



NEEDS TAILORED **INTEROPERABLE** RAILWAY INFRASTRUCTURE

NeTIRail

Needs Tailored Interoperable Railway Infrastructure

Deliverable D1.3

Cost model development report

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Executive Summary

This deliverable should be read in conjunction with D1.1 and D1.2. It outlines the cost modelling research that is being undertaken within WP1, which has two parts:

1. The development of a high level strategic cost model that will draw life cycle cost (LCC) information from the technical work packages (WP2-WP4) and incorporate them within a cost-benefit-analysis (CBA) framework to establish the business case for the relevant innovations.
2. Econometric modelling aimed at pushing forward the research frontier in the area of rail marginal cost estimation.

In addition, qualitative research will be carried out in the area of incentives: that is how different incentive mechanisms (track access agreements, franchise agreements, performance regimes and the wider regulatory and government funding regimes) operate and interact / contradict.

In respect of the high level strategic cost model, the inputs required will derive from the LCC analysis that will be done within WP2-WP4. It is therefore very important that there is close interaction between WP1 and WP2-WP4 to ensure that the required information is provided. The LCC will consider how maintenance practices and asset lives will change as a result of the proposed innovations, such that an estimate of costs, with and without the innovations (and with different assumptions about future traffic and service growth) can be estimated. These cost estimates will be integrated within the overall cost benefit analysis (CBA) framework to establish the business case.

The data gaps established in Deliverable 1.2 will need to be closed and the first step is a session at the Consortium meeting in Istanbul in July 2016. One important consideration at that meeting will be the extent to which the involvement of staff involved in costing / budgeting within the railway organisations might become more closely involved with the project.

In respect of the econometric research, an ambitious research programme has been set out. This will feed into the high level strategic cost modelling by providing a high level cross-check against the bottom-up engineering LCC analysis, and also for scaling the results (e.g. making estimates about how costs change with increased future traffic levels). It also pushes forward the research frontier in a number of areas: (1) cost variability with respect to quality and climate; (2) the impact of aggregation of datasets on marginal cost estimates; (3) and methodological aspects relating to functional form and obtaining improved estimates of cost elasticities and marginal costs¹. Whilst the research is ambitious, datasets have already been collected from non-case study countries (due to lack of data in the case study countries). Preliminary literature reviews have been carried out.

¹ Marginal cost is the change in total cost that arises from increasing production by one additional unit. Elasticity is a popular measure in economics analyses, which determines how sensitive a given variable is to changes in another variable (e.g. how sensitive is the cost of a railway line with respect to changes in output). For example, a cost elasticity of 0.25 with respect to train-km means that a 1% rise in train-km results in an increase in infrastructure costs of 0.25%.

The incentives aspects of the research will consider how the different aspects of the funding and regulatory environment impact on rail innovation, investment and implementation. This is expected to be based on desk research and limited interviews in the three case study countries; with a high level comparison against wider European experience. It is expected that UIC will play an important part in this aspect of the research.

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Abbreviations and acronyms

Abbreviation / Acronym	Description
LCC	Life Cycle Costs

1. Task description

Quoting from the NeTIRail-INFRA grant agreement Annex 1 (Part A – section 1.3.3 WT3 Work Package Descriptions, p.12):

This task focuses on developing a strategic, top-down cost model that estimates the impact of the relevant technologies on whole life costs. This assessment will be made against a baseline of existing costs. The costs will be context specific. Based on University of Leeds experience from leading the business case work package on the SUSTRAIL project, this work package will start early in the project so that the partners in the technical work packages are clear about what information will be needed to carry out the business case. Further, a high level, strategic approach will be adopted, in line with the needs of the project.

Synthesising the cost model: The approach adopted here builds on and develops the methodology used in the SUSTRAIL project. The data for the whole life cost model (baseline and projected for the new technology) will be generated by the relevant technical work packages. The role of this task is to set out the framework for the cost model and provide the forums (e.g. workshops; specific data requests) needed to obtain the cost estimates needed to populate the model. Importantly, as well as estimates of each cost element, the frequency of occurrence (e.g. maintenance interventions) needs to be identified. Based on experience from the SUSTRAIL project, we consider a high level, strategic modelling approach to be most appropriate, given the needs of the project, data requirements and availability, and the technological readiness of the project. The cost estimates will be synthesised using a consistent approach, underpinned by the principles of cost benefit analysis. It will also be important to ensure that costs are aggregated to the same level so that we are comparing like with like.

Since charging frameworks (see task 1.5) in the EU reflect marginal cost it will be important to understand both the total cost and marginal cost (of varying usage) implications of the technological innovations and how these vary with different types of traffic on different types of infrastructure). The cost estimates for the baseline will be cross-checked against the previous top-down econometric literature, and those for the new technical approaches compared in order to consider the implications for track access charges.

2. The Business Case

2.1 The Business Case framework

The NeTIRail-INFRA project offers a series of innovations for the railway infrastructure. The innovations will have impacts (in terms of changes in costs and benefits) on society as a whole, but also particularly on different groups: infrastructure managers (IMs), train operators (freight and passenger) and end users. As part of the Business Case, we need to identify and quantify the impacts. See the table below for a generic description of impacts and groups considered.

	Groups			
	IMs	Train Operators	End users	3 rd Parties
Impacts	Changes in costs and revenues	Changes in costs and revenues	Changes in costs and benefits for passengers and freight users (e.g. improvements in reliability, availability, safety, etc.)	<ul style="list-style-type: none"> Environmental externalities (CO₂, noise). Government: grant or subsidy requirements

Table 2.1 – Business Case – Impacts table

Note that some of the benefits and costs of the innovations appear more than once in the table above (e.g. imagine a change in the price for the passengers that would also be a change in revenue for the operator). The aim here is simply to identify and quantify all impacts; the construction of the Business Case will deal with the addition of impacts afterwards to avoid double counting (some impacts may simply be transfers from one group to another, and this will be accounted for adequately within the analysis).

This deliverable deals with the expected changes in costs. Most, if not all, are expected to be changes in costs for the IMs.

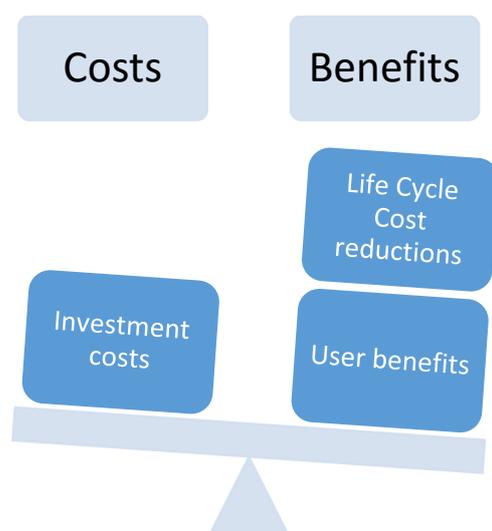
A Business Case will be developed to evaluate the overall net benefit of these innovations to society and to the different stakeholders. The Business Case will include a Cost-Benefit Analysis (CBA) with two main elements:

- A socio-economic CBA, covering all affected parties (i.e. society²).
- A financial CBA, analysing the impacts on each of the relevant stakeholders.

The CBA will be developed for each of the case studies separately. This means that what the CBA will measure is the net benefit of the innovations for a given railways line. In general, all impacts mentioned above can be summarised into three categories that will determine the output of the CBA:

² It is useful to note the link to WP5 here. WP5 is concerned with a societal analysis of the innovations. Hence, the societal angle is shared between WP1 and WP5. The difference lies in the type of analysis that is conducted under each WP. Here we focus on the economic analysis using a Cost-Benefit Analysis, whereas WP5 uses other analytical tools to study the non-economic societal effects of the innovations. Deliverable D5.3 will integrate WP1 and WP5 results.

Costs	Benefits
<ul style="list-style-type: none"> Investment costs 	<ul style="list-style-type: none"> Life cycle cost reductions End-user benefits



In order to be more specific about the benefits and costs from this project, the following table broadly summarises the expected impacts of the innovations.

Benefit/Cost		No. of innovations (12 total)	Proportion of all innovations
Life cycle costs	Reduction in rolling stock operating costs	8	67%
	Change in maintenance regime	12	100%
	Reduction in the cost of replacements	8	67%
User benefits	Less train cancellations/delays (less track possessions for maintenance)	11	92%
	Improvement in punctuality (less failures)	12	100%
	Reduced journey time	1	8%
	Improved comfort	5	42%
	Improved safety	5	42%

User benefits (subject to operator response)	Lower ticket prices (cost reductions are fed through into lower ticket prices)	6	50%
	Increase in track capacity allowing more services if operator wishes	9	75%

Table 2. List of costs and benefits

To develop the CBA, the starting point is the definition of the baseline scenario, also called the Do-Minimum scenario. The baseline should represent the situation of the line if the innovations are not applied. Secondly, a Do-Something scenario should be defined: e.g. the application of all innovations. Note that there is a scope to consider several different Do-Something scenarios.

The Business Case will reveal whether the benefits of the NeTIRail-INFRA innovations outweigh the costs.

This deliverable will present the approach for the estimation of costs under the Do-Minimum and Do-Something scenarios. For that matter, we are concerned with those costs that are likely to vary between these scenarios. For the Do-Something scenarios we will also undertake sensitivity analysis for example as to how the business case might change under different assumptions about traffic growth. Certain innovations that reduce delays for example would be expected to have higher benefits in a situation where there is higher traffic. Thus an innovation may be worth implementing in some situations and not others; and there may be uncertainty over the degree of traffic growth in future which needs to be considered.

2.2 The Innovations and the Case Study Lines

A key input for the Business Case is a clear definition of the Do-Something scenarios that will be considered. Currently, there is a total of 12 innovations and 7 case study lines. It is necessary to know, for each case study, which of the innovations will be considered (e.g. all innovations, only a sub-set, or only one) to define the Do-Something scenario/s. For example, the SUSTRAIL project included 3 Do-Something scenarios that were compared against the baseline scenario.

A first step on the process of matching the innovations with the case studies has been already taken and is reported in **Deliverable D5.1 from WP5**: section 4 of D5.1 reports what the planned innovations are for each of the 7 case study lines. At this stage, it is expected that each line will implement between 3 and 7 innovations. The table below summarises D5.1 information:

List of innovations	Case study lines						
	Secondary line Bartolomeu-Zarnesti	Busy line Ljubljana-Kamnik	Secondary line Pivka – Ilirska Bistrica	Freight line Divča – Koper	Busy line Ankara- Kayaş	Secondary line Divriği- Malatya	Freight line Malatya- Iskenderun
	R	S1	S2	S3	T1	T2	T3
The use of heavier rail sections (e.g. 54kg/m; 60 kg/m, etc.)	x	x	x	x	x	x	
Replacing wooden sleepers with concrete sleepers or even pre-stressed concrete sleepers on the entire route	x						
Replacing wooden sleepers with concrete sleepers or even pre-stressed concrete sleepers.		x	x	x			
Adopting mechanized maintenance to ensure better track geometry and no human errors.	x	x	x	x	x	x	x
Adopting rail grade quality from R260 to R350HT and beyond.	x	x	x	x	x	x	x
Replacing the remaining 10% of jointed rail with welded rail	x						
Adopting long welded rails or even continuously welded rails on the entire route				x			x
Replacing the remaining 20% of jointed rail with welded rail						x	
Upgrading ballast from lime stone to a hard stone composition.		x	x	x			x
Converting power supply system from 3kVcc to the European standard: 25kVac/ 50Hz.			x				
Reducing high gradient for gaining traction power and lowering energy consumption.			x				

Table 3. List of innovations by case study lines

In the table, R, S and T are the initials of the countries (Romania, Slovenia and Turkey), and the numbers represent the case studies, ordered as they appear in other deliverables (e.g. D5.1). The details are not relevant for this report; the table simply provides a summary of the innovations and the extent to which they will be applied. It will also be essential to know whether the innovations will occur at a single point in the line, at several points (e.g. curves), or over the whole line. In some cases, D5.1 provides details on this, but for many of the planned innovations this information is still missing or was not available for D5.1. Finally, a further challenge to be addressed will be to understand the effects of several innovations simultaneously, taking a holistic view in cases where synergies can occur.

3. Life Cycle Costs

3.1 An overview of the Life Cycle Costs (LCC) analysis

Life Cycle Costs (LCC) analysis will be used to estimate the costs for the relevant groups (IMs and train operators) under the different selected scenarios. In this way, LCC analysis will provide us with the changes in costs for the relevant groups due to the innovations, always in relation to the baseline scenario. This methodology was used in another project of similar nature: SUSTRAIL.

The LCC model predicts the cost profile for the track over a period of years to be determined (e.g. for the SUSTRAIL project, the predictions were made over a 30 year period), both for the existing track (baseline costs) and for the track with innovations (do-something costs).

Deliverable D2.1 (WP2) contains an extensive section on LCC: section 3 “RAMS&LCC in railway transport infrastructure”. Please see D2.1 for details on LCC. The following sections below will be limited to a pragmatic overview of what are the needs of the Business Case in terms of LCC data.

3.1.1 Track cost items – by segments vs. by Case Study Line

The LCC model may provide results based on a particular segment of the track (e.g. curves or radius 0-1200m). If this is the case, it will be necessary to scale-up the results to the Case Study Line level, i.e. to obtain the costs for the whole track of the corridor object of the study. This can be done using data on track maintenance and renewal costs for the corresponding Case Study Line (if data at the corridor level was not available, a backup option would be to use data at the network level). Additionally, more generalized data (at the network level) could also be useful, since a further contribution of this project could be to provide policy recommendations on a more generalized implementation of the innovations (e.g. at a national level or even at the European level).

For the LCC analysis, a list of the different costs considered should be provided: e.g. track corrective maintenance, track preventive maintenance, renewals, investments/innovations. It is important to know that, at this stage, we are not expecting changes in train operators' costs. The reason for this is that we are assuming that service patterns will remain mainly unchanged following the innovations. However, if changes in train operators' activities and hence costs were expected, these will be quantified too. It should be noted that in some cases the innovations will improve the availability of the network and we will want to value this capacity increase. As part of the valuation we would look at the costs and benefits associated with changes in service patterns (taking account also of where the traffic may have been diverted from).

The overarching aim is to obtain the total costs of a given line, without and with the innovations.

At the end of the process, the expected output of the LCC analysis at the Case Study Level for the Business Case should provide us with information about the changes in costs following the implementation of the innovations under the do-something scenario/s. See the table below for an example from the SUSTRAIL project, where three different do-something scenarios were considered. For each cost category (e.g. maintenance, renewals...) the percentages represent changes in track LCC compared to the baseline scenario. Note that these percentages were generated after having computed the total cost of each cost item under each scenario. For example, the Do-Something scenario named “Sustrail0” allows a new corrective maintenance regime which is 80% less costly than the Do-Minimum (baseline) scenario over the period considered in the appraisal (e.g. 60 years).

Aggregating the changes at the route level, this gives an overall saving of 0.6% in the corrective maintenance category, and a 1.6% cost saving overall. It can also be seen in this example the importance of considering different Do-Something scenarios: the second do-something scenario (namely SUSTRAIL1) provides an overall cost saving of 10.1%, the highest among the three do-something scenarios analysed.

	Track LCC data % changes:			Track cost % changes at route level:		
	SUSTRAIL0 (vehicle only)	SUSTRAIL1	SUSTRAIL2 (140kph)	SUSTRAIL0 (vehicle only)	SUSTRAIL1	SUSTRAIL2 (140kph)
Track Maintenance and Renewal Costs				-1.6%	-10.1%	-7.5%
Maintenance				-0.8%	-2.4%	-1.8%
Corrective maintenance	-80%	-80%	-50%	-0.6%	-0.6%	-0.3%
Preventive maintenance	-6%	-45%	-37%	-0.2%	-1.8%	-1.5%
Renewals				-0.8%	-7.7%	-5.6%
General renewals	-10%	-86%	-60%	-0.8%	-7.8%	-5.7%
Investments/innovations	0%	2%	2%	0.0%	0.05%	0.05%

Table 2.6: Impacts of SUSTRAIL0,1&2 on track costs

Figure 1. Example of LCC analysis output from SUSTRAIL

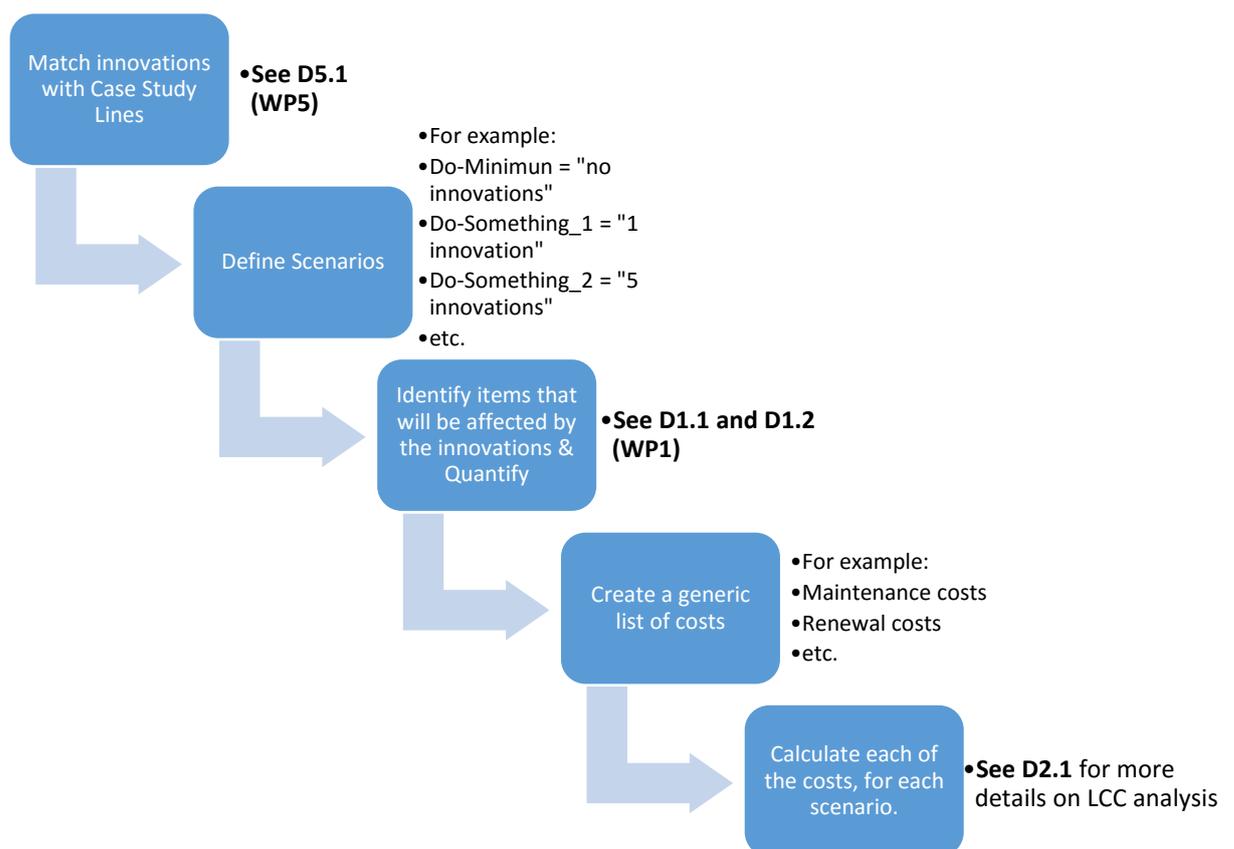
It will be important to remember that we are dealing with technological changes that can, in due turn, produce changes in the activities performed by the railways (e.g. maintenance regime). Ultimately, these changes in the activities will be driving (at least part of) the changes in cost. Hence, it is necessary to obtain data on the changes in activities in order to adequately quantify changes in cost.

Deliverable D1.1 from WP1 ('Report on selection of case studies') provided an initial overview on the data needs for LCC analysis as part of the criteria for selecting case studies. We reproduce the relevant section in the appendix. However, note that this list was generated at an early stage of the project and hence it should only be taken as an approximate guide. One of the roles of this deliverable is precisely to highlight the importance of understanding the steps of the process that will ultimately generate the data needed.

Deliverable D1.2 (WP1), on 'Database of economic data on case study lines', contains a description of the economic data needed which includes data on costs. This description is specific for the innovations of WP2, WP3 and WP4 respectively, although many of the items are common across them. D1.2 also provides details of the current state of the data collection process, whereas only a small fraction of the necessary cost data has been obtained at this stage.

3.1.2 Cost modelling process and links with other work packages

In order to facilitate the understanding of the steps needed to achieve the aim of the cost modelling stage, the key messages from sections 2 and 3 are summarised in the graph below:



An important point to note is that the information about asset life, interventions and hence life cycle cost changes will be developed within each of the individual technical work packages for the specific innovations considered there (WP2-WP4). The role of WP1 is to develop a high level strategic cost modelling tool which draws on the information provided and integrates into a cost-benefit analysis (CBA) framework. WP1 will work closely with the other work packages to specify clearly what is needed in terms of data and analysis, and to facilitate the process such that it will be possible to provide a high level assessment of cost (and benefit) changes of the technologies. This will build on the work and communication described in Deliverables 1.1 and 1.2.

The next important step in this process is a break-out session at the Consortium meeting in Istanbul (July 2016) where representatives from WP1 and the technical work packages (WP2-WP4) will discuss data and process; starting with the “do-nothing” current state data.

4. Econometric approach

As noted in the description of works, as part of our research we wish to push forward the research frontier in several ways. A quote below is taken from the description of works:

The research frontier is to develop new understanding of the impact of climate and quality (e.g. reliability) on marginal and average costs; develop our understanding of cost variability and relative efficiency by exploiting new datasets that are more closely aligned to business units; and to extend the research on the impact of track access regimes on behaviour to incorporate the wider regulatory frameworks in which railways operate and how these impact on costs and efficiency. In developing all of these research strands best practice approaches from SUSTRAIL will be built into the approach. The proposed incentives research provides the link between technical solutions, implementation and impact.

The methodology in this case is to obtain data that enables the econometric estimation of a cost function – that is a function that relates costs (say of different track sections; regions or train companies) to the drivers of costs, for example, traffic, size of network, characteristics and quality of the infrastructure. For illustrative purposes, consider a cost function which has double log functional form and two traffic types A (passenger) and B (freight):

$$\ln(C_i) = \alpha + \beta_1 \ln(Q_{Ai}) + \beta_{11} \ln(Q_{Ai})^2 \dots + \beta_2 \ln(Q_{Bi}) + \beta_{21} \ln(Q_{Bi})^2 + \gamma \ln(I_i) \quad (1)$$

Where

- C_i is the maintenance and, if applicable, renewal cost per annum for the track section, region or train operating company being analysed (i);
- Q_i is outputs for section / region / company i ; here in terms of traffic with vehicles of different types (A and B). In the above formulation a squared term is also included; and
- I_i is a vector of fixed input levels for section / region / company i – these include the infrastructure variables i.e. track length, track quality etc.³

In previous EU funded projects, CATRIN and SUSTRAIL, these type of models have been used to estimate marginal costs, for the purpose of identifying the marginal costs of running additional vehicles (and different types of vehicles) on the network. In turn this information has been used for setting track access charges.

To implement the econometric approach, as noted, data is needed at a disaggregate level. For example, data exists at track section level within France, covering infrastructure maintenance costs, traffic and infrastructure characteristics for over 1000 sections. In terms of the number of observations, this dataset provides an excellent basis for econometric work. In other countries there may be a smaller number of sections (c. 200 in Sweden) and in some cases (e.g. Great Britain), data sets might be organised on a regional basis (10 strategic routes/zones; c. 40 maintenance delivery units). In such cases econometric estimation may still proceed, potentially by using panel data (multiple observations on the same region / delivery unit over time).

³ See CATRIN Deliverable D8.

In this project there have been challenges in respect of obtaining data for the individual case study lines. We therefore do not expect to be able to get data on multiple sections that would be required for econometric work for the countries covered by this project. Our approach therefore is to push forward the methodological literature using datasets that we have access to from Great Britain, France, Switzerland and Sweden. As noted below there are some permission issues still to be cleared regarding the use of some of these sources.

The focus of our research, as set out in the description of works is as follows:

1. Studying the impact of quality on costs. Reliability of services (i.e. quality) has been identified as one of the main potential benefits of NeTIRail-INFRA innovations. A key limitation in the cost modelling literature in general (not only in respect of railways) is the challenge of including measures of quality in cost models. A particular focus of this project is the study of the cost of reliability. An initial literature review has been undertaken which indicates that there are very few papers in the rail (or wider) literature that incorporate reliability into cost functions. We therefore propose to do this using a dataset of 20 train operating companies over a period of 5-20 years (the appropriate time period will be chosen depending on data comparability for some of the older data that we have). This analysis should reveal new findings on how much it costs to improve the reliability of train services. The focus here is on train operating companies. The University of Leeds also has a PhD student studying the same question using rail infrastructure data on 10 routes in Great Britain over 10 years. The new findings will complement the research elsewhere in the project on the benefits of improving reliability; and may be used to cross-check against the bottom-up estimates coming from the LCC analysis generated in WP2-WP4. The majority of the data has been collected and a literature review is underway.
2. Studying the impact of climate on costs. Similar to point 1, climate clearly has an impact on costs (either reactive; or increased spend to make infrastructure more resilient). However, the econometric approach has not been used to our knowledge to study the impact. A current dataset has been provided by SNCF Reseau as part of some wider research conducted by the University of Leeds. This is under analysis with the aim of producing indicative results in September. This approach may then be developed further, depending on the results, data, and permission by SNCF Reseau to take the work further. The description of work envisaged work on climate / quality so it may not be possible within the timescale to do detailed work on both aspects; the preliminary work during Summer 2016 may therefore not be taken further depending on resourcing and the progress of the other aspects of work.
3. Three methodological aspects from CATRIN and SUSTRAIL will be considered. First, research on the impact of aggregation on marginal cost estimates. An issue that arose during the CATRIN and SUSTRAIL projects was the possible sensitivity of marginal cost results to the degree of aggregation. Evidence from Switzerland, for example, suggested that more aggregated data produced higher elasticities of cost (see Smith and Nash, 2015). There is also concern over whether the allocation of costs to track sections was accurate in studies that use very disaggregate data. Thus there is a motivation to carry out analysis at a level that is aligned with an actual

business unit carrying out maintenance and renewal activity. At this stage relevant data sets are being considered and permission will be sought to use the Swiss data to study this important question. Swedish data may also be used and this source will be investigated. The second concerns the choice of the functional form. This has been a major issue in recent work undertaken by University of Leeds (with EcoPlan and Stratec) for SNCF Reseau (see Smith et. al., 2016). In particular, the general cost modelling literature has favoured a translog functional form; whereas the rail infrastructure marginal cost literature has estimated particular forms of Box-Cox models. The research will look from a theoretical, mathematical and empirical perspective at the relationship between the translog model and the family of Box-Cox models (and in what circumstances they may be nested within each other), and also at the flexibility properties and why the Box-Cox models appear to date to have produced more intuitive results. The third aspect is an exploration of Bayesian techniques for estimating rail infrastructure cost models. The aim is to use prior information from engineering understanding to improve the results from the econometric methods as compared to the traditional classical approach. This approach therefore brings together economic / econometric approaches and engineering understanding.

4. Finally we proposed some work on incentives and how different incentive mechanisms operate and interact / contradict. These include track access agreements, franchise agreements, performance regimes and the wider regulatory and government funding regimes. The latter is particularly important and relevant for the case study countries, whilst the former mechanisms are more important in other countries. This aspect of the work needs to be developed further but currently it is envisaged that there will be a desk based review of relevant mechanisms in the different countries, together with interviews. This will shed light on how incentive arrangements support (or otherwise) rail innovation and investment in the case study countries. At a high level the emerging picture will be compared against the UK and other western European countries. We envisage that UIC will play a significant role in this aspect of work.

In general, the results above will develop the relevant literatures. The new results should also inform aspects of the strategic cost model, as high level cross-checks against the bottom-up engineering LCC analysis, and also for scaling the results (e.g. making estimates about how costs change with increased future traffic levels).

The above is an ambitious programme of new research. As the project emerges it may be necessary to make prioritisation decisions to place greater emphasis on one aspect as compared to the other, particularly as datasets may not be available to support all aspects simultaneously (though as noted above we have already carried out preliminary literature reviews, accessed important datasets and started processing with a view to estimating new models). In particular we envisage that new work on 1 and 2 may not be possible simultaneously (that is, we may focus on 1 or 2, but most probably area 1). Likewise in part 3, three different methodological advances are within scope, but we will most probably focus on two of these.

5. Conclusions

This deliverable should be read in conjunction with D1.1 and D1.2. The cost modelling approach that will be developed in this project can be broadly divided into two aspects: (1) the development of a high level strategic cost model that will draw life cycle cost (LCC) information from the technical work packages (WP2-WP4) and incorporate them within a cost-benefit-analysis (CBA) framework to establish the business case for the relevant innovations; (2) econometric modelling aimed at pushing forward the research frontier in the area of rail marginal cost estimation. In addition, qualitative research will be carried out in the area of incentives.

The main conclusion of this deliverables are as follows.

In respect of the high level strategic cost model, the inputs required will derive from the LCC analysis that will be done within WP2-WP4. It is therefore very important that there is close interaction between WP1 and WP2-WP4 to ensure that the required information is provided. The LCC will consider how maintenance practices and asset lives will change as a result of the proposed innovations, such that an estimate of costs, with and without the innovations (and with different assumptions about future traffic and service growth) can be estimated. These cost estimates will be integrated within the overall cost benefit analysis (CBA) framework to establish the business case. The data gaps established in Deliverable 1.2 will need to be closed and the first step is a session at the Consortium meeting in Istanbul in July 2016. One important consideration at that meeting will be the extent to which the involvement of staff involved in costing / budgeting within the railway organisations might become more closely involved with the project.

In respect of the econometric research, an ambitious research programme has been set out. This will feed into the high level strategic cost modelling by providing a high level cross-check against the bottom-up engineering LCC analysis, and also for scaling the results (e.g. making estimates about how costs change with increased future traffic levels). It also pushes forward the research frontier in a number of areas: (1) cost variability with respect to quality and climate; (2) the impact of aggregation of datasets on marginal cost estimates; (3) and methodological aspects relating to functional form and obtaining improved estimates of cost elasticities and marginal costs. Whilst the research is ambitious, datasets have already been collected from non-case study countries (due to lack of data in the case study countries). Preliminary literature reviews have been carried out.

The incentives aspects of the research will consider how the different aspects of the funding and regulatory environment impact on rail innovation, investment and implementation. This is expected to be based on desk research and limited interviews in the three case study countries; with a high level comparison against wider European experience. It is expected that UIC will play an important part in this aspect of the research.

6. References

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NeTIRail-INFRA Deliverable 1.1. Report on selection of case studies.

NeTIRail-INFRA Deliverable 1.2. Database of economic data on case study lines

NeTIRail-INFRA Deliverable 2.1. Analysis of “big data”: geospatial analysis of costs, drivers of failure and life of track infrastructure.

NeTIRail-INFRA Deliverable 5.1. Societal and legal effects of transport decision: Stakeholder analysis.

Appendix

Availability of data relative to costs and life cycle

WP2 and WP4 will be addressing technical improvements with respect to tracks, power supply, and monitoring activities, respectively. In order to be able, in the future, to perform cost and benefit comparisons as part of impact assessments, the following items are deemed necessary. The table illustrates the track case (WP2).

Type of data needed	Availability
<u>Total maintenance cost (annual cost)</u> . This must be reported in a way that makes it possible to identify how much is spent today on various subsystems, for instance on switches & crossings (S/C). The important point is that <u>disaggregate cost data</u> is needed in two senses: firstly, information that it is available at the level of the line / route chosen for analysis (national data is not sufficient); second that it is broken down into the relevant type of cost, in the case of the example above, S&C maintenance costs.	
<u>Total replacement (or renewal) costs</u> , for example for S&C on the given route. This should ideally also be expressed as a unit replacement cost, given that volumes of S&C replacements on the line will change from year to year.	
<u>Traffic over each line</u> , including information about number of freight and passenger trains (expressed as passenger and freight train-km, passenger-km and passenger journeys, and freight gross tonne.km), payload and number of passengers, respectively as well as revenue for each.	
<u>Number of failures in total over each line</u> , but in particular failures generating delays that may be linked to each of the four technical components under review. This includes the number of minutes of train disruptions each disturbance generates, including knock-on consequences on subsequent trains.	
<u>The age of S/C and other technical components</u> that may be affected by each type of intervention.	
<u>Potentially other measures</u> relating to the environment (carbon; noise), and also safety if we consider that these will be materially affected by the new technology.	

Table 4 - Selection criteria: cost data availability

The same logic applies to WP3 and WP4. The need for ultimately getting a sufficient level of cost disaggregation was emphasized.

Availability of data for assessing the effects of innovation

Type of data needed	Is it available (YES/NO)
<u>The investment cost of the new asset(s)</u> as well as any consequences for the future replacement scenario compared to the equipment used under the current scenario (that is, how does the life of the asset, in terms of years or cumulative tonne-km, change as a result of the new technology). This includes the implications of the change in maintenance regime (frequency of inspection, etc.) or other innovations with implications for the life of the asset /frequency of replacement.	
<u>Information relating to the changes in rates of failure and thus implied delays</u> – so that we can estimate the impact on delays and the availability of the network (taking into account also changes to the maintenance regime noted in 1. above).	
<u>To the extent than an intervention has implications for variables other than delays</u> , information about these aspects are also necessary under both “with” and “without” cases. Examples include but are not restricted to speed on the line; ride quality; noise and possibly other environmental consequences as well as accident risk.	

Table 5 - Selection criteria: assessment of innovation effects