Deliverable D6.5

Case study line data scenarios playable in the web application

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Executive Summary

D 6.5 is the first part of the realisation of NeTIRail-INFRA task 6.4 “Presentation of the cost benefit analysis (WP1), and societal analysis (WP5) using the Web application”. This task is meant to illustrate the results of the economic analysis done in WP1 and of the societal analysis done in WP5 using the GIS tool developed in WP6. This way the results of the economic and societal analyses should be made accessible to the GIS tool users, so that the web application can offer support for informed decision making regarding transport innovations.

This aim is pursued in two steps:

1) D6.5 shows how the information resulting from WP1 and WP5 can be used for the illustration in the GIS tool. Specifically, it presents the functionalities that have been added to the GIS tool for the illustration of the economic and social analyses, the methodology to use the data for illustration in the web tool and one example of data scenarios from WP1 and WP5 that can be played in the GIS tool.

2) D6.6 refines the methodology presented in D6.5 and demonstrates how the economic analysis and the societal analysis can be visualized in the web tool.

This deliverable develops the first step. Section 1 introduces the topic. Section 2 presents the functionalities of the Web application, explaining how different categories of users will be able to interact with the online platform. Section 3 contains the methodology for translating the results of WP1 and WP5 into data usable for the Web application. Section 4 presents an example of a scenario playable in the web application. Section 5 concludes.

There are no deviations from the description of work regarding the content of the deliverable.
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## Abbreviations and acronyms

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<th>Description</th>
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<tbody>
<tr>
<td>AC</td>
<td>Alternating current electrification</td>
</tr>
<tr>
<td>C</td>
<td>Cost</td>
</tr>
<tr>
<td>CBA</td>
<td>Cost-benefit analysis</td>
</tr>
<tr>
<td>CRUD</td>
<td>Create, Read, Update and Delete</td>
</tr>
<tr>
<td>CSV</td>
<td>Comma Separated Values (file format)</td>
</tr>
<tr>
<td>D</td>
<td>Deliverable</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current (electrification)</td>
</tr>
<tr>
<td>EL</td>
<td>Electrification</td>
</tr>
<tr>
<td>GeoJSON</td>
<td>Geographical JavaScript Object Notation</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographical Information System</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>OP</td>
<td>Operational Point</td>
</tr>
<tr>
<td>PDF</td>
<td>Portable Document Format</td>
</tr>
<tr>
<td>PPP</td>
<td>Purchasing Power Parity</td>
</tr>
<tr>
<td>Q</td>
<td>Quality</td>
</tr>
<tr>
<td>REST</td>
<td>Representational state transfer</td>
</tr>
<tr>
<td>RINF</td>
<td>Register of Infrastructure (Database)</td>
</tr>
<tr>
<td>S</td>
<td>State</td>
</tr>
<tr>
<td>S&amp;C</td>
<td>Switches and crossings</td>
</tr>
<tr>
<td>SIA</td>
<td>Social impact assessment</td>
</tr>
<tr>
<td>SOL</td>
<td>Section of Line</td>
</tr>
<tr>
<td>T</td>
<td>Task</td>
</tr>
<tr>
<td>Tp</td>
<td>Passenger Train</td>
</tr>
<tr>
<td>Tf</td>
<td>Freight Train</td>
</tr>
<tr>
<td>TW</td>
<td>Trolley wire</td>
</tr>
<tr>
<td>WP</td>
<td>Work Package</td>
</tr>
</tbody>
</table>
1 Introduction

The innovations developed in the technical WPs of NeTIRail-INFRA have been evaluated from both an economical and a societal point of view in the WPs 1 and 5 respectively. Deliverable 5.3 “Balancing societal effects and cost-benefit of different infrastructure decisions” combined the results of the economic and societal assessments.

The present deliverable aims to set the methodology for presenting these results using the GIS Web Tool developed in WP6. The purpose of the Web Application is to inform the user about impact of innovations when applied to the identified categories of lines. Several challenges have to be addressed:

- As the impact assessments summarized under D1.4 “Cost and User Benefit Report” are tailored to each individual innovation, a generalized, and probably simplified method for assessing cost savings needs to be provided;
- As, especially, the societal benefit estimates rest on line-specific questionnaires, generalisation is not obvious.

Section 3 and 4 below address these challenges and the strategy adopted to deal with them.

2 Specifications of the web application

User stories have been formulated in order to develop the specifications which will enable the web application to play the case study line scenarios. The user stories consider the user’s point of view and aim to identify what the user should be able to accomplish with the tool and how they will interact with it. These user stories then form the basis of the specification.

In order to allow displaying of the results of the cost and societal impacts of the innovations the web based GIS application must be able to allow the user to specify a custom formula which is used to calculate the cost and societal impacts, and the user must be able to add new parameters which describe cost and factors for societal perspectives (NEW PARAMETERS). These added values will change between different lines and routes, and therefore need to be linked to the relevant sections of lines (SOL) and operational points (OP) contained within the RINF database.

These user stories are added to the list of existing user stories for the GIS web application which have been previously defined for the specification of the user interface and display of the RINF and GIS data.

The number, in front of the user stories, corresponds to their reference throughout all the documentation of the development project. It also gives information about the nesting of user stories among them.
## 2.1 User stories regarding parameters and formulas of the WEB-APPLICATION (Formula, RINF, NEW PARAMETERS for other GIS Web Application)

<table>
<thead>
<tr>
<th>User Story</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>The admin user and application will be able to manage and access RINF data (SOL/OP)</td>
</tr>
<tr>
<td>3.2</td>
<td>The admin user and application will be able to manage and access NEW PARAMETERS (social impact and economic costs related to innovation) (SOL/OP)</td>
</tr>
<tr>
<td>3.2.1</td>
<td>The admin user will be able to manage (Create, Read, Update and Delete - CRUD) the NEW PARAMETER which must be compatible with the RINF database structure</td>
</tr>
<tr>
<td>3.2.2</td>
<td>Important: this User Story is in “GIS Web Application” and not in “Parameters and formulas of the WEB-APPLICATION” : The admin will be able to input the value of a NEW PARAMETER for a given SOL or OP</td>
</tr>
<tr>
<td>3.2.3</td>
<td>REST Services : The GIS web application will be able to manage (CRUD) value of New Parameters connected to SOL / OP</td>
</tr>
<tr>
<td>3.2.4</td>
<td>REST Services : The GIS web application will be able to access New Parameters (name and .... New Parameter as if it is a SOL or OP) connected to SOL / OP</td>
</tr>
<tr>
<td>3.2.5</td>
<td>REST Services : The GIS web application will be able to have permission to use REST Services</td>
</tr>
<tr>
<td>3.3</td>
<td>The admin user and application will be able to manage, access and use FORMULA based on value of parameter (RINF Parameter and New Parameter)</td>
</tr>
</tbody>
</table>
| 3.3.1      | The admin user will be able to manage FORMULA connected to PARAMETERS and/or NEW PARAMETERS  
  o The admin user will be able to input a formula  
    ▪ The admin user will be able to select a parameter (new parameter or RINF parameter)  
    ▪ The admin user will be able to create a formula based on selected parameters  
    ▪ Permitted Operations: sqr, ^, +, -, *, /, log, ...  
    ▪ The formula will be applied in the GIS web application for a set of selected SOL  
    ▪ The admin user can choose a color set associated with result ranges (of the formula) in order to represent on the map the result of the formula by colorizing SOL/OP  
  o The admin user will be able to view, modify and delete FORMULA |
| 3.3.2      | REST Services : The GIS web application will be able to access FORMULA |
| 3.3.3      | REST Services : The GIS web application will be able to apply a FORMULA to a SOL set |
| 3.3.4      | REST Services : The GIS web application will be able to have permission to use REST Services |
### 2.2 User stories regarding the GIS Web Application

<table>
<thead>
<tr>
<th>User Story ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2</td>
<td>The user must be able to visualize a map of the railway network on a web application</td>
</tr>
<tr>
<td>4.3</td>
<td>The user must be able to log in, navigate on the map</td>
</tr>
<tr>
<td>4.4</td>
<td>The logged user will be able to select and save a set of RINF SOL/OP in the tab &quot;selection&quot;</td>
</tr>
<tr>
<td>4.5</td>
<td>The admin user will be able to add value for NEW PARAMETERS SOL/OP in the tab &quot;selection&quot;</td>
</tr>
<tr>
<td>4.5.1</td>
<td>The admin user will be able to filter the SOL/OP according to criteria (network/region/technical parameter) (4.4.2)</td>
</tr>
<tr>
<td>4.5.2</td>
<td>The admin user will be able to filter SOL/OP by area selection (zoom) on the map, by means of screen limit (boundary) (4.4.3)</td>
</tr>
<tr>
<td>4.5.3</td>
<td>The admin user will be able to visualize a list of the filtered SOL/OP by network, region and technical parameter in a geographical zoomed area on the screen (4.4.4)</td>
</tr>
<tr>
<td>4.5.4</td>
<td>The admin user will be able to select on the SOL/OP that he/she is interested in (4.4.5)</td>
</tr>
<tr>
<td>4.5.5</td>
<td>The admin user will be able to select NEW PARAMETERS for adding values on the SOL/OP selected</td>
</tr>
<tr>
<td>4.5.6</td>
<td>The admin user will be able to add value on SOL/OP selected on the NEW PARAMETER selected</td>
</tr>
<tr>
<td>User Story ID</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>4.6</td>
<td>The logged user will be able to view information on a set of SOL/OP (already selected), in the tab &quot;Parameter information/value/...&quot; and on the map, in order to make a decision</td>
</tr>
<tr>
<td>4.6.1</td>
<td>The user must be able to <strong>select a set of SOL/OP (already selected)</strong> to display and export information (note: no link with selection for filtering).</td>
</tr>
<tr>
<td>4.6.2</td>
<td>The user must be able to <strong>select one or more parameters (from RINF Parameters or NEW PARAMETERS)</strong> to display and export information (note: no link with selection for filtering).</td>
</tr>
<tr>
<td>4.6.3</td>
<td>The user must be able to <strong>visualize the result of the &quot;calculation&quot;</strong> (using different methods for extensive vs. intensive values) for all the selected SOL/OPs for each parameter to be explored in the widget/tab.</td>
</tr>
<tr>
<td>4.6.4</td>
<td>The user must be able to <strong>visualize the result of the &quot;formula&quot;</strong> (calculation based on formula using selected parameters) for all the selected SOL to be explored in the widget/tab.</td>
</tr>
<tr>
<td>4.6.5</td>
<td>The user must be able to <strong>visualize the result of the &quot;calculation&quot;</strong> (kind of count on one parameters of a set of SOL) (extensive and intensive values) for the selected SOL/OP with a <strong>pop-up</strong> by clicking on the item on the map</td>
</tr>
<tr>
<td>4.6.6</td>
<td>The user must be able to <strong>visualize the result of the &quot;formula&quot;</strong> (calculation based on formula using some parameters) <strong>for the selected SOL/OP</strong> with a <strong>pop-up</strong> by clicking on the item on the map. The user must be able to <strong>visualize the value of each technical parameter of the selected SOL/OP</strong> with a <strong>pop-up</strong> by clicking on the item on the map. Each SOL/OP will be colored according to the result value of the formula.</td>
</tr>
<tr>
<td>4.6.7</td>
<td>The user must be able to <strong>visualize the result of the &quot;formula&quot;</strong> (calculation based on formula using some parameters) <strong>for the selected SOL/OP by the SOL/OP colored on the map</strong></td>
</tr>
<tr>
<td>4.6.8</td>
<td>The user must be able to export:</td>
</tr>
<tr>
<td></td>
<td>o <strong>Set of selected SOL/OP</strong>,</td>
</tr>
<tr>
<td></td>
<td>o the parameters values for each SOL/OP,</td>
</tr>
<tr>
<td></td>
<td>o the formula result for each SOL/OP of the set,</td>
</tr>
<tr>
<td></td>
<td>o and the calculation of parameters value for the set of SOL/OP in CSV format (optional PDF, GEOJson)</td>
</tr>
<tr>
<td>4.6.9</td>
<td>The user must have an optimized &quot;user interface&quot; to work with up to 4 different parameters</td>
</tr>
</tbody>
</table>
3 Methodology for the incorporation of the CBA and SIA results into the GIS tool

3.1 Economic analysis

3.1.1 CBA
Some of the economic effects considered in the CBA conducted in the NeTIRail-INFRA WP1 accrue at the same time to different stakeholders. This is the case, for instance, of availability and punctuality, from which both IM and operating companies can benefit. However, for the sake of simplicity, we can break down economic effects of innovations into:

1) Effects on the infrastructure manager: cost variations;
2) Effects on the operating company: changes in availability and punctuality;
3) Effects on customers: socio-economic effects related to better service in general.

We focus on effect 1). Effect 2) would result on decrease of operating costs, amplifying the effects of 1) but not fundamentally changing them. Effect 3) is most difficult to generalize.

3.1.2 Cost variations
Establishing cost variations for the general case requires the following knowledge:

- What lines are likely to benefit from what innovation?
  - Necessary conditions: e.g. to benefit from trolley wire, a line must be non-electrified in the first place.
  - Knowledge about technical state and usage of lines can be derived from sources such as the European Register of Infrastructure (RINF). However, knowledge about technical details, such as type of fastenings, is not generally available. It is all the more true for immaterial processes (such as lean methods).
  - Consequently, the GIS tools will deliver an “optimistic” set of lines concerned.

- If the innovation were applicable and applied, what would be the cost variations?
  - Here, we expect to get the sign and order of magnitude right, which certainly is a tall order in economic sciences.
  - The GIS tool is expected to deliver figures per lines, and total figures for user-selected sets of lines.

3.1.3 Cost function, inputs and outputs
Maintenance costs (excluding renewals) are generally represented using a cost function \( C = f(T, X) \), where \( T \) is the traffic vector, and \( X \) the technical characteristics.
The traffic vector itself may consider train classes independently from each other; in the context of NeTIRail-INFRA, distinguishing freight from passenger trains would make sense: \( T = f(T_p, T_f) \). However, no innovation is linked with shifts in line usage (e.g. less passengers, more freight), so this distinction may appear superfluous in the limited context of the GIS application, where only cost \( variations \) are of interest.
Following Gaudry (2013), the technical characteristics vector $X$ can be broken down into two parts: state, $S$, and quality, $Q$, hence:

$$X = f(S, Q)$$

In the context of the GIS application, there is little hope to get and update track state characteristics on a large scale, but the application user may be interested in providing this information for the particular cases he considers. Moreover, most econometric studies relating railway infrastructure are national and concern one (national) infrastructure manager; the GIS application however does not focus on a particular country, company, and associated general price levels (materials and workmanship). The dependence of price upon national economies and company policies could be expressed, in general, by another vector $P$.

Overall, the GIS application should use a cost functional form with the shape:

$$C = f(T, S, Q, P)$$

This looks more complex than any of the forms published in literature, but the complexity is only apparent: vectors $T$, $S$, $Q$, $P$ are expected to be much simpler than in any of the specialized studies encountered.

### 3.1.3.1 Traffic vector

As stated, the primary effect of innovation would not be to change the “train mix”. Instead of considering train categories separately (such as Gaudry, 2013), the functional form could limit itself to using a scaling factor on the current train mix, expressed either in total number of trains, or total train mass.

Total number of trains is the information most easily captured by Infrastructure Managers; however, total train mass is most relevant to track maintenance cost estimates (while number of trains relates to operational costs), so we propose to simply use the scalar:

$$T = \text{total train mass} = \text{total number of trains} \times \text{average train mass}.$$

### 3.1.3.2 Quality vector

In the following, we will break it down into two parts, the quantitative (example: maximum allowed speed…) and the qualitative one (example: electrification system). For qualitative parameters, we will use dummy variables; see below.

### 3.1.3.3 State Vector

The individual state of repair of each particular line section cannot be documented in the database, we will use average costs (with / without innovation) as a basis.

### 3.1.3.4 Pricing vector

Maintenance costs are related to materials and workmanship, the latter with considerable national and company variations. The materials consumed for maintenance have various proportions of traded- and non-traded goods. In addition, maintenance services may be externalized (usually to companies having a subsidiary in the concerned country).

Bringing an innovation to a piece of infrastructure may affect the materials and workmanship cost separately, an aspect which is taken care of by the respective CBA. The problem, for the GIS application, would be to modulate the CBA results according to the country considered.
Lacking in-depth insight about the infrastructure costs in various countries, we suggest to use PPP (purchasing power parity) indexes for consumer goods, as published by OECD, as a simple correction.

3.1.4 Functional form

3.1.4.1 Choice of the functional form

Log-log functional forms are a commonplace in railway infrastructure marginal cost calculations; see for instance the overview provided by the CATRIN project (Mattias Haraldsson, 2008):

Table 14: Methodological approaches used in econometric rail cost studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Cost considered</th>
<th>Data type</th>
<th>Functional form</th>
<th>Number of trains/weight of trains distinction included</th>
<th>Input prices included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andersson (2006a and 2006b)</td>
<td>Sweden</td>
<td>Maintenance plus operations &amp; Maintenance plus Operations plus Renewals</td>
<td>Panel (Pooled OLS and Random effects)</td>
<td>Translog</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Tervonen and Idstrom (2004)</td>
<td>Finland</td>
<td>Maintenance and maintenance plus Renewal</td>
<td>Panel (Pooled OLS)</td>
<td>First order Double Log</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Gaudry and Quinet (2003)</td>
<td>France</td>
<td>Maintenance plus operations</td>
<td>Cross section</td>
<td>Unrestricted Generalized Box-Cox</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Marti and Neuenischwander (2006)</td>
<td>CH</td>
<td>All maintenance, track maintenance plus operations, and maintenance plus renewals</td>
<td>Panel (Pooled OLS)</td>
<td>First order Double Log</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Wheat and Smith (forthcoming)</td>
<td>UK</td>
<td>Maintenance</td>
<td>Cross-section</td>
<td>Double log with squared and cubic terms</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Source: Work carried out by Phil Wheat, ITS, University of Leeds.

As will become clear in the following, we are aiming at a “double log with (some) interaction terms” form. Setting up a more sophisticated functional form:
- Would require fundamental research not commensurate with our illustrative purpose;
- Would however NOT require any fundamental change in the GIS-based software we are proposing.

The Log-Log (or double log) model is problematic when some independent variable has frequent zero values (or negative values), in which case a variable transform would become necessary. That was the reason for Gaudry & Quinet adopting the more general Box-Cox transform, given that their studies considered the types of trains running over sections of lines, and some lines for instance would never see passenger trains, or high speed trains, etc. In our particular case, we already made sure that the traffic scalar could not be null, as
long as the line is under usage (which is a condition for getting significant maintenance costs).

3.1.4.2 Handling of innovations
NeTIRail-INFRA innovations are either present or not present; therefore it is natural to use dummy variables. NeTIRail-INFRA innovations are mutually independent (introducing one does not depend on another one pre-existing, and does not require another one to be also introduced or removed). Therefore each innovation will have its own associated dummy variable, with value 0 (“not applied”) or 1 (“applied”). Innovations requiring certain features to be present (as: trolley wire TW needs electrification EL) can be handled in two ways:
• (preferred) using the term TW * EL in the functional form;
• (fallback) blocking the innovation algorithmically: if (TW = 1 and EL = 0) then TW = 0

Incorporating the pre-condition in the functional form is the preferred solution, as all cost model information would remain in one place. Moreover, in our example case, electrification-related costs could broadly be categorized into two categories: AC and DC, since DC systems on main lines are usually more expensive than AC. In such case, one would introduce two dummy variables, AC and DC (and no variable, of course, for the non-electrified case). Different cost impacts of trolley wire for AC and DC would be expressed by the terms:

\[ \beta_{AC,TW} \cdot AC \cdot TW + \beta_{DC,TW} \cdot DC \cdot TW \]

In the following, the innovations vector will be designated IN.

3.1.4.3 Suggested functional form
Overall, the functional form has the following structure (the last term form pricing corrections):

\[ \log(C) = \beta_0 + \beta_T \cdot \log(T) + \sum_{i} \beta_i \cdot \log(Q_i) + \sum_{j} \beta_j \cdot Q_j + \sum_{k,n} \beta_{k,n} \cdot Q_k \cdot IN_n + \beta_P \]

The list of independent variables made available to the cost function is given in appendix.

3.1.4.4 Usage
The user shall be able to edit the independent variables and the relevant beta coefficients, but not (for the time being) to introduce new variables or coefficients. Suppression of variables, especially in cases where data are not homogeneous, is possible by nullifying (manually) the corresponding coefficients. Initial values have been determined, using the CBA results and former publications (see annex 1 to this Deliverable).

1 See for instance the ENE TSI impact assessment, ERA, 2008
3.2 Demonstrating the Socio-Economic Impact

The generalization of socio-economic impacts is not obviously done, since an important part of the impact assessments were based on survey results, rather than on generally available data.

Our final aim is to have a Web application which displays the results of the SIA for all the NeTIRail-INFRA case-study lines and which is able to calculate them for other lines, if survey data comparable to the ones from the NeTIRail-INFRA survey is available and users input them into the Web application. For the lines in which data is not available a provisory computation will be possible using an approximation method presented in section 3.9.2 below.

Summarizing, we will have three cases:

1) For the NeTIRail-INFRA passenger-dominated lines the web application will be able to operationalize empirical data from surveys and to display the results of the SIA carried out during the project;
2) For the other lines the web application will be able to compute the SIA of a given NeTIRail innovation if users input into the application data from surveys. To that purpose users can use the survey questionnaires developed in the project and reproduced in Appendix 2 of this Deliverable and rely on the methodology presented in the NeTIRail-INFRA D5.2;
3) Provisionally, as long as empirical data from surveys are not available, the Web tool will apply the approximation method presented in section 3.9.2 below.

3.2.1 Display of societal impact based on survey data

In this case (admin) users of the Web Application add for each line (SoL) data deriving from passengers’ surveys regarding in particular passengers’ perceptions and train use characteristics of a given line (for the survey results on the NeTIRail-INFRA case study lines see the NeTIRail-INFRA D5.2 “Perception of different service options: User study and data analysis”).

The application then computes the impact using the formula presented in D5.3.

The most general expression of this formula looks as follow:

\[
\text{Benefits} = \left( (S_{impact})(S_{perceptions})_{crowding} + \frac{(S_{impact})(S_{perceptions})_{comfort}}{3} + (S_{impact})(S_{perceptions})_{safety} \right) \cdot \left( (S_{impact})(S_{perceptions})_{punctuality} + \frac{(S_{impact})(S_{perceptions})_{frequency}}{3} + (S_{impact})(S_{perceptions})_{journey\ time} \right) \cdot S_{route}
\]

For each considered travel element (crowding, comfort, safety, punctuality, frequency of trains and journey time) the expected benefits are calculated tacking into account the expected impact of the innovation and passengers’ perceptions: \((S_{impact})(S_{perceptions})\).

The partial results of the impact assessment are then compounded with the use characteristics of the line \((S_{route})\). For further explanations on the assessment methodology see D5.3, Section 2.
3.2.2 Display of societal impact without survey data.

As long as survey data are missing, we can simplify as follows.

We assume, as a very rough, first approximation, that socio-economic impact of a given innovation would be proportional to the traffic it serves, i.e. passenger.km or ton.km. This of course ignores all possible non-linearities, e.g. resulting from:

- User experience: one incident may become a good story, repeated incidents may trigger class actions and modal shift;
- Reliability improvements on a network: for instance, if an innovation reduced the likelihood of a catenary failure over one span, the likelihood of catenary failure over one line (= a succession of spans) will decrease exponentially as further spans benefit from the innovation, and the passengers or customers will react accordingly.

The following non-monetary assessment will however be implemented by the GIS application:

1) User selecting a set of lines of interest or a specific route (this second option being in principle possible, even if not developed in the remaining timeframe of the NeTIRail-INFRA project);
2) User selecting one particular innovation;
3) Software checking lines where innovation is applicable, based on line characteristics (Q vector)
4) The results of the expected benefits weighted by the traffic are:

\[ \text{Impact} = \sum_{\text{segments}} B_{\text{innovation}} \cdot T_{\text{segment}} \cdot \text{Length}_{\text{segment}} \]

5) Since however the impact is expected to be displayed on a map, the route segment length is readily perceptible by the viewer. It is therefore more sensible to display the impact “per length unit”, preferably by using a color scale for the concerned sections of lines. The viewer will naturally integrate the impact over the apparent line length – the longer the route, the higher the impact. The formula to be evaluated would then be:

\[ \text{Impact per length unit} = \sum_{\text{segments}} B_{\text{innovation}} \cdot T_{\text{segment}} \]

It is important to stress that the mentioned benefits (“\(B_{\text{innovation}}\)” in the formula) here are not the benefits compounded by passengers’ perceptions and line use characteristics as they have been assessed in the NeTIRail-INFRA Deliverable 5.3 “Balancing societal effects and cost-benefit of different infrastructure decision”. Rather, they just include the expected benefits deriving from an innovation on selected travel elements, abstracting both from passengers’ perceptions and from line use characteristics.

For instance, the expected benefits of the innovation developed in the NeTIRail-INFRA T4.1 “On-track monitoring of turnouts S&C sections” on travel elements have been assessed as follows:
### Table 3.1 – Expected effects of the innovation in T4.1 “On-track monitoring of turnouts S&C sections” on travel elements: score „impact“

This means that implementing the innovation “On-track monitoring of turnouts S&C sections” is expected to have a high positive impact on safety and a medium positive impact on punctuality.

In this simplified assessment the values associated to the expected impact (fourth column of table 3.1 above) are multiplied by a figure relating to the traffic on that line ($T_{segment}$ in the formula above). These data are available, or can be derived, from the RINF database.

### 4 Selected line-scenarios data that can be demonstrated into the Web Application

In this section, we exemplify how the data from WP1 and WP5 can be prepared for being displayed into the Web Application.

#### 4.1 Cost benefit data

The generic cost function described under section 3.1.4 above is flexible enough to match most of the individual comparative cost analyses provided by deliverable D1.4. The purpose is not however to provide exactly the same results, but to provide correct orders of magnitude.

The CBAs provided under D1.4 provide sample cost values for determined track parameters (Q) and traffic levels (T). Generalisations to other cases are based on other sources, such as the “Baumgartner report” (Baumgartner, 2001). The latter document, though resting on non-published econometric analyses, has withstood the test of time concerning derivation of orders of magnitude. The general price level of course needs refreshing.
4.2 Societal benefits data

In this section we show how data for displaying the societal benefits are prepared in order to display into the GIS Web Tool of the NeTIRail-INFRA innovations if realised in the NeTIRail-INFRA case-study lines. As an exemplary case-study we use the innovation developed in T 4.1 “On-track monitoring of turnouts S&C sections” applied to the Bartolomeu-Zărneşti case-study line.

4.2.1 Display of societal impact based on survey data

The input data for the Web Application will look like this:

<table>
<thead>
<tr>
<th>INDICATOR QUALITY OF TRAVEL</th>
<th>Travel Elements</th>
<th>Expected Impact</th>
<th>Value assigned to the expected impact (innovation-specific)</th>
<th>Score “perceptions” (line-specific)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crowding</td>
<td>None</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Comfort</td>
<td>None</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>High</td>
<td>2</td>
<td>1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INDICATOR TRAVEL TIMES</th>
<th>Punctuality</th>
<th>Medium</th>
<th>1,5</th>
<th>1,5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency of trains</td>
<td>None</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Scheduled journey times</td>
<td>None</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4.1 – Input data for the innovation “On-track monitoring of turnouts S&C sections” applied to the line Bartolomeu-Zărneşti line (Romania)

The score “route” for the Bartolomeu-Zărneşti line, taking into account train use characteristics, is 2.75. For more details regarding the calculation of the scores s. D5.3, Section 3. Using the formula presented in Section 3.9.1 above, the Web Tool will then calculate the SIA for that innovation on that line and display it to the users.

5 Conclusions

This deliverable has shown how the results of the cost-benefit analysis and of the societal impact assessment can be presented into the GIS web tool. Even if not all the functions can be used in the current state of affairs, the NeTIRail-INFRA project provided:

- a set of methodology for assessing the expected costs of an innovation (s. D1.4 for a summary);
a methodology for assessing the social impact of given innovation, including the design of a survey to collect the necessary empirical input for the assessment (s. D5.2 and D5.3);

- a GIS web tool with a set of functionalities that can display the results of the CBA and the SIA for the NeTIRail-INFRA case-study lines and the technical infrastructure which enables the web tool to perform further tasks, including the calculation of CBA and SIA for other case-study line if users provide the necessary data as an input.

6 References


Mattias Haraldsson, Andrew Smith et al. (2008). Cost allocation practices in the European Transport sector (CATRIN project, deliverable D1).


Sabine Blum, Elisa Orrù (2017). Perception of different service options: User study and data analysis (NeTIRail-INFRA Project, Deliverable 5.2).

Elisa Orrù, Manuel Ojeda. Balancing societal effects and cost-benefit of different infrastructure decisions” ( NeTIRail-INFRA Project, Deliverable 5.3).


7 Annex 1: “Quality” variables

The variables below are a selection from the currently about 150 variables made available by the European Register of Infrastructure. The selection was made with the usability of these variables in mind, for establishing a cost function.

**IPP_TENClass**: Indication of the part of the trans-European network the line belongs to.
Single selection from the predefined list:
- Part of the TEN-T Comprehensive Network
- Part of the TEN-T Core Freight Network
- Part of the TEN-T Core Passenger Network
- Off-TEN

**IPP_LineCat**: Classification of a line according to the INF TSI. INF TSI classifies lines based on the type of traffic (traffic code). TSI categories of line shall be used for the classification of existing lines to define a target system so that the relevant performance parameters will be met.

Explanation on applicability:
Technical scope of the INF TSI now includes all the networks (TEN and off-TEN) for nominal track gauges 1435, 1520, 1524, 1600 and 1668 mm.

Single selection of the following traffic codes
- Passengers: P1, P2, P3, P4, P5, P6, P1520, P1600
- Freight: F1, F2, F3, F4, F1520, F1600

**IPP_FreightCorridor**: Indication whether the line is designated to a Railway Freight Corridor

Single selection from the predefined list:
- Rhine-Alpine RFC (RFC 1)
- North Sea-Mediterranean RFC (RFC 2)
- Scandinavian – Mediterranean RFC (RFC 3)
- Atlantic RFC (RFC 4)
- Baltic-Adriatic RFC (RFC 5)
- Mediterranean RFC (RFC 6)
- Orient-EastMed RFC (RFC 7)
- North Sea-Baltic RFC (RFC 8)
- Rhine – Danube RFC (RFC 9)

**IPP_MaxSpeed**: Nominal maximum operational speed on the line as a result of INF, ENE and CCS subsystem characteristics expressed in kilometres/hour.

**IPP_TempRange**: Temperature range for unrestricted access to the line according European standard.

Single selection from the predefined list:
- T1 (-25 to +40)
- T2 (-40 to +35)
- T3 (-25 to +45)
- Tx (-40 to +50)

**IPP_MaxAltitude**: Highest point of the section of line above sea level in reference to Normal Amsterdam’s Peil (NAP).
**ILL_InteropGauge**: Gauges GA, GB, GC, G1, DE3, S, IRL1 as defined in European standard. For the purpose of RINF only GA, GB, GC, G1, DE3, S, IRL1 were selected as interoperable gauges as they are the only gauges mentioned as performance parameters in CR INF TSI and HS INF TSI.

Single selection from the predefined list: GA, GB, GC, G1, DE3, S, IRL1, none

**ILL_MultiNatGauge**: Multilateral gauge or international gauge other than GA, GB, GC, G1, DE3, S, IRL1 as defined in European standard. For the purpose of RINF only G2, GB1 and GB2 were selected as multinational gauges as they are the only gauges mentioned as multinational/national agreements in the European standard.

Single selection from the predefined list: G2, GB1, GB2, none

**ILL_NatGauge**: Domestic gauge as defined in European standard or other local gauge.

Single selection from the predefined list: BE1, BE2, BE3, FR-3.3, PTb, PTb+, PTc, FIN1, Sec, DE1, DE2, Z-GCD, UK1, UK1[D], W6, F, S, GHE16, GEA16, GEB16, GEC16, IRL1, IRL2, IRL3

**ILL_ProfileNumSwapBodies**: Coding for combined transport with swap bodies as defined in UIC Code.

Single selection from the predefined list: C 22, C 32, C 38, C 45, C 50, C 55, C 60, C 65, C 70, C 80, C 90, C 341, C 349, C 351, C 357, C 364, C 380, C 385, C 390, C 395, C 400, C 405, C 410, C 420, other

**ILL_ProfileNumSemiTrailers**: Coding for combined transport for semi-trailers as defined in UIC Code.

Single selection from the predefined list: C 22, C 32, C 38, C 45, C 50, C 55, C 60, C 65, C 70, C 80, C 90, C 341, C 349, C 351, C 357, C 364, C 380, C 385, C 390, C 395, C 400, C 405, C 410, C 420, other

**ILL_GradProfile**: Sequence of gradient values and locations of change in gradient

**ILL_MinRadHorzCurve**: Radius of the smallest horizontal curve of the track in metres.

**ITP_NomGauge**: A single value expressed in millimetres that identifies the track gauge

Single selection from the predefined list: 750, 1000, 1435, 1520, 1524, 1600, 1668, other

**ITP_CantDeficiency**: Maximum cant deficiency expressed in millimetres defined as difference between the applied cant and a higher equilibrium cant the line has been designed for

**ITP_RailInclination**: An angle defining the inclination of the head of a rail relative to the running surface

**ITP_Ballast**: Specifies whether track construction is with sleepers embedded in ballast or not

**ISC_TLSWitchCrossing**: Switches and crossings are maintained to in service limit dimension as specified in TSI.

**IHS_LevelCrossing**: Indication whether level crossings exist on the section of line.

**ECS_SystemType**: Indication of the type of the contact line system.

Single selection from the predefined list: Overhead contact line (OCL), Third Rail, Fourth Rail, Not electrified

**ECS_VoltFreq**: Indication of the traction supply system (nominal voltage and frequency)
Single selection from the predefined list: AC 25kV-50Hz, AC 15kV-16.7Hz, DC 3kV, DC 1.5kV, DC (Specific Case FR), DC 750V, DC 650V, DC 600V, other

**ECS_MaxTrainCurrent**: Indication of the maximum allowable train current expressed in amperes.

**ECS_RegenerativeBraking**: Indication whether regenerative braking is permitted or not.

**ECS_MaxWireHeight**: Indication of the maximum contact wire height expressed in metres.

**ECS_MinWireHeight**: Indication of the minimum contact wire height expressed in metres.

**EPA_TSIHeads**: Indication of which TSI compliant pantograph heads are allowed to be used.

Single selection from the predefined list: 1950 mm (Type 1), 1950 mm (Type 1) with insulated horns, 1600 mm (EP), 2000 mm – 2260 mm, none

**EPA_OtherHeads**: Indication of which pantograph heads are allowed to be used.

Single selection from the predefined list: 1950 mm (Type2), 1950 mm (PL), 1800 mm (NO, SE), 1760 mm (BE), 1600 mm, (GB, CTRL), 1600 mm (GB), 1450 mm, other, none

**EPA_StripMaterial**: Indication of which contact strip materials are permitted to be used.

Single selection from the predefined list: copper, plain carbon, copper steel, copper alloy, impregnated carbon ([NN] % of metallic content), carbon with additive material, carbon with cladded copper, sintered copper, other

**CPE_Level**: ERTMS / ETCS application level related to the track side equipment.

Single selection from the predefined list: N, 1, 2, 3

**CPE_Baseline**: ETCS baseline installed lineside.

Single choice from the predefined list: prebaseline 2, baseline 2, baseline 3

**CPO_Installed**: Indication if other train protection, control and warning systems in normal operation are installed lineside.

**CTD_DetectionSystem**: Indication of types of train detection systems installed.

Single selection from the predefined list: track circuit, wheel detector, loop

**CTD_MinRimWidth**: Indication of width given in millimetres.

**CTD_MinWheelDiameter**: Indication of wheel diameter given in millimetres.

**CTD_MinFlangeThickness**: Indication of flange thickness given in millimetres.

**CTD_MinFlangeHeight**: Indication of height of flange given in millimetres.

**CTD_MinAxleLoad**: Indication of load given in tons.

**CBP_MaxBrakeDist**: The maximum value of the braking distance [in metres] of a train shall be given for the maximum line speed.

**IPL_TENClass**: Indicates the part of the trans-European network the platform belongs to.
Single selection from the predefined list:

- Part of the TEN-T Comprehensive Network
- Part of the TEN-T Core Freight Network
- Part of the TEN-T Core Passenger Network
- Off-TEN

**IPL_AssistanceStartingTrain**: Indication of existence of equipment or staff supporting the train crew in starting the train.

**ITU_EmergencyPlan**: Indication whether emergency plan exists.

**ITU_FireCatReq**: Categorisation on how a passenger train with a fire on board will continue to operate for a defined time period.

Single selection from the predefined list: A, B, none