



# NEEDS TAILORED **INTEROPERABLE** RAILWAY INFRASTRUCTURE

# NeTIRail

Needs Tailored Interoperable Railway Infrastructure

## **Deliverable 1.2**

## **Database of economic data on case study lines**

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## Executive Summary

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The overall purpose of NeTIRail-INFRA is to identify interventions that will reduce costs for maintaining railway lines as well as improve quality of services. More specifically, the idea is to identify interventions that will reduce costs for infrastructure condition monitoring and maintenance at the same time as overall performance is improved. The first task (T1.1) in WP 1 – Contrasting market needs, and business case – was to select case study lines which fit the three line categories set out in the application. These are busy capacity limited passenger railway; under-utilised rural/secondary lines; and a freight dominated route. Seven case study lines were selected that fit these three line categories from countries with industry representation in NeTIRail-INFRA (Romania, Turkey and Slovenia).

The present deliverable concerns task T1.2. The purpose of this task is to start identifying and collecting relevant economic information about the selected case study lines. As noted in the description of work, the data needed for assessing the impact on costs as well as on reliability, capacity and the environment will be in focus for the relevant technical work packages. T1.2 therefore primarily identifies the nature of the interventions addressed in WP2, WP3 and WP4. Based on this description, the need for economic information and related data is specified. In addition, collection of information about demand (number of users etc. on the case study lines) has been initiated. This is an important statistic for computing user benefits of technical infrastructure improvements.

The collection of demand data has proceeded according to plans. There is, however, still some scope for improving the understanding of the precise interventions that are being considered in each technical work package. This must then be combined with a mutual understanding of the type of information about costs and related information, such as interventions, delays and failures that will be needed in order to implement a comprehensive understanding of the impact of each intervention. Ultimately, such information will be required if we are to demonstrate the overall net benefit of the innovations and thus establish the business case.

The production of D1.2 has generated a strategy for closing this gap: As part of WP1, an example database has been produced that comprises data from another country (Sweden). This template will be used in the next phase of to communicate requirements within the consortium and to identify similar information for each case study line.

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## 1. Introduction

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The overall purpose of NeTIRail-INFRA is to develop interventions that will reduce costs for monitoring and maintaining railway lines as well as to improve quality of services. Several different interventions are addressed in three different Work Packages; WP 2, WP 3 and WP 4.

The first task (T1.1) in WP 1 – Contrasting market needs, and business case – was to select case study lines which fit the three line categories set out in the application. These were; busy capacity limited passenger railway; under-utilised rural / secondary line; and a freight dominated route. Case studies have been selected that fit the three line categories from the countries with industry representation (Romania, Turkey and Slovenia). See Deliverable D1.1 (NeTIRail-WP1-D1.1-PU-v1.1-FINAL).

The present deliverable concerns task T1.2. The purpose of this task is to start identifying and collecting relevant economic information about the selected case study lines. As noted in the description of work, the data needed to assess the cost impacts and also the effects on reliability, capacity and the environment will be collected in the relevant technical work packages. The focus of T1.2 has therefore been on identifying the nature of the interventions addressed in WP2-WP4 from a perspective of economic evaluation. Based on a detailed understanding of how each innovation will affect the industry, the need for economic (cost and demand) information and related data has been specified. In addition, collection of information about demand (number of users etc. on the case study lines) has been initiated. This is an important statistic for computing user benefits of technical infrastructure improvements.

The lead partner in this task is VTI with ULEEDS, UIC, AFER, INTADER, SZ, RCCF as partners. VTI coordinates the work to identify information requirements in order to assess the viability of the different types of improvement on each case study line. The eventual outcome from this task is a database comprising technical and economic information about case study lines. Using this information, task 1.3 within WP 1 will be concerned with developing a strategic, top-down cost model that estimates the impact of the relevant technologies on whole life costs, drawing on the detailed cost assessment work undertaken within each of WP2-WP4. This will then be combined with a quantification of user benefits.

The idea behind WP1 is thus to establish the business case for the technical innovations, i.e. to formulate an analytical framework for demonstrating that new gadgets, techniques or new information made available are financially and/or economically viable. To do so, information must be provided about both the "do nothing" (or baseline) and the "do something" (or treatment) scenarios. This includes costs for maintenance and (re-)investment as well as information about the current reliability of the case study lines and how that may change with the technical improvements. Overall then, the information highlighted in this task will provide the basis for the cost model and for assessment of the impact of interventions on key measures such as reliability, capacity and the environment.

This deliverable reports the current situation with respect to data collection. We set out the specific nature of each intervention and the data needs on demand, cost and other metrics described above. For obvious reasons, data collection has only been initiated for the current situation, generating some data related to the "do nothing" alternative in the subsequent analysis. A comprehensive

understanding of the possible cost savings and other benefits as a result of the respective interventions will not be available until after the conclusion of WP2, WP3 and WP4.

To be more specific, Section 2 gives a coherent presentation of demand data while Section 3 details the interventions considered in the three work packages and the information about costs and technical qualities that needs to be collected. Section 4 concludes. Appendix A describes how information about the network and about costs is stored in Sweden, thereby providing an example of how information that must be available for the subsequent analysis can be compiled.

## 2. Demand data

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This section summarises the current state of the data collection for the demand analysis. Technical innovations will affect maintenance costs and line performance in different ways. The same number of passengers using each case study lines will however be affected, irrespective of which precise technical innovations that are considered. This is the reason for presenting the identification and collection of demand data in a separate section.

One component of the analysis of current and future demand concerns the number of freight and passenger trains using each case study line. This will also provide the platform for providing an understanding of the capacity situation. In combination with technical information about the signalling system and the number of instances on single-track lines where meetings and over-taking is feasible, it will be straight-forward to relate demand to capacity. To the extent that technical improvements will affect ridership and the number of trains on each line, it will thus be feasible to assess whether capacity shortages will result.

We start by presenting the overall framework of passenger demand modelling in Section 2.1 while the current state of data collection is described in Section 2.2.

### 2.1 Passenger demand modelling

Transport interventions (such as the NeTIRail-INFRA technological innovations in the railway) provides two types of benefits; lower costs for maintenance and better conditions for users. To quantify and measure user benefits, it is necessary to understand the current state of the demand of the train lines analysed. Based on a clear understanding of the current situation, it is feasible to forecast future situations with and without the innovations. To achieve this goal, some form of demand analysis tool is needed. The selected tool for this project is the PRAISE (Privatised Rail Services) demand model developed at the Institute for Transport Studies, University of Leeds (Whelan et al, 1997, Preston et al, 1999, Whelan, 2002).

#### 2.1.1 PRAISE Outline

In order to undertake this analysis, an implementation of the PRAISE rail forecasting model suggested by Johnson and Nash (2008) will be used. PRAISE forecasts rail demand between Origin-Destination (OD) pairs on a network as well as for individual services and ticket type, taking account of fares, journey times, desired departure times and possibly overcrowding. The tool is useful for considering different aspects of competition and for analyzing the impact of capacity shortages on demand. It can also be used for forecasting the impact on demand as well as estimating the benefits of service improvements.

There are four stages to the calibration of the demand model.

- Estimation of the generalized cost of travel for each service and ticket combination.
- Calibrating ticket specific constants to ensure that the base market shares can be replicated.
- Setting the sensitivity of the model to replicate known elasticities of demand.
- The final stage iterates to adjust for overcrowding on trains (may be skipped).

An upper level of the model scales overall changes in rail demand following service level changes based on generalized journey time or cost. The package also includes a model for considering

operator costs, using a cost accounting approach. This facilitates the incorporation of costs that are related to operating hours, costs that are related to train kilometers and fixed costs in the analysis.

PRAISE yields results for changes in consumer surplus, operating profits, modal switch values and vehicle kilometers, which can be used in conjunction with external cost valuations to undertake an appraisal.

### 2.1.2 Data Requirements.

#### *OD level data*

1. Demand and revenue information (for a typical weekday) for each OD pair on the network. Ideally this will be by class of travel and by ticket type (e.g. full, reduced, season).
2. The model uses 'desired departure time profiles' to generate desired departure times for each simulated individual for each OD pair. These help to allocate simulated individuals on services to mirror patterns of loadings on specific services throughout the day. These have been based on service types (eg Long distance service from Large station to small station) in previous applications.
3. Ideally, information on actual passenger loadings (or ticket sales) on specific services throughout the day would be obtained. This might be used to proxy for the above if absent.
4. Breakdown of journey purpose of passengers (ideally by OD), in order to determine an appropriate value of time for each simulated individual

#### *Network Level values/parameters*

5. Generalized Journey Time or Cost Elasticities – these more aggregate, network level parameters are usually based on previous Revealed and Stated Preference research.
6. Values of time and adjustment time will also be taken from previous Revealed and Stated Preference research.
7. Crowding Penalty valuations, when used, are required in pence per crowded minute of journey, varying by route, and degree of crowding. It will be based on average costs per train km.

Without some form of 1 and some understanding of loadings via 2 and/or 3 modelling using PRAISE will be overkill and a more simplistic aggregate direct demand approach would be required. This would be a lot broader brush and may not deal with issues around differential impacts by peak/off-peak and journey class and purpose and ticket type. Outputs from PRAISE readily lend themselves to inclusion in appraisal (e.g. consumer surplus).

An on board survey may help plug some data gaps such as 2-4 (see reference to the D5.1 survey plans under 3.2 below). Values from 5-8 might be available or adapted from previous research (possibly from countries other than the NeTIRail-INFRA case studies).

## 2.2 Current state of data collection

The data requests have been made keeping the final aim in mind: running the PRAISE demand model. Hence, the efforts to obtain the necessary inputs for the model. Several spreadsheets have been generated: a generic one, showing the variables and data needed for the model in the appropriate format (i.e. replicating an existing study that implemented PRAISE in the UK), and seven specific versions, each tailored to include the details of each of the rail lines.

In short, in relation to passenger transport, the following information has been requested:

- Number of passengers (per OD pair)
- Ticket prices (by types of tickets)
- Revenue
- Distances (between each OD pair)
- Timetables

The following data will be obtained through the surveys conducted (the pilot survey in June and the final survey in October; for more details, the survey plans are described in D5.1):

- Purpose of travel (commute, leisure, business...)
- Experience/Perception/Valuation of travel time reliability (this is a critical factor for NeTIRail-INFRA, and the PRAISE model will be extended to account for the role of reliability in demand).

Other inputs of the PRAISE model, such as elasticities of demand and values of time, will be obtained from the existing literature or making use of existing European meta-analysis models in the relevant areas.

Note that the above applies to passenger transport. For freight transport, a different model (other than PRAISE) will be used. Data has been requested on:

- Tonnes.km and train.km (freight transport)
- Prices or revenue per tonne.km (freight transport)

No surveys are planned in relation to freight transport.

Table 1 summarises what data is already available for each case study. The word 'PART' indicates that data have been received but the format in which the data is available is not directly applicable as an input of the PRAISE demand model (e.g. data are not provided at the OD pair level), and further work is required to assess whether and how it can be transformed in an appropriate way. Therefore, this is still work in progress: in some cases, the partners and ourselves are still involved in active communication to improve the data availability; in other cases, the data is ready but it is up to us to find out to what extent we will be able to use/transform the data to generate the necessary inputs for the PRAISE model.

When this deliverable is concluded, ITS representatives will continue to be in regular communication with the partners in relation to demand data collection. Therefore, it is expected that the amount and quality of the data available will be further improved. Data will gradually be updated and is available for all NeTIRail-INFRA participants (with access to the NeTIRail-INFRA online file manager) and the Commission officer at the following link, within WP1 folder:

<http://workspace.netirail.eu/index.php?tg=fileman&idx=list&id=1051&gr=Y&path=NeTIRail+Documents>

Table 1: Current status of demand data availability for each case study.

Category	Detail within category	Slovenia			Turkey			Romania
		Busy	Under Used	Freight	Busy	Under Used	Freight**	Under Used
Number of passengers (per OD pair)		PART	PART	PART	NO*	PART	PART	YES
	<i>at OD pair level</i>	PART	PART	PART	NO	NO	NO	YES
	<i>by ticket type</i>	NO	NO	NO	NO	NO	NO	YES
Ticket prices (by ticket types)		YES	YES	YES	PART	PART	PART	YES
Revenue		PART	PART	PART	PART	PART	PART	PART
Distances (between each OD pair)		YES	YES	YES	YES	YES	YES	YES
Timetables		YES	YES	YES	YES	YES	YES	YES
Freight quantities		NO	NO	NO	YES	PART	PART	PART
Freight prices/revenues		NO	NO	NO	YES	PART	YES	PART

\*Only the total for the whole line

\*\*Note: line potentially shorter (Fevzi Pasa instead of Iskenderun)

### 3. Interventions and cost data requirement

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This section reports about the interventions considered by each Work Package as well as which information is required for the economic analysis.

#### 3.1 WP 2 - Tailored track infrastructure, design and maintenance

##### 3.1.1 The objectives of WP2

The overall purpose of WP2 is to develop tailor made track infrastructure solutions for improved, cost efficient and sustainable rail track infrastructure. It comprises six tasks with the following objectives:

1. Reveal the real underlying drivers of cost and maintenance for track through combining maintenance data with GIS mapping techniques.
2. Develop track specifications suitable for busy passenger, low density rural/secondary line, and a freight dominated route.
3. Apply lean and automotive industry techniques to railway switches & crossings (S&C) to achieve a step change in life and costs
4. Achieve track life extension through prevention of rail corrugation
5. Specify lubrication regimes suited to route type and climate, taking into account environmental impact of lubricants.
6. Design a new and more cost effective transition zone to avoid sharp changes in track vertical stiffness that are known to drive dynamic loading leading to many track defects.

##### 3.1.2 The interventions in WP 2

A first task of WP 2 is to improve the management of railway switch and crossing (S&C) life and costs. Based on an understanding of existing S&C failure and performance, opportunities for performance improvement at different stages will be considered. This includes the design of new equipment as well as installation, operation and maintenance.

The purpose of a second task is to identify clips and pads that avoid, reduce or delay corrugation and to do so for different traffic loads. One part is to estimate the development mechanism of short pitch rail corrugation. This provides the backdrop for understanding under which conditions corrugation grows and for finding means to reduce growth. The analysis will be validated by field observations and measurements as well as experimental testing. Moreover, experiments will seek to determine contact forces, as well as vibrating regime of the rail and various forms of pads and clips will be tested in order to evaluate the impact on corrugation.

A further task for establishing ways to reduce corrugation is to get a better understanding of the fastening system in order to develop a model that accounts for the most relevant parameters. A sensitivity analysis of the fastening parameters on vertical track dynamics (unloaded track) will therefore seek to identify the relevance of vibration frequency, temperature, toe load, rail pad type and rail pad aging for rail pad dynamic properties, and consequently, for track vibrations. Next,

simulations of a vehicle-track model (loaded track) with different pad and clips seek to select the pad and clips that will be tested in the field for experimental testing.

The idea of this task is to look for ways to reduce the Life Cycle Costs of railway maintenance with focus on the choice between different fastenings: Could LCC be reduced by way of implementing a new way of fastening rails? Is it feasible to establish that one means for fixing the rails that is already in use in some country(-ies) is superior to the other(s)?

The purpose of a third task is to identify clips and pads that avoid, reduce or delay corrugation and to do so for different traffic loads. One part of this task is to estimate the development mechanism of short pitch rail corrugation. This provides the backdrop for understanding under which conditions corrugation grows and for finding means to reduce growth. The analysis will be validated by field observations and measurements as well as experimental testing. Moreover, experiments will seek to determine contact forces, as well as vibrating regime of the rail and various forms of pads and clips will be tested in order to evaluate the impact on corrugation.

A crucial component of this task is to develop a better understanding of the fastening system in order to develop a model that accounts for the most relevant parameters. A sensitivity analysis of the fastening parameters on vertical track dynamics (unloaded track) will therefore seek to identify the relevance of vibration frequency, temperature, toe load, rail pad type and rail pad aging for rail pad dynamic properties, and consequently, for track vibrations. Next, simulations of a vehicle-track model (loaded track) with different pad and clips seek to select the pad and clips that will be tested in the field for experimental testing.

A fourth component of WP 2 is to research and test effective rail-wheel lubrication and suitability of it for different traffic density and weather conditions. The output of this research is therefore an indication of the best type of lubrication to use for low and high density lines and the choice of lubrication system (on-board or track side) for different traffic densities

The idea is to look for ways to reduce the Life Cycle Costs of railway maintenance from the perspective of lubrication. In order to avoid waste, it is important to determine how much lubrication is required for different types of curve sections. Cost efficient lubrication will reduce maintenance costs for both tracks and train wheels. In the same way as for the other interventions, this may contribute to improvements in train reliability by reducing track unavailability. It may also extend the rail grinding intervals and reduce profile changes in rail and wheel profiles, in particular under extreme weather (hot and humid) conditions. The baseline data should therefore include current costs for the maintenance and replacement. The current costs are used to develop representative costs.

The final task of this WP is to design a cost effective transition zone. The background to this work is that the transition zones between ballasted tracks and other structures such as bridges is an expensive part of a new line since it involves costly earthworks and complicated designs to form the transition. Transition zones also require frequent maintenance activities. The current understanding of the relationship between transition zone design and costs is inadequate. Traditionally, the solution to problematic transition zones have included extensive rehabilitation of the ground works and costly modifications of the transition zone substructure. One in-expensive way to reduce these cost could be to modify sleepers.

The key LCC perspective of this innovation is therefore to reduce cost for both installation and maintenance. The baseline data should therefore include current costs of constructing transition zones and current maintenance costs. Transition zone maintenance costs can vary significantly between different cases, where some particular transition zones are known to be problematic. Maintenance cost data should therefore be gathered from a significant sample of transition zones to develop representative costs. New solutions may also improve passenger comfort as well as train reliability (reduced numbers of speed restrictions/cancellations due to track geometry issues). The reduced need for maintenance should also free up capacity for increase numbers of passenger and freight train paths.

### 3.1.3 Cost data needed for analysis of WP 2

In order to estimate the consequences of the types of interventions considered, comprehensive information about the infrastructure is necessary. This includes a specification and enumeration of the following items:

1. Switches & Crossings
2. Clips and pads
3. Means for lubrication
4. Design of transition zones

For all enumerated items, there is also needs for

5. The annual maintenance cost, and
6. the information about the failure mode and failure frequency for each.

In addition, historic data of S&C failures is needed, including

7. Date
8. Place
9. Type
10. Faulty component
11. Cause
12. Loss
13. Reparation process

In order to understand asset life, and how that might in turn change with the innovations, there is need for information about the following items:

14. The current /historic frequency of major replacements for Switches & Crossings,
15. The current age of the relevant technical components as well as the cost of replacement of the relevant technical components.

All the above is related to the infrastructure. Since several train delays may originate from breakdowns of the above items, there is also need for data on:

16. Frequency of train delays emanating from infrastructure related maintenance and failures and associated RAMS data for the failures such as Mean Time to Maintain or Mean Time to Repair
17. Length of train delays

Another important data requirement concerns the capacity on the different case study lines, i.e.

18. How close to capacity is a line and what consequences may this situation have for the different interventions?
19. Is the need for track possessions for maintenance a current constraint with respect to capacity?

Finally, the analysis may require information about climate conditions, e. g. prevalence of sand, rainfall, and the possible implications on train delays from these features.

The type of information set out above will be needed for each specific case study line. It is, thus, important to avoid, where possible, an average of costs over the whole network, or some subset thereof in each country. However, to the extent that this disaggregate information is not available, it may be necessary to use an average cost per maintenance or repair task and then scale this to the number of incidents on the case study lines.

### 3.1.4 Currently available information

Some work with data capture has already been done and reported. Deliverable 2.1 (NeTIRail-WP2-D2.1-PU-v1.0-FINAL) reports several features of the rail infrastructure. The aim of D2.1 is to identify the type of geographic railway information available at level of country partners involved in this task. It also reports about costs for maintenance and number of failures at the railway and region level. This means that at least some information required for T1.2 could be derived from this source. However, further and more detailed data is required to fulfil the requirements of T1.2 (see Appendix A). The main reason is that the data needed may not exist or that infrastructure managers in the three countries where the case studies are located have not yet been able to provide the data.

The following information can be found in the current database collected by WP2:

1. Number of S&C, representing bullet 1 above
2. Cost of removal of existing switches on one case study line, some costs of lubrication on another case study line and cost for replacement of pads and fasteners in yet another case study line (representing bullet 5 above).

## 3.2 WP3 - Tailored overhead line power supply infrastructure

### 3.2.1 The interventions in WP3

This is a technical work package developing technologies relating to power supply infrastructure and providing information about their costs and benefits to the business case being developed in WP1. It focuses on the challenges which lead to delay through unreliable performance of overhead line power supplies, the investment costs for installing overhead power on low density lines, and on the ongoing operational cost of maintaining the power system. Its objectives are to:

1. Develop evidence based links between the grade of overhead line and components installed the traffic mix which uses it, and the life of the system.
2. Specify tailored solutions for improving the quality and performances of overhead line power infrastructure.
3. Develop technologies for monitoring and minimizing the life cycle costs of overhead line power infrastructure.

Testing will be conducted to support these objectives. The work will support increased utilisation of capacity as well as a reduction in the recurrent costs of rail operations, and reduced power supply operational and maintenance costs.

WP3 consists of 5 tasks. Task T3.1 will analyse existing systems for providing power supply specific to rail infrastructure with a focus on distinguishing system specifications appropriate to low and high density lines. Task T3.2 uses GIS mapping to support the identification and prevention of the underlying cause of failures. It will find the factors that influence the performance of overhead line power infrastructure, identifying solutions for minimising their negative impact, including the mitigating effects of climate change. Task 3.3 focuses on planning for new power infrastructure installation where radical changes can be made, and beneficial decisions which can achieve optimal performance appropriate to the line type. Task 3.4 provides tailored solutions for improving operational performance and life cycle cost for existing overhead line power infrastructure where choices are more constrained than for new build. Task 3.5 will use testing to validate and evaluate the power supply solutions elaborated in the other WP tasks.

### 3.2.2 Data needed for analysis of WP 3

In order to address the economic consequences of interventions with respect to power supply, the following information is required:

1. Power system currently in use
2. Types of failures for the current power system
3. Cost for major (historical or recent) (re-)investments in power systems and the associated asset age and (existing technology) asset life information
4. The annual maintenance cost for the power system
5. Pan head strip material

When there are train delays originating from the above, there is also a need for data on:

6. Frequency of train delays
7. Length of train delays

As above, another data requirement is about capacity, i.e.

8. How close to capacity is a line and what consequences may this situation have for the different interventions
9. Is the need for track possessions for maintenance an issue with respect to capacity?

The analysis may also require information about climate conditions, e. g.

10. Maximum/minimum temperature
11. Wind velocity and wind load
12. Ice accretion and ice load
13. Precipitation

### 3.2.3 Currently available information

Deliverable 3.2 (NeTIRail-WP3-D3.2-PU-v1.0-FINAL) identifies environmental factors that influence the performance of overhead line power supply infrastructure. Secondly, it produces identification of grades and quality of components, electrical design configurations and mechanical parameters that strongly influence rate of failures and life of the power supply system.

The data thus consists of:

1. Failures due to environmental factors
2. Failures due to the grades and quality of component, electrical design configuration and mechanical parameters.
3. GIS mapping of all power supply system
4. GIS mapping for influences of environmental factors
5. GIS mapping correlation and analysis to understand the drivers of overhead power system failures

Weather data is also available in Deliverable 3.2 (NeTIRail-WP3-D3.2-PU-v1.0-FINAL), both:

6. Minimum/maximum temperature
7. Wind velocity and wind load
8. Ice accretion and ice load
9. Precipitation

### 3.3 WP 4 Monitoring and Smart Technology

The aim of this WP is to develop smart technology solutions for cost effective inspection and asset management. This includes methods of interfacing equipment with existing systems of data communication, location information and interlocking and data mining and interpretation capability to convert monitoring data into management information.

#### 3.3.1 The four tasks

The purpose of task 4.1 is to develop low cost track based monitoring modules based on specialised devices tailored to the trackside environment. This will be used in order to gather more data than has previously been possible. In this way it will be feasible to tailor maintenance to actual loads experienced, including dynamic effects as trains pass S&C and other features which excite dynamic loading. The data acquired will also help in achieving improvements in ride comfort and safety of passengers, as well as noise and vibration through improved understanding of how these relate to infrastructure quality.

The influence of dynamic loads on rails, sleepers and fastenings for the plain line, as well as for sections with switches and crossings will be simulated in laboratory environment (AFER laboratories, Romania). This will establish which vibrations and the dynamic forces that are generated when a railway vehicle pass over railway track components. The values generated by laboratory tests will be compared with the values obtained under dynamic test line of Faurei Testing Ring. Different speeds and different axle loads, will be tested.

Task 4.2 seeks to develop monitoring technology that can be installed on any rolling stock. This is done against a background of dedicated monitoring trains being is costly. As a consequence, low density lines will only be measured with long time intervals. Data covering each of the categories of line studied in NeTIRail-INFRA will be collected and the different behaviour of each line (i.e. frequency information and track stiffness behaviour for trains of different weight) will be modelled. Corresponding inspection of actual track quality and defects will seek to validate the defects revealed through in-vehicle monitoring.

The availability of more information about the actual condition of the railway infrastructure (i.e. rail top short wave defects such as squats and short pitch corrugation) will make it possible to reduce the Life Cycle Costs of maintenance. The baseline for an economic analysis is the current maintenance costs, maintenance frequency and defect rates. The more detailed information about grinding, rail replacement and other activities to improve rail surface condition that can be provided, the better is the chance to undertake the assessment and to implement appropriate remedial measures.

The aim of task 4.3 is to develop software for a smartphone-based technology for vehicle and infrastructure monitoring from within passenger vehicles. The System Architecture of this task comprises two parts:

- At rail unit level (Application for low cost smartphone):
  - Development of Android app service for sensor acquisition data
  - Development of Android app gateway for data transmission (Adhoc OR Automatic by Scheduler) via RESTfull-service using the phone 3G/4G or WiFi connection
  - Development basic Android app for local reporting and interrogation data
- At Control Center (Application for crowd-data server):
  - Development application for crowd-data server (RESTfull service & common database)
  - Development BI application (reporting web interface) for crowd-data server

Software processing will extract the underlying information in order to extend the availability of good quality asset management data and to support improved management and lean operation. This task is aimed to increase passenger comfort, security transport along the lines monitored and not least improving the frequency of maintenance works.

Applications that will be developed in this task will be used for collecting information about vibrations and temperature for each vehicle and where it is travelling and at what time. Based on this information, decisions about which activities that will improve the situation along the line will be facilitated. One particular aspect of this is to seek to distinguish vibrations that origin from rolling stock from vibrations that are due to irregularities in tracks. Collecting information about vibrations and correlating observations with geographical points will make this feasible. Using data collected over long periods of time, the purpose is to reduce cost effective inspections and asset management by minimising maintenance interventions without dedicated inspection vehicles.

The more information that is generated, the larger will the challenge to process data become. Task 4.4 is designed to harmonize the interface to transmit monitoring data acquired through sensors on-board the train to a central database. The solution will build on the SATLOC implementation of ETCS which enables the application of an advanced line and operation management system that includes also all other data in the correlated “equation” (not only infrastructure, but also vehicle condition and traffic management data). The task is therefore first and foremost intended to establish an appropriate means for handling data generated by previous tasks.

### 3.3.2 Data needed for analysis of WP 4

For each case study line the following information will be required to assess the monitoring and maintenance periods. This data should be provided by the infrastructure manager and much of the data is already presented in deliverable D1.1 and D2.1.

- number of trips,
- volume of freight,
- number of passenger,
- line speeds
- service frequencies

WP 4 provides an additional challenge for the analysis as compared to WP 2 and WP 3. While these two work packages result in making new techniques for infrastructure maintenance available, WP 4 results in new and better information. If that information results in LCC of the infrastructure is reduced, substantial benefits may materialise. This is, however, no simple “if”. There is a latent risk that new information will not be used. In addition, it is necessary to know precisely how decisions about maintenance activities are taken today and how better information may affect decisions. The initial assumption is that WP 4 has knowledge about this chain of decisions. The uncertainties generated by this chain structure will be one part of the upcoming analysis.

The below template indicates how the consequences of changes triggered by the development in task 4.2 may affect infrastructure managers and rolling stock operators.

	Data type	Source of data	
		Base line	Innovation
Operational costs – Infrastructure maintenance and repair	Grinding cost (per activity or per km)	Infra managers	No expected change
	Rail replacement cost (per activity or per km)	Infra managers	No expected change
	Cost other maintenance activities to improve rail surface conditions (per activity or per km)	Infra managers	No expected change
	Frequency of grinding (incl. depth, location, how often, etc.)	Infra managers	TU Delft will provide data from models and expertise
	Frequency of rail replacement (incl. historical replacement activities, etc.)	Infra managers	TU Delft will provide data from models and expertise
	Defect rates of squats (incl. location and severity, etc.)	Infra managers	TU Delft will provide data from models and expertise
	Cost of track possession/ cost of capacity lost due to maintenance or repair (could be related to cost of delay minutes in the case of unplanned repairs)	Infra managers	WP4 will provide data from models and expertise
	Grinding – mean time to maintain (time per activity or time per km)	Infra managers	WP4 will provide data from models and expertise
	Rail replacement – mean time to maintain (time per activity or time per km)	Infra managers	No expected change
	Squat repair (e.g. cutting out squat and replacing short rail section or using a thermite weld kit to fill) – mean time to repair	Infra managers	No expected change
	Mean time to maintain for other	Infra managers	No expected change

	rail surface condition activities		
	Track inspection car frequency	Infra managers	TU Delft will provide data from models and expertise
Operational costs – Infrastructure inspection	Manual inspection frequency	Infra managers	TU Delft will provide data from models and expertise
	Cost of inspection car per km	Infra managers	No expected change
	Cost of manual inspection per km	Infra managers	No expected change
	Cost of wheel turning	Railway operator	No expected change
Operational costs – Rolling stock	Frequency of wheel turning	Railway operator	No expected change
	Monitoring equipment costs	N/A (unless we expect it to replace track recording cars)	PI
Capital costs	Installation costs	N/A (unless we expect it to replace track recording cars)	PI
	Societal value of unscheduled delays to passengers		? No expected change
Other effects	Societal value of unscheduled delays to freight users		? No expected change
	Frequency of delays and extent of unscheduled delays	Infra Manager	Changes expected but this topic goes beyond the scope of the work package
	Value to passengers of improved ride comfort		? No expected change
	Value of ride comfort	Infra Managers	From modelling

## 4. Conclusions and Next Steps

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Task 1.2 has surveyed the Work Package Leaders and identified information about the technical innovations from each work package. This is a decisive component of the subsequent financial and economic analysis of the viability of each intervention; without having a detailed knowledge about how changes will affect activities and ultimately Life Cycle Costs, it is impossible to establish whether it is worthwhile to implement a technical improvement.

From this survey, the key data requirements for the economic impact studies have been identified. One key component of this is the demand side of the analysis. For each of our seven case study lines it is necessary to identify current ridership and freight volumes. This is used in order to assess the benefits of shorter and more reliable usage of the infrastructure, resulting from the innovations considered in the three technical work packages. If improvements are sufficiently large they may also trigger additional passengers and freight customers to the services.

The second aspect of the viability analysis concerns the costs for each intervention as well as their consequences for the Life Cycle Costs of maintenance and rehabilitation. To estimate the impact on LCC of technical improvements it is necessary to go deep into the details of how track quality drops over time and how maintenance activities are implemented in order to put a brake on the degradation of quality. This deliverable demonstrates how the nuts and bolts of these aspects on railway infrastructure maintenance is made part of the economic analysis.

Information about costs for current maintenance and costs if an intervention is implemented will be compiled by the technical work packages in close cooperation with WP 1. This will make it possible to accumulate this information and incorporate it into a high level, strategic cost modelling tool. Ultimately, this information is combined with the benefits assessment to complete the overall cost benefit analysis.

The following plan for closing the current data collection gaps will be followed:

1. On the demand data, where data collection has so far proceeded well, there is a need to follow up on those areas not yet fully populated, and those areas where the data is available but is not in the right format.
2. On the cost and related data, a template of data in excel, populated by Swedish data, is included in this deliverable as appendix A. This provides a tool for populating this framework with information about the case study lines. As indicated above, this data is to be provided by the technical work packages.

## References

Johnson, D.H. and Nash, C.A. (2008) [Charging for Scarce Rail Capacity in Britain: A Case Study](#), *The Review of Network Economics*, **7**, pp.53-76.

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Whelan, G.A., Preston J.M., Wardman, M., and Nash, C.A. (1997) 'The Privatisation of passenger rail services in Britain: an assessment of the impacts of on-the-track competition', Presented to European Transport Forum, PTRC 1997.

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## Appendix A

### Template description of Swedish rail infrastructure

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Information about the infrastructure can be provided in a number of ways. As an example, a separate Excel file documents how information about two track sections in Sweden can be retrieved.<sup>1</sup> These two examples can not in isolation be used for systematic analysis. There are, however, well over 100 track sections in the Swedish network and since the same type of information is available for all of these, it is feasible to use econometric techniques for estimating the impact of different types of installations for costs.

#### Data description

The first tab provides baseline information about two track sections, no. 111 and 129, both being about 140 km long, for the period 1999-2014. This includes information also about bridge- and switch-length and age as well as some additional information.

Three tabs provide cost information, specifically the annual costs for day-to-day maintenance, as well as costs for renewals of overhead lines and switches. Additional tabs indicate the number of clips of different makes as well as the number of lubrication devices of different makes. There are four tabs providing information about failures, first about overhead lines, then about switches, the third about clips and the final about track lubrication equipment. The final tabs are related to the previous four, but here focus is on interventions rather than failures.

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<sup>1</sup> The spreadsheet is available at the same internet address as given above.