVI.1 Project details

Full Title: SUSTAINABLE BRIDGES is the acronym for the EU Framework 6 collaborative research project: Assessment for Future Traffic Demands and Longer Lives.

Started in 2003 – Ended in 2007

XVI.2 Partners

The project is executed by the following partners:

- Skanska, Coordinator, Swedish
- Network Rail Infrastructure Ltd
- Banverket, Swedish National Rail Administration
- Bundesanstalt Fuer Materialforschung Und -Pruefung
- Cowi A/S
- Eidgenoessische Materialpruefungs- Und Forschungsanstalt
- Lulea Tekniska Universitet
- Laboratoire Central Des Ponts Et Chaussees
- Kortes
- City University
- University Of Salford
- Swedish Geotechnical Institute
- Sto Skandinavia Ab
- Designtech Projektsamverkan Ab
- Vaegverket - Swedish National Road Administration
- Deutsche Bahn Ag
- Universitaet Stuttgart
- Rheinisch-Westfaelische Technische Hochschule Aachen
- Norut Teknologi A.S.
- Ecole Polytechnique Federale De Lausanne
- Chalmers Tekniska Hogskola Ab
- University Of Oulu
- Finnish Rail Administration
- Finnish Road Administration
- Societe Nationale Des Chemins De Fer Francais
- Universidade Do Minho
- Universidad Politecnica De Catalunya
- Pkp Polskie Linie Kolejowe Sa
- Vladimir Cervenka - Consulting
- Kungliga Tekniska Hoegskolan
- Lunds Universitet
- Wroclaw University Of Technology

XVI.3 Objective and description

Sustainable bridges is a project which assesses the readiness of railway bridges to meet the demands of the 2020 scenario and provides the means for up-grading them if they fall short. The 2020 scenario requires increased capacities with heavier loads to be carried and bigger forces to be absorbed due to longer faster trains and mixed traffic. All type of bridges are being considered.

The main objectives of the project are to:

- Increase the transport capacity of exisiting bridges by allowing axle loads up to 33 tonnes for freight traffic with moderate speeds;
- Increase the residual lifetime of existing bridges with up to 25 %;
- Increase the capacity for passenger traffic with low axle loads by increasing the maximum speeds to up to 350 km/hour;
- Enhance strengthening and repair systems.

The intention is to develop a “toolbox” of new systems and methods for assessment, strengthening and monitoring of the European railway bridges. A new generation of methods that can be directly applied by the railway owners, by consultants and by contractors, will be presented and demonstrated ensuring the safe and proper behaviour of the bridges for new and higher demands.

XVI.4 Possible relevance

This project has been identified as not relevant. Project overview included just for information and perhaps a second review later in the project.

Appendix XVII. **SUSTRAIL**

Optimised track and substrate design and component selection to increase sustainable freight traffic as part of mixed traffic operations.

XVII.1 Project details

Full Title: SUSTRAIL is the acronym for the EU Framework 7 collaborative research project: "The sustainable freight railway: Designing the freight vehicle – track system for higher delivered tonnage with improved availability at reduced cost".

Started in 2011 – Ended in 2015

XVII.2 Partners

- Consorzio Per La Ricerca E Lo Sviluppo Di Tecnologie Per Il Trasporto Innovativo – Train
- Network Rail Infrastructure Ltd – Nr
- National Railway Infrastructure Company – Nric
- Administrador De Infraestructuras Ferroviarias – Adif
- Bdz - Tovarni Prevozi Eood – Bdzeood
- Lucchini Rs Spa
- Kes Gmbh
- Mer Mec Spa
- Gruppo Clas Srl – Gclas
- Marlo As
- Autoritatea Feroviara Romana
- Damill Ab
- Tata Steel Uk Limited
- Ecoplan Mueller, Neuenschwander, Sommer, Suter & Walter – Ecoplan
- Higher School Of Transport - Todor Kableshkov
- University Of Newcastle Upon Tyne – Unew
- Lulea Tekniska Universitet
- Technische Universitat Berlin – Tub
- University Of Leeds – Unileeds
- The University Of Sheffield – Usfd
- Universidad Politecnica De Madrid – Upm
- Kungliga Tekniska Hoegskolan – Kth
- Politecnico Di Milano – Polimi
- Petersburg State Transport University – Spt
- Georgian Technical University – Gtu
- Union Internationale Des Chemins De Fer – Uic
- Union Des Industries Ferroviaires Europeennes – Unife
- Societatea Comerciala De Intretinere Si Reparatii Vagoane De Calatori Cfr-Sirv Brasov Sa – Sirv
- Kes Keschwari Electronic Systems Gmbh & Co Kg – Kes
- Holding Bulgarian State Railways Ead – Bdzead
- University Of Huddersfield - Uoh

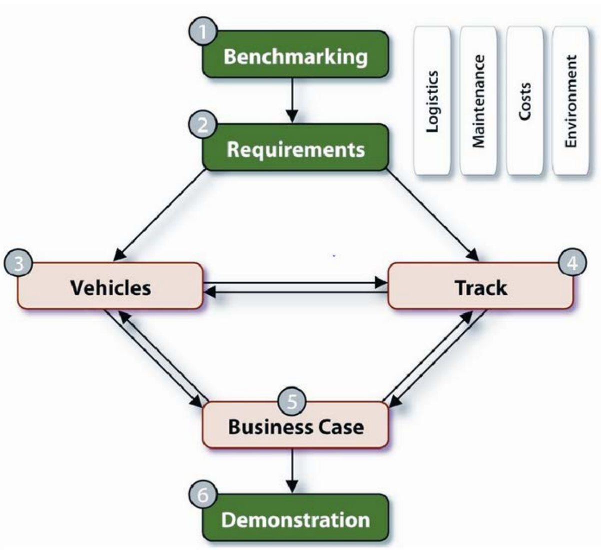
XVII.3 Objective and description

The SUSTRAIL objective is to contribute to the rail freight system to allow it to regain position and market. The project provides the approach, structure, and technical content to improve the Sustainability, Competitiveness, and Availability of European railway networks thanks to an integrated approach.

XVII.4 Possible relevance

The main targets of SUSTRAIL, which have relevance with the In2Rail objectives, are:

- Advanced condition based predictive maintenance tools for critical components of both railway vehicles and the track;
- Identification of performance based design principles to move towards the zero maintenance ideal for the vehicle/track system;
- Optimisation of the ballast system and novel ground stabilisation and monitoring techniques to reduce track geometry degradation;
- Optimisation of the track system and geometry, including switches and crossing.



Source: www.sustrail.eu