# Assessment of unit costs (standard prices) of rail projects (CAPital EXpenditure)"

REGIO Rail Unit Cost Tool Instructions

*13th July 2018*

*Version 3.0*

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**pwc**

# Contents

# *Glossary*

| | |
|---|---|
| **Base Year** | Reference year for the costs of the project. |
| **Conventional line** | Railway lines with a maximum speed of 249 km/h for new lines and 199 km/h for upgraded lines. |
| **ERTMS/ECTS level** | The ERTMS/ETCS functional level employed in the railway. |
| **High Speed** | New lines designed for speeds equal to or above 250 km/h and upgraded existing lines for speeds equal to or above 200 km/h ; |
| **Maximum axial load** | The maximum axle load of the railway determines the strength of the track. |
| **Maximum slope** | The "maximum slope" represents the "steepest climb" between two points on a railroad and it dictates how powerful the locomotive must be in order to complete the run without assistance. |
| **Minor structures** | Minor structures which are significantly smaller than the other structures in the project and which have only a marginal impact on the total cost. Examples of minor structures are pipes, boxes and small bridges. |
| **New Line** | Project related to the deployment of a new railway line or to the deployment of additional tracks on an existing line; |
| **Operation type** | The operation type of the railway line (or section). The possible options are: freight, pax, mixed (pax/freight) |
| **Project ID** | Standard identification code assigned to the project by the EC; |
| **Project Title** | Name of the project; |
| **Railway speed category** | Speed category of the project analysed. The possible options are either *High speed* or *Conventional* |
| **Rehabilitation** | Project aimed to reinstall the design capacity of an existing line which has worsened in quality due to a lack of sufficient maintenance. Rehabilitation can also refer to works that are executed to make an existing line compliant with new EU regulations; |
| **Signalling, electrification, telecommunication** | Projects related to the deployment of a signalling system, telecommunication and/or electrification system along a railway line. |

| | |
|---|---|
| **Traction power** | The type of traction power of the railway line. The traction power should be one of the following options: Diesel, electric, mixed. |
| **Upgrade** | Project aiming to improve the original design parameters of an existing line, usually in terms of capacity or speed; |

# 1. Introduction

This guide is designed to support the users of the REGIO Rail Unit Cost Tool (hereunder also referred to as RRUCT or the Tool) in the compilation of the necessary inputs and in the interpretation of the outputs. It presents practical examples and screenshots from the Tool to allow for a better and simpler understanding of the process.

The aim of the REGIO Rail Unit Cost Tool is to aid the assessment of investment costs in rail infrastructure projects. Specifically, the Tool performs two activities a benchmarking analysis and forecasting. The former verifies whether the investment cost of a rail infrastructure project is comparable to the investment cost of similar projects. The latter supports the evaluation of infrastructure investments by providing cost estimation of the project and of each cost component. The projects used for the analysis are identified on the basis of the factors that impact the investment cost, thus the **technical characteristics** of the railway line (e.g. category of works, line category, structures included in the investment, etc.) and the **external conditions of the project** (e.g. geographical features of the construction site, presence of urban environment, etc.).

Therefore, the REGIO Rail Unit Cost Tool allows its user to:

- Calculate the unit cost of the different cost items which make up the investment cost (i.e. base infrastructure, signalling, permanent way, etc.);

- Forecast the cost of a rail infrastructure investment;

- View the positioning of the specific infrastructure in comparison with similar projects;

- Receive a set of indicators per infrastructure category type that are identifying eventual criticalities, if individual cost elements appear to be out of the average ranges of the benchmark.

It is worth highlighting that the Tool is designed as a **support** for **benchmarking and assessment activities** and **cannot replace the cost analysis of the construction works which shall be carried out during planning and design phases.** The RRUCT cannot substitute a detail assessment of an investment and it does not include a risk assessment exercise.

The REGIO Rail Unit Cost Tool is not designed to identify *wrong* cost estimates in application forms for European Commission financial support. The Tool is designed to spot unexpected cost variations in rail infrastructure projects, which are not included in the usual range of cost variations of similar projects. It does not mean that a project with unexpected high or low unit cost values is poorly evaluated; it may nonetheless require detailed explanations to make sure that the reasons leading to such exceptional unit cost values are known and can be duly controlled.

# 1.1. How the RRUCT works

The REGIO Rail Unit Cost Tool enables the user to perform two different activities:

1. Benchmarking a project (i.e. insert the technical details and costs of a project not yet included in the database connected to the Tool);
2. Forecasting rail infrastructures cost (i.e. based on the comparable projects included in the database, derive median values for overall unit costs).

## 1.1.1. Benchmark

The processes underlying these functions are displayed in the figures below.

*Figure 1 - The algorithm of the BENCHMARKING TOOL– Process 1: Evaluate new project*
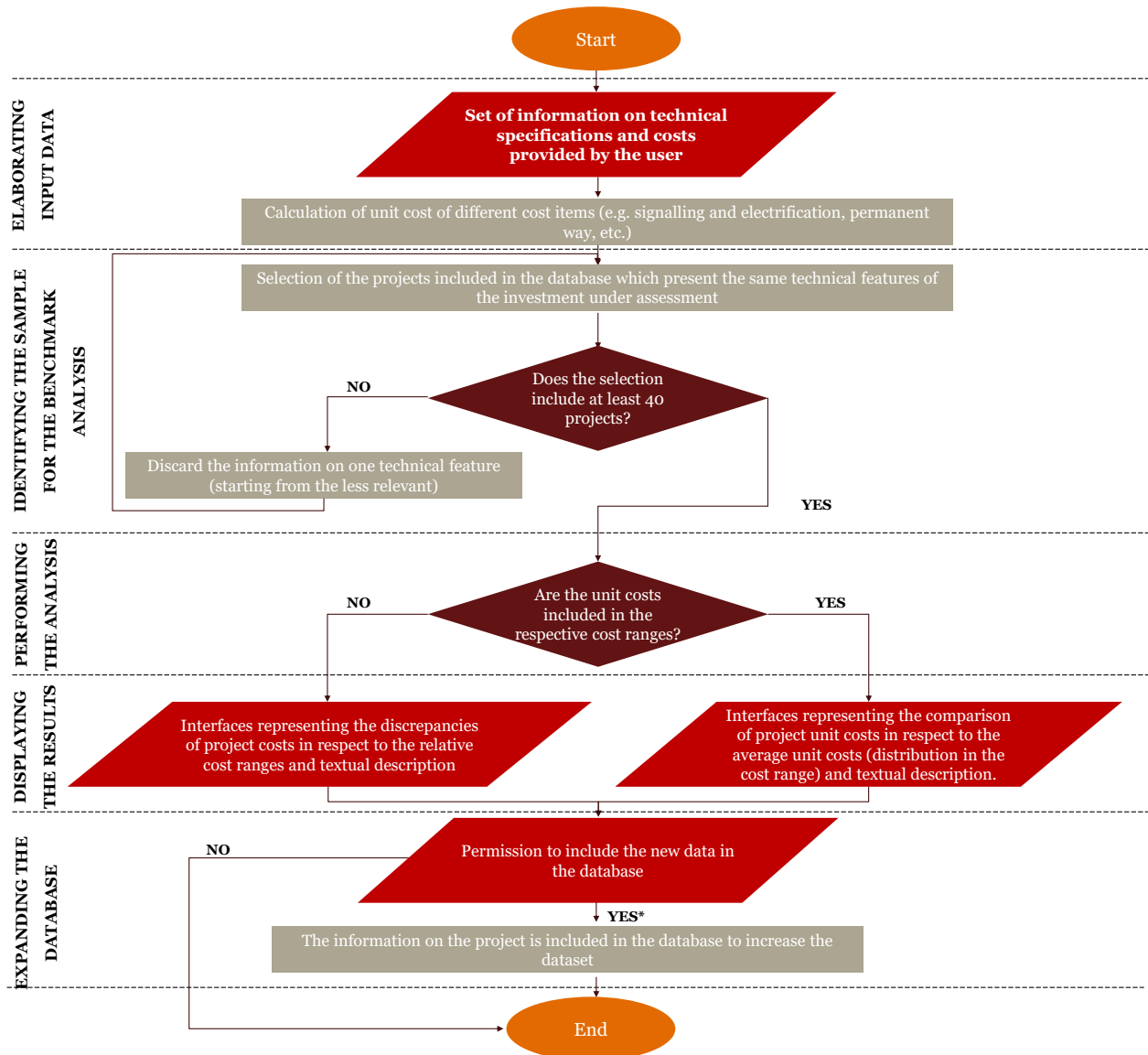


The activities included in this process be classified into five main phases:

1. **Elaborating input data.** The REGIO Rail Unit Cost Tool is composed of several masks and interfaces to enable the user to input the information concerning the investment under evaluation. In order to have valid results, a minimum set of information must be input depending on the type of infrastructure.

2. **Identifying the sample for the benchmark analysis**. The REGIO Rail Unit Cost Tool applies the clustering logic and identifies the sample of projects to perform the benchmarking analysis on.

3. **Performing the benchmark analysis**. The REGIO Rail Unit Cost Tool considers the unit cost of the projects included in the sample selected to define the unit cost range used for the benchmark. Specifically,

   o   the minimum and the maximum values encountered in the sample correspond to the extreme values of the range;

   o   all other values are considered to identify the quartiles, the median and the mean of the distribution and to calculate the position of the unit cost of the investment under assessment within this range.

   The analysis concerns different cost items, depending on the infrastructure category and the input provided by the user, and proceeds the analysis in order of increasing level of detail (from total cost to each individual cost item).

4. **Displaying the results.** The REGIO Rail Unit Cost Tool compares the unit cost of the investment under assessment with that of the selected sample and displays the results.

   Additionally, the REGIO Rail Unit Cost Tool provides an indication of the expected variation of final cost from the estimated cost provided, based on the analysis of historical data.

5. **Expanding the database.** Once the analysis is completed, the user has the possibility to expand the database with the data related to the investment previously assessed. This is also possible in case the investment's results fall outside the cost ranges identified. Indeed, this does not necessarily mean that the cost of the investment is not appropriate according to its characteristics and/or is wrongly estimated. It may be the case that the project presents specific characteristics which justifies the higher or lower cost.

*Figure 2 - The algorithm of the BENCHMARKING TOOL– Process 2: Add final cost*
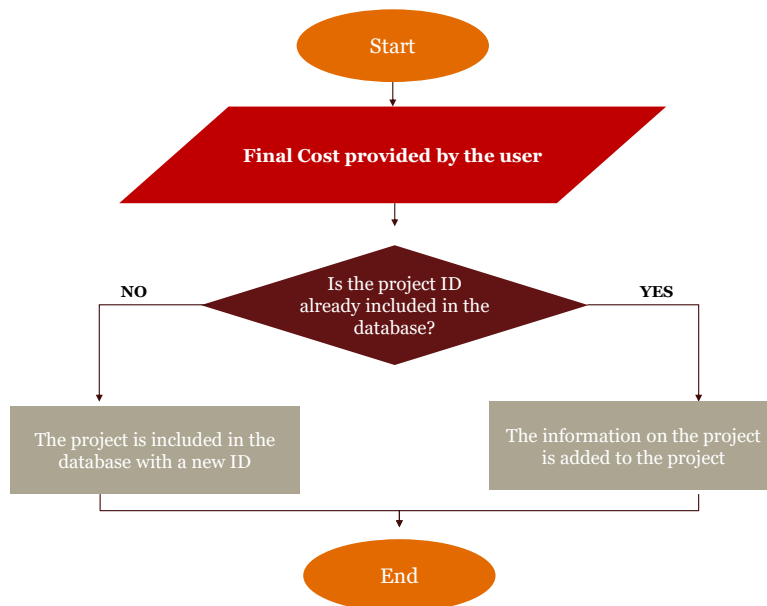


The process enables the user to complement the information included in the database. The data on the final cost of a project can be inserted through a specific form, by specifying the project ID. The REGIO Rail Unit Cost Tool checks if the project is in the database (by verifying the project ID) and stores the information in the database.

## *1.1.2. Forecast*

The REGIO Rail Unit Cost Tool following the same logics of the Benchmarking tool, take four actions.

1. **Elaborating input data.** An input mask enable the user to input the information concerning the technical characteristic of the project.

2. **Identifying the sample for the forecasting**. The REGIO Rail Unit Cost Tool applies the clustering logic and identifies the sample of projects to perform the forecasting.

3. **Performing the forecasting**. The REGIO Rail Unit Cost Tool considers the unit cost of the projects included in the sample selected to define unit cost ranges.

    The analysis concerns different cost items and proceeds with an increasing level of detail (from total cost to each individual cost item).

4. **Displaying the results.** The REGIO Rail Unit Cost Tool select the cost information of projects with the characteristic provided by the user and displays the results of the forecast.

*Figure 3 - The algorithm of the BENCHMARKING TOOL (Forecast)*



8
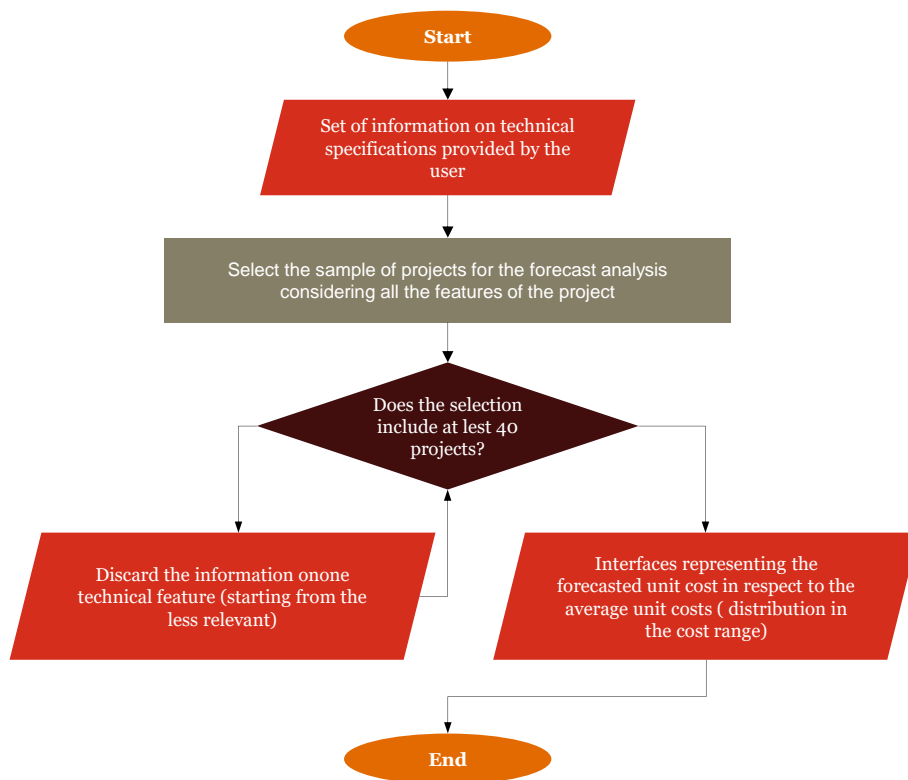
# 2. The structure of the RRUCT user guide

## 2.1. The structure of the document

The structure of the document follows the structure of the Tool.

Firstly, the home page of the tool is presented (section **Home page**). In this page, the user can select which of the activity he/she wants to undertake, i.e. evaluate a new project or forecast.

In order to make the description as clear as possible, the information has been grouped based on the two actions of the Tool: Benchmark and Forecast.

The following section (section **Data input**) presents the different spreadsheets that are displayed to the user in the data input phase:

**Benchamark**

1. General_Project Info;
2. Project_Info (tech);
3. Project_Info (cost);
4. Final cost input (This spreadsheet is displayed in case the users choose to use the function "or just insert the project outturn cost" from the General Project Info).

**Forecast**

5. Configuration interface

At the beginning of each section, the overview of the spreadsheet is presented, specifying the main elements of the interface. A detailed description of each element is provided in the subsequent paragraphs.

The last section (section **Guide to output understanding)** presents a detailed description of the outcomes of the evaluation and provides instructions on how these should be interpreted. Also in this case, the information is provided for each action.

Orange boxes with this symbol ⚠ are used to highlight elements requiring the user to pay particular attention.

## 2.2. Before you start

There are few notes below to help the user with the correct compilation of the Tool:

- All costs should be **VAT excluded and in M€**;

- The cells where inputs can be included are **unlocked**. Unlocking the Tool to insert manually data on locked cells would not work.

- The **asterisk (*)** denotes mandatory fields; the mandatory fields are the minimum set of information to be fulfilled in order to perform the analysis on the selected project;

- **The input part of all the sheets is structured with the following main columns:**

   o **FIELD:** the cell field defines the input field to be selected;

   o **VALUE**: the cell value requires the input data. Depending on the field the input data can be selected from a numerical value, i.e. money amount, where the number format of the cell is a Currency, or a drop-down menu.

- To perform a benchmark analysis that has a validity at EU level, the estimated investment cost inserted by the user is normalised by a specific index (wherefore the unit cost displayed in the benchmark outcomes often slightly vary from the actual unit cost input).

**The tool aims to develop an analysis that has validity on a European level, therefore, a tailored approach to normalise the differences between the economies of the European MS has been adopted. Based on the literature review carried out and the analysis of the methodology followed by similar assignments, a mixed approach has been employed to ensure to account for the national and time differences:**

- **Normalisation based on Purchasing Power Parity (PPP) rates, aims to convert all costs in a fictional currency that represents the (weighted) average of the EU28 countries in terms of purchasing power parity (EUR EU28). The normalisation enables to take into account the differences encountered in the analysis of investments carried out in different countries and in different time periods.**
- **Normalisation based on inflation, aims to adjust costs incurred in different years to values relative to one base year. The inflation adjustment factors are based on the producer price index of each country.**

**For further information on the normalisation and PPP methodologies, please consult the Final report**

# 3. Home page

## Rail Unit Cost Tool

Benchmark

Forecast

*Powered by* pwc
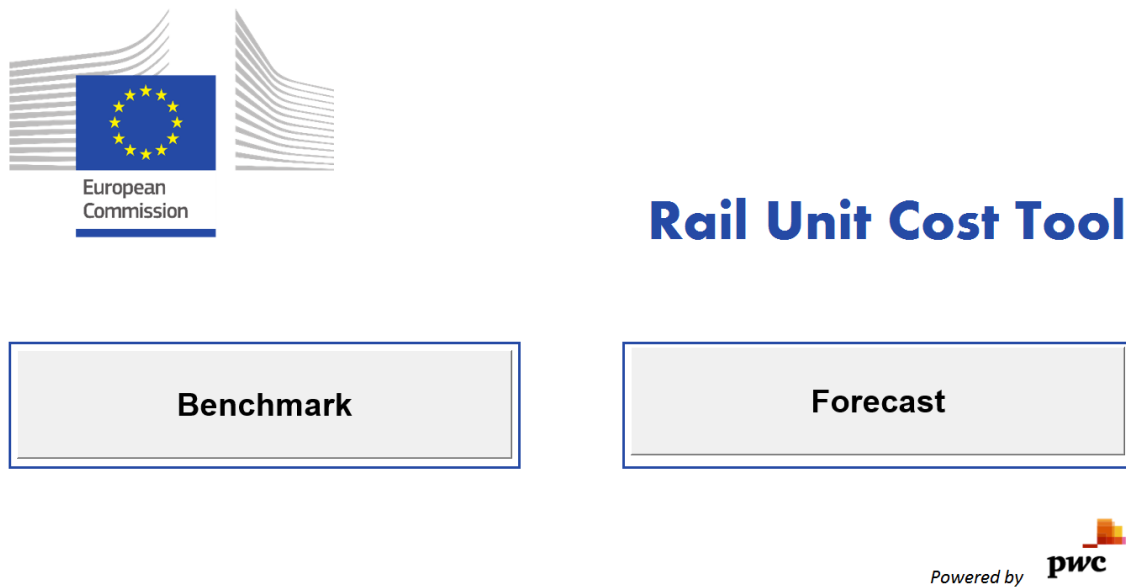
## 3.1. Activity selection

The user should click the button specifying the activity he/she wants to undertake.

- **Benchmark.** The user can use the Tool to compare the investment cost of a railway infrastructure project with the investment cost of projects sharing similar technical characteristics.

- **Forecast.** Users can input the main characteristics of the desired infrastructure project, the Tool will return the average costs that projects with similar characteristics have.

# 4. Data Input

## 4.1. Benchmark

### 4.1.1. General Project Info

*Figure 5: Overview of the General Project Information sheet and main elements*
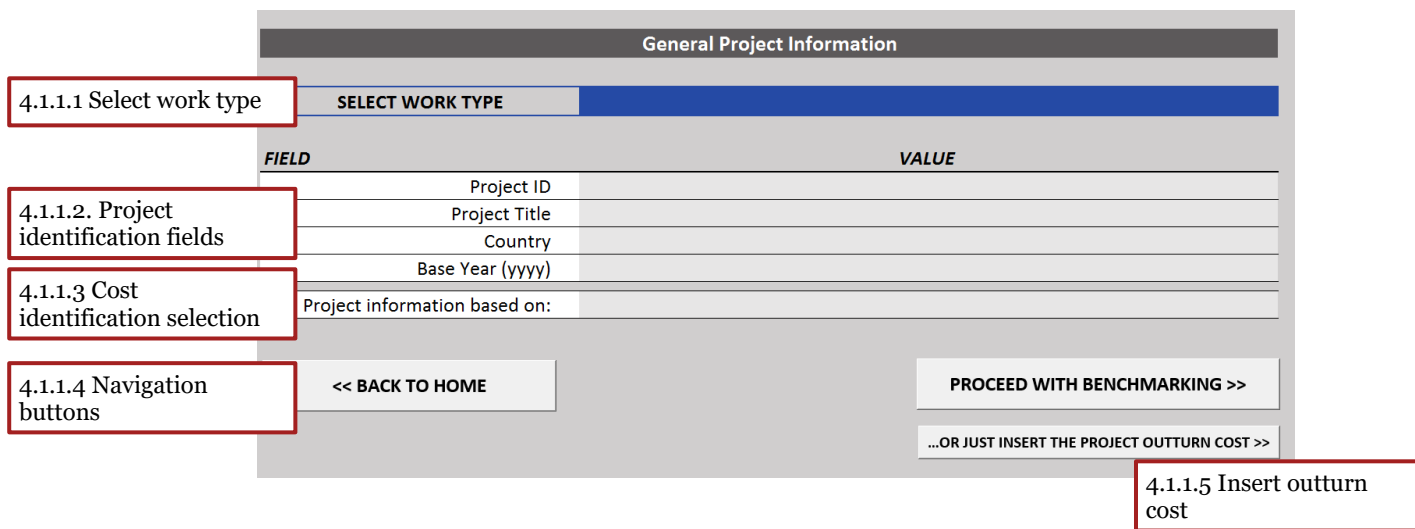


The general information spreadsheet (**1.Gen. Project Info**) requires as input the basic information of the project to be analysed as outlined in the following paragraphs.

### 4.1.1.1. Select work type

The **SELECT WORK TYPE** field requires to select the type of work performed on the line from a drop-down menu (see Figure 6).

The user should select one of the four options available based on the objective of the project:

- **NEW LINE:** project related to the deployment of a new railway line or to the deployment of additional tracks on an existing line;

- **REHABILITATION:** project aimed to reinstall the design capacity of an existing line which has worsened in quality due to a lack of sufficient maintenance. Rehabilitation can also refer to works that are executed to make an existing line compliant with new EU regulations;

- **UPGRADE:** project aiming to improve the original design parameters of an existing line, usually in terms of capacity or speed;

- **SIGNALLING, ELECTRIFICATION, TELECOMMUNICATION:** projects related to the deployment of a signalling system, telecommunication and/or electrification system along a railway line.

## 4.1.1.2. Project identification fields

The information on these fields refer to the name of the project, the country where it is located and the reference year of the investment cost as specified below:

- **Project ID:** requires the standard identification code assigned to the project by the EC;

- **Project Title:** requires to specify the name of the project;

- **Country:** requires to specify the country where the project is located (from a drop-down menu). In case of cross-border projects or projects located in more than one country, the project should be entered in the Tool as two (or more) separate projects, one for each country;

- **Base Year (yyyy):** requires to select the reference year for the costs of the project. It is important to insert a coherent value, as this is considered in the choice of the normalisation factor applied to the project cost.

⚠️
- **All the costs of a project inserted in the Tool should refer to the same base year.**
- **The Tool cannot evaluate projects whose base year is in the future.**

## 4.1.1.3. Cost identification selection

Users need to select the type of cost information they would like to input form the scroll down menu.

- **Estimated cost:** rail investment cost reported in the feasibility study or assessed in the planning & design phase.

- **Final cost:** outturn cost related to the actual sum disbursed for the implementation of the rail project.

*Figure 7 Cost identification selection*

### 4.1.1.4. Navigation buttons

- **NEXT** button: once all **General Project Information** fields are compiled, the user can proceed with inserting data on the technical features and cost of the project by clicking the NEXT button. This way he/she is redirected to the next spreadsheet (see section 4.1.2).

- **BACK TO HOME** button: by clicking on this button, the user is redirected to the home page of the REGIO Rail Unit Cost Tool.

### 4.1.1.5. Insert outturn cost

The user can complement the data included in the database connected to the Tool by inserting the final cost of a project already included in the database. When the user click to the button the Final cost input page will open.

## 4.1.2. Project Info (tech)

By clicking the **NEXT** button, the **1.Gen. Project Info** spreadsheet will be hidden, whilst the **2.Project_Info (tech)** will appear. The **2.Project_Info (tech)** spreadsheet allows to enter the technical information and is customised for each work type selected. The name of the sheet includes the name of the selected work type, e.g. by selecting NEW LINE as work type, the name of the spreadsheet will be: 2.Project NEW LINE Info (tech).

*Figure 8: Project_Info (tech) spreadsheet overview and main elements*

4.1.2.1 Home

4.1.2.2 Project summary

4.1.2.3 Navigation buttons

4.1.2.5 Project features

4.1.2.4 Technical characteristics input fields

4.1.2.6 Characteristics of the environment

4.1.2.7. Structures included in the project

4.1.2.8. Insert further details button

4.1.2.9. Detail input fields*

*These fields are not displayed if the user does not click the INSERT FURTHER DETAILS button

## 4.1.2.1. Home

By clicking the HOME button, the user is redirected to the home page of the Tool.

> ⚠️
> - **If the user goes back to the home page, all data previously inserted is deleted**

## 4.1.2.2. Project summary

The section **Project Summary** in the top left corner of the **2.Project_Info (tech)** spreadsheet displays the general information on the project, specified in the previous spreadsheet (**1.Gen. Project Info**. The Project Summary fields are <u>not</u> input fields, and should <u>not</u> be modified on the **2.Project_Info (tech)** spreadsheet.

## 4.1.2.3. Navigation buttons

- **BACK button.** Once the **2.Project_Info (tech)** sheet is selected, it will still be possible to change the input of the of the **1.Gen. Project Info** sheet by clicking on this button.

- **NEXT button.** Once the user has inserted complete and coherent information on the technical characteristics of the project, this button enables to shift to the following sheet to insert the information on the cost of the project (see section 4.1.3).

## 4.1.2.4. Technical characteristics input fields

The input interface of the **2.Project_Info (tech)** spreadsheet is divided into the following main boxes:

- **Project features;**

- **Characteristics of the environment;**

- **Structures included in the project.**

Each field is further divided into additional input fields as described in the following paragraphs.

> ⚠
> - **The technical features input section is tailored based on the project work type (e.g. for the category "signalling, electrification, telecommunication" the section on "Structures included in the projects" is not displayed).**

## 4.1.2.5. Project features

*Figure 9: Project features input box*



| FIELD | VALUE | DESCRIPTION |
|---|---|---|
| **Project features** | | |
| Railway speed category* | | |
| Maximum design speed* | | |
| Operation type* | | |
| Traction power* | | |
| Maximum axial load* | | |
| Maximum slope* | | |
| **Project length*** | | |
| Kilometres of single track line | | |
| Kilometres of double track line | | |
| Kilometres of three-track line | | |
| Kilometres of four-track line | | |
| Kilometres of five-track line | | |

The input box for the ***Project features*** requires the following technical information on the project to be inserted:

- **Railway speed category***: the speed category of the project analysed should be selected from a drop-down menu, between the following options:

  - **High Speed**: new lines designed for speeds equal to or above 250 km/h and upgraded existing lines for speeds equal to or above 200 km/h[1];

  - **Conventional:** all the other design speeds  (up to 249 km/k for new line and up to 199 km/h for upgraded lines).

- **Maximum design speed* [km/h]**: The maximum design speed should be selected from a drop-down menu between the following ranges[2]:

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[1] www.uic.org/highspeed

[2] The ranges have been taken from: *Guidance on the Conventional Rail and High Speed Infrastructure Technical Specifications for Interoperability (TSI)*

- **< 120 km/h**
- **120 km/h**;
- **160 km/h**;
- **200 km/h**;
- **250 km/h**
- **>= 300 km/h**.

- **Operation type**: the operation type of the railway line (or section) should be selected out of three options from a drop-down menu:

  - **Freight:** the option Freight should be selected if the railway line is designed for the operation of freight trains only;

  - **Pax**: the option Pax should be selected if the railway line is designed for the operation of passenger trains only;

  - **Mixed (pax/ freight)**: the option Mixed (pax/ freight) should be selected if the railway line is designed for the operation of both freight and passenger trains.

- **Traction power**: the operation type of the railway line (or section) under analysis should be selected from the following options:

  - **Diesel:** the option diesel should be selected if the railway line is designed for the operation of diesel trains only;

  - **Electric:** the option electric should be selected if the railway line is designed for the operation of electric trains only;

  - **Mixed (diesel – electric):** the option Mixed (diesel – electric) should be selected if the line has been partially designed for diesel trains and partially for electric trains.

- **Maximum axial load  [t/m]**: the maximum axial load (expressed in tonnes per meter) should be selected form a drop-down menu containing four ranges[3]:

  - **< 6.4 t/m** (up to 6.40 tonnes/meter);

  - **6.40 – 7.19 t/m** (between 6.40 and 7.19 tonnes/meter);

  - **7.20 – 8.00 t/m** (between 7.20 and 8.00 tonnes/meter);

  - **> 8.00 t/m** (more than 8.00 tonnes/meter).

- **Maximum slope [‰]:** The "maximum slope" represents the "steepest climb" between two points on a railroad and it dictates how powerful the locomotive must be in order to complete the run without assistance. The maximum slope (expressed in part per thousand) of the railway line should be selected form a drop-down menu covering three ranges:

  - **< 15‰** (less than 15‰);

  - **15‰  - 25‰** (between 15‰ and 25‰ );

  - **> 25‰** (more than 25‰).

- **Project Length [km]:** the project length subsection requires the length of the project under investigation as input per number of tracks:

  - **Kilometres of single track line [km]:** includes the length (in kilometres) of single track sections included in the project;

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[3] Guide for the application of the INF TSI – European Railway Agency

- **Kilometres of double track line [km]:** includes the length (in kilometres) of double track sections included in the project ;

- **Kilometres of three-track line [km]:** includes the length (in kilometres) of three-track sections included in the project ;

- **Kilometres of four-track line [km]:** includes the length (in kilometres) of four-track sections included in the project;

- **Kilometres of five-track line [km]:** includes the length (in kilometres) of five-track sections included in the project.

## 4.1.2.6. Characteristics of the environment

*Figure 10: Characteristics of the environment input box*



The following environmental characteristics of the project can be inserted:

- **Share of project in urban environment [%]:** the cell should be filled with the percentage of the length of the line (percentage on the total length) passing through a urban environment (i.e. characterised by contiguous built-up areas, where houses are typically not more than 200 m apart);

- **Share of project in mountainous terrain [%]:** the cell should be filled with the percentage of the length of the line (percentage on the total length) running in mountainous terrain (higher than 600 m above sea level);

- **Share of project in hilly terrain [%]:** the cell should be filled with the percentage of the length of the line (percentage on the total length) running in hilly terrain (between 200 and 600 m above sea level);

- **Share of project in flat terrain [%]:** the cell should be filled with the percentage of the length of the line (percentage on the total length) running in flat terrain (lower than 200 m above sea level).

> ⚠
>
> - **The sum of the fields indicating the percentage of the project in mountainous, hilly and flat terrain should be equal to one, meaning that the terrain characteristics are defined for 100% of the line under analysis.**

## 4.1.2.7. Structures included in the project

The input box on structures included in the project requires the number (and length) of the structures included in the project to be analysed.

*Figure 11: Structures included in the projects input box*



The following input data should be provided:

- **Number of tunnels*[#]:** the cell should be filled with the number of tunnels included in the project; in case no tunnels are included in the project, <u>the cell should be filled with the number zero</u>;

- **Total length of tunnels [km]:** the cell should be filled with the total length of tunnels included in the project. This length refers to the length of the tunnel itself, not the railways within, therefore if a tunnel is 6 km long and it contains 2 lines, the input value in this cell should still be 6 km. In case of two double bored tunnels of 6 km each, the input value should be 12 km (i.e. 6 km per tunnel times 2 tunnels).

- **Number of bridges and viaducts*[#]:** the cell should be filled with the number of bridges and viaducts included in the project. <u>In case no bridges and/or viaducts are included in the project, the cell should be filled with the number zero</u>;

- **Total length of bridges and viaducts [km]:** the cell should be filled with the total length of bridges and viaducts included in the project;[4]

- **Number of stations* [#]:** the cell should be filled with the number of stations and yards built/ upgraded/ rehabilitated within the project. <u>In case the project does not entail works to build / upgrade/ rehabilitate stations and/ or yards, the cell should be filled with the number zero</u>.

> ⚠
> - **The section "structures included in the projects" is not displayed if the work type category "signalling, electrification, telecommunication has been selected".**
>
> - **The fields number of tunnels/ bridges and viaducts/stations are mandatory. If they are left blank, the system does not allow the user proceed with the data input when clicking the NEXT button. In case no tunnels/ bridges and viaducts/stations are included in the project the user should fill these fields with the number zero.**
>
> - **In case the number of tunnels/ bridges and viaducts/stations is higher than zero, the length of the tunnels/ bridges and viaducts/stations should be specified. Otherwise, the system does not allow the user proceed with the data input when clicking the NEXT button.**
>
> - **The fields length of tunnels/ bridges and viaducts refer to the length of the structures. They do NOT refer to the length of the line included. In case two parallel structures are built (e.g. two single bored tunnels), the length should be the sum of the length of the two structures.**

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[4] This refers to the length of the bridges and viaducts only, not the railways on them.

## 4.1.2.8. Insert further details button

This button enables to show additional fields where the user can insert data on the single cost-elements included in the project.

## 4.1.2.9. Detail input fields

This section is displayed when the user clicks on the INSERT FURTHER DETAILS button.
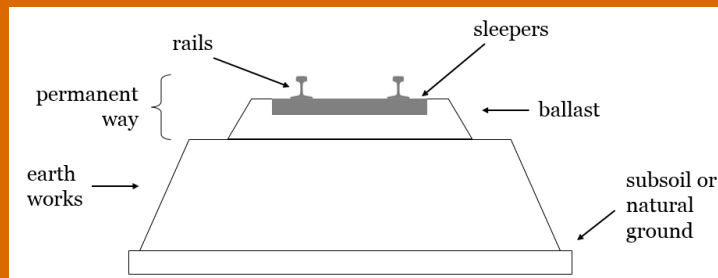
*Figure 12: Detail input boxes*

> ⚠️
> - **The information on the technical characteristics (and cost) of the earthworks and permanent way should be inserted considering the scheme below.**
>
> *Figure 13: Earthworks and permanent way scheme*
>
> 
>
> - ○ **Permanent way: finished trackbed of a railway together with the track and includes: subgrade, ballast, sleepers, rails and fastenings, switches, turnouts and related assembly, tune and finishing operations**
> - ○ **Earthworks: tracking, roading, cleanfill sites, cut and fill operations, quarrying/ mining and transport and re-contouring.**

### EARTHWORKS AND MINOR STRUCTURES

The input box "Earthworks and minor structures" requires the input data on minor structures, interfaces and earthworks included in the project, as shown in Figure 14.

*Figure 14: Earthworks and minor structures input box*



The following input data can be provided:

- **Number of minor structures [#]:** the cell should be filled with the number of minor structures built/ upgraded/ rehabilitated within the project (i.e. pipes, boxes, small bridges, etc. with a length significantly smaller than the other structures in the project and which have only a marginal impact on the total cost);

- **Number of interfaces [#]:** the cell should be filled with the number of interfaces built/ upgraded/ rehabilitated within the project, i.e. access ways for passengers and goods, including access by road and access for passengers arriving or departing on foot;

- **Km of single/double/three-track/four-track/five-track (earthworks) [km]:** specify the length in kilometres of works related to tracking, roading, cleanfill sites, cut and fill

operations, quarrying/ mining and transport and re-contouring included in the project. The user should specify the kilometres of earthworks performed on single/double/three-track/four-track or five-track sections of the project.

## PERMANENT WAY

*Figure 15: Permanent way input box*



The "Permanent way" subsection requires as input the length and type of the permanent way included in the project analysed:

- **Permanent way type:** the permanent way type can be selected from **Ballasted**, **Slab Track** and mixed (**Ballasted and Slab Track**) though a drop-down menu;

- **Km of single track line (permanent way) [km]:** includes the length in kilometres of permanent way constructed/ upgraded/ rehabilitated in single track sections of the project;

- **Km of double track line (permanent way) [km]:** includes the length in kilometres of permanent way constructed/ upgraded/ rehabilitated in double track sections of the project;

- **Km of three-track line  (permanent way) [km]:** includes the length in kilometres of permanent way constructed/ upgraded/ rehabilitated in three-track sections of the project;

- **Km of four-track line  (permanent way) [km]:** includes the length in kilometres of permanent way constructed/ upgraded/ rehabilitated in four-track sections of the project;

- **Km of five-track line  (permanent way) [km]:** includes the length in kilometres of permanent way constructed/ upgraded/ rehabilitated in five-track sections of the project;

- **Does the work include stations? [Y/N]:** the user should specify whether the works on the permanent way entail (or not) works partially or completely performed in a railway station and/ or yard.

## ELECTRIFICATION

*Figure 16: Electrification input box*



The electrification[5] subsection requires as input the length of electrification included in the project analysed:

---

[5] The electrification includes the works related to the whole electrification system, thus also to OCL (Overhead Contact Line)

- **Km of single track line (electrification) [km]:** includes the length in kilometres of electrification works performed in single track sections of the project;

- **Km of double track line (electrification) [km]:** includes the length in kilometres of electrification works performed in double track sections of the project;

- **Km of three-track line (electrification) [km]:** includes the length in kilometres of electrification works performed in three-track sections of the project;

- **Km of four-track line (electrification) [km]:** includes the length in kilometres of electrification works performed in four-track sections of the project;

- **Km of five-track line (electrification) [km]:** includes the length in kilometres of electrification works performed in five-track sections of the project;

- **Works on electrification structures? [Y/N]:** the user should specify whether the electrification works entail (or not) works on one or more electrical substation (i.e. traction substations) and/or spot interventions (i.e. not related to the electrification of the railway line).

### SIGNALLING

*Figure 17: Signalling input box*



The signalling[6] subsection requires as input the data on the signalling works included in the project analysed:

- **ERTMS/ECTS level:** specify the ERTMS/ETCS functional level (level 1, level 2 or level 3);

- **Km of single track line (signalling) [km]:** includes the length in kilometres of signalling works performed on single track sections of the project;

- **Km of double track line (signalling) [km]:** includes the length in kilometres of signalling works performed on double track sections of the project;

- **Km of three-track line (signalling) [km]:** includes the length in kilometres of signalling works performed on three-track sections of the project;

- **Km of four-track line (signalling) [km]:** includes the length in kilometres of signalling works performed on four-track sections of the project;

- **Km of five-track line (signalling) [km]:** includes the length in kilometres of signalling works performed on five-track sections of the project;

- **Works on signalling structures? [Y/N]:** the user should specify whether the signalling works entail (or not) works on one or more signalling structures (i.e. interlocking, radio block centres, etc.) and/or spot interventions (i.e. not related to the deployment of the signalling system on the railway line).

---

[6] The signalling includes the costs related to the equipment installed on the track, stations/control points for managing the train movement and for guaranteeing that passengers and freight can be transported with as little risk as possible

- **Works on signalling in stations? [Y/N]:** the user should specify whether the signalling works entail (or not) works to deploy signalling equipment within a station.

*Figure 18: Telecommunication input box*

| Telecommunication | |
|---|---|
| Km of single track line (telecom.) | |
| Km of double track line (telecom.) | |
| Km of three-track line (telecom.) | |
| Km of four-track line (telecom.) | |
| Km of five-track line (telecom.) | |
| Works on telecom. structures? | |

The telecommunication[7] subsection requires as input the length of telecommunication included in the project analysed:

- **Km of single track line (telecommunication) [km]:** includes the length in kilometres of telecommunication works performed on single track sections of the project;

- **Km of double track line (telecommunication) [km]:** includes the length in kilometres of telecommunication works performed on double track sections of the project;

- **Km of three-track line (telecommunication) [km]:** includes the length in kilometres of telecommunication works performed on three-track sections of the project;

- **Km of four-track line (telecommunication) [km]:** includes the length in kilometres of telecommunication works performed on four-track sections of the project;

- **Km of five-track line (telecommunication) [km]:** includes the length in kilometres of telecommunication works performed on five-track sections of the project analysed;

- **Works on telecom. structures?:** the user should specify whether the telecommunication works entail (or not) works on one or more telecommunication structures (e.g. radio towers, etc.) and/or spot interventions (i.e. not related to the deployment of the telecommunication system on the railway line).

**FENCING**

*Figure 19: Fencing input box*

| Fencing | |
|---|---|
| Kilometres of fencing | |

The fencing[8] subsection requires the length of fencing works included in the project as input:

- **Kilometres of fencing [km]:** includes the total length in kilometres of fencing deployed within the project.

## 4.1.2.10. Technical details on tunnels

Technical details on tunnels is an additional box which is not mandatory, and is presented only for the projects which contain tunnels (i.e. only if the values in the fields **number** and **total km of tunnels** in the project features section are higher than zero).

---

[7] Telecommunication includes the works related to telecommunication and Public Address System installations on the open track, in stations and in marshalling yards;
[8] Fencing includes costs to protective barriers, noise barriers, doors, or windows

The box on technical details on tunnels is further comprised of 13 different input fields:

- **Number of cut & cover tunnels [#]:** number of tunnels which are excavated in a trench and roofed over with concrete support. These artificial tunnels are significantly different from excavated tunnels.

- **Km of cut & cover tunnels [km]:** kilometres of cut & cover tunnels included in the project.

- **Cut & cover tunnels geotech:** geotechnical conditions of cut & cover tunnels as defined at international level by the Rock Mechanic Classification systems (RMC) as RMR, GSI, Q system. A value from the drop-down menu must be selected. These are the possible options:

  - **Very bad -** crushed or highly disturbed rock fragments even sheared, rock filling, debris;

  - **Bad -** poorly interlocked intact rock blocks intensely disturbed by many discontinuities or sheared;

  - **Fair -** many interlocked intact rock blocks with several systems of ubiquitous discontinuities;

  - **Good -** well interlocked intact rock blocks with systematic ubiquitous discontinuities;

  - **Very good -** massive hard rock bodies with few large spaced discontinuities.

- **Num. of tunnels conventional excavation [#]:** number of tunnels excavated with conventional tunnelling methods included in the project.

- **Km of tunnels conventional excavation [km]:** kilometres of the previously mentioned tunnel type included in the project.

- **Tunnel conventional structure:** the cell requires the user to select the structure of the conventional tunnel from the dropdown menu. The options are:

  - **Single bored-** single tunnel, with a clear section of approximately between eight and twelve metres;

  - **Double bored –** two twin parallel tunnels which are part of the same railway line.

- **Tunnel conventional diameter [m]:** diameter of the conventional tunnels in meters.

- **Conventional tunnel geotech:** geotechnical conditions of conventional tunnels as defined at international level by the Rock Mechanic Classification systems (RMC) as RMR, GSI, Q system. A value from the drop-down menu must be selected as previously described under Cut & cover tunnels geotech.

- **Num. of tunnels mechanised excavation [#]:** number of tunnels constructed with mechanised tunnelling methods within the project.

- **Km of tunnels mechanised excavation [m]:** Length (in kilometres) of the previously mentioned tunnels with mechanised excavation.

- **Tunnels mechanised structure:** the cells requires the user to select the structure of the mechanised tunnel from the dropdown menu, as previously mentioned in Tunnel conventional structure.

- **Tunnel mechanised diameter [m]:** diameter of the mechanised tunnel in meters.

- **Mechanised tunnel geotech:** Geotechnical conditions of mechanised tunnels as defined at international level by the Rock Mechanic Classification systems (RMC) as RMR, GSI, Q system. A value from the drop-down menu must be selected as previously described in Cut & cover tunnels geotech.

## 4.1.3. Project_Info (cost)

By clicking the **NEXT** button, the **2.Project_Info (cost)** will appear. The **2.Project_Info (cost)** spreadsheet allows the user to enter the cost information and is customised to each work type selected. The name of the sheet includes the name of the selected work type, e.g. by selecting NEW LINE as work type, the name of the spreadsheet will be: 2.Project NEW LINE Info (cost).

*Figure 21: Project_Info (cost) spreadsheet*



The spreadsheet interface is similar to the one relative to the technical specifications.

The input interface of the **2.Project_Info (cost)** spreadsheet is divided into two main boxes:

- **Project cost;**

- **Structures included in the projects.**

In case technical information on the different cost items of the project is provided in the 2.**Project_Info (tech)** sheet, additional fields are displayed, to insert the investment cost of:

- **Earthworks and minor structures;**

- **Superstructure;**

- **Technical details on tunnels.**

### 4.1.3.1. Project summary and home

See section 4.1.2.1 and 4.1.2.2.

### 4.1.3.2. Navigation buttons

- **BACK button.** Once the 2.**Project_Info (cost)** sheet is selected, it will still be possible to change the input of the **2. Project_Info (tech)** sheet by clicking on this button.

- **NEXT button.** Once the user has inserted complete and coherent information on the technical cost of the project, this button enables to shift to the next sheet, which presents the outcomes of the evaluation (see section 5).

### 4.1.3.3. Project cost

*Figure 22: Project cost input box*



The input box for the **Project cost** requires the following technical information on the project to be inserted:

- **Total cost of the project\* [M EUR]:** is the overall cost for the project and **it must be equal to the sum of the costs for Planning and Design, Construction and Ancillary**.

- **Cost of construction works\* [M EUR]:** consists of the costs for the construction of the project components.

- **Cost of the planning & design\* [M EUR]:** includes costs related to opportunity study, preliminary design, feasibility study, and final/detailed design of the project.

- **Cost of ancillary works [M EUR]:** includes costs that do not belong to any of the previously stated categories, but have significant influence on the total project cost. It is composed of the sum of the cells described below: indirect costs, land acquisition cost, contingencies, project management.

    - **of which indirect costs [M EUR]:** indirect cost of the project (e.g. cost of archeologic works included in the project);

    - **of which land acquisition cost [M EUR]:** cost of the land acquisition;

    - **of which contingencies [M EUR]:** cost of contingencies of the project;

    - **of which project management [M EUR]:** cost of project management and publicity measures.

## 4.1.3.4. Structures included in the projects

The input box on the structures included in the project requires to insert the costs of the structures included in the project, as shown in Figure 23.

*Figure 23: Structures included in the project input box*

```
Structures included in the project
A.1. Cost of works for tunnels*
A.2. Cost of works for bridges/ viaducts*
A.3. Cost of works in stations*
```

The following input data should be provided:

- **Cost of works for tunnels\* [M EUR]:** the user should insert the total cost of the tunnels whose length and number were specified in the Info_tech (cost) sheet (see section 4.1.2.7);

- **Cost of works for bridges/viaducts\* [M EUR]:** total construction cost for all the bridges and viaducts whose length and number were specified in the Info_tech (cost) sheet (see section 4.1.2.7);

- **Cost of works in stations\* [M EUR]:** Include only costs related to the infrastructure of the stations (Station Yards included) whose number was specified in the Info_tech (cost) sheet (see section 4.1.2.7).

## 4.1.3.5. Detailed cost fields



Earthworks and minor structures

**Earthworks and minor structures**
minor structures
interfaces
A.6. Cost of earthworks

Superstructure

*Permanent way*
A.7. Cost of the permanent way works

*Electrification*
A.8. Cost of electrification on tracks
A.9. Cost of electrification structures

*Signalling*
A.10. Cost of signalling on tracks
A.11. Cost of signalling structures

*Telecommunication*
A.12. Cost of telecom on lines
A.13. Cost of telecom structures

*Fencing*
A.14. Cost of fencing

Cost details on tunnels*

A.1.1. Cost of cut & cover tunnels
A.1.2. Cost of tunnels classic excavation
A.1.3. Cost of tunnels excavated with TBM

*This section is displayed only if the fields Km of cut & cover tunnels/ Km of tunnels classic excavation/ Km of tunnels excavated with TBM are higher than zero.

**EARTHWORKS AND MINOR STRUCTURES**

The input box on the costs of earthworks and minor structures requires to fill in the grey cells with information on the cost minor structures, interfaces and earthworks cost, as shown in Figure 24.

*Figure 24: Earthworks and minor structures input box*



**Earthworks and minor structures**
A.4. Cost of minor structures
A.5. Cost of interfaces
A.6. Cost of earthworks

The following input data can be provided:

- **Cost of minor structures:** include the cost of minor and hydraulic structures included in the project which number was specified in the Info_tech (cost) sheet (see section 4.1.2.8);

- **Cost of interfaces:** includes the cost of the interfaces and interferences included in the project which number was specified in the Info_tech (cost) sheet (see section 4.1.2.8);.

- **Cost of earthworks:** includes the cost of earthworks which lenght was specified in the Info_tech (cost) sheet (see section 4.1.2.8).

**SUPERSTRUCTURE**

The input box on superstructures includes the input data on the cost for the permanent way, electrification, signalling, telecommunication and fencing as shown in Figure 25.

*Figure 25: Superstructures input box*



The following input data can be provided:

- **Permanent way:** include the cost of permanent way works which characteristics were specified in the Info_tech (cost) sheet (see section 4.1.2.9);

- **Electrification:** include the cost of electrification works which characteristics were specified in the Info_tech (cost) sheet (see section 4.1.2.9);

- **Signalling:** include the cost of signalling works which characteristics were specified in the Info_tech (cost) sheet (see section 4.1.2.9);

- **Telecommunication:** include the cost of telecommunication works which characteristics were specified in the Info_tech (cost) sheet (see section 4.1.2.9);

- **Fencing:** include the cost of fencing which characteristics were specified in the Info_tech (cost) sheet (see section 4.1.2.9).

**TECHNICAL DETAILS ON TUNNELS**

*Figure 26: Cost details on tunnels*

The input box on the cost details on tunnels requires information on:

- **Cost of cut & cover tunnels [M EUR] –** in this field, the cost of the cut & cover tunnels – which characteristics were specified in the Info_tech (cost) sheet (see section 4.1.2.10) – should be included.

- **Cost of tunnels conventional excavation [M EUR] –** in this field, the cost of the tunnels using conventional excavation methods should be included – which characteristics were specified in the Info_tech (cost) sheet (see section 4.1.2.10).

- **Cost of tunnels mechanised excavation [M EUR] –** in this field, the cost of the tunnels excavated using mechanised excavation should be included – which characteristics were specified in the Info_tech (cost) sheet (see section 4.1.2.10).

## *4.1.5. Final Costs Input*

The Final cost input spreadsheet (**1.Ins. Final Cost**) enables the user to insert the final costs of a project which is already included in the Database.

*Figure 27 – Final cost input box*



## 4.1.5.1. Project identification data

The user should insert the project ID. Once the Project ID has been inserted, the full **Project Title will be automatically retrieved from the database.**

## 4.1.5.2. Planned cost

The planned cost [M EUR] is automatically displayed by the Tool in case the project is already included in the database.

## 4.1.5.3. Final cost

The Final Cost should be manually inputted.

## 4.1.5.4. Insert final cost button

Once the user has inserted the final cost of the project, he/she can conclude the process by clicking the button "INSERT FINAL COST". That will allow to include the Final Cost in the database and update the project details.

# 4.2. Forecast

## 4.2.1. Configuration interface

The configuration interface is the input page of the forecasting tool. This page gives the possibility to the user to select the technical characteristic of the project, of which the user would like to forecast the unit cost.

*Figure 28 Configuration interface*



When a technical characteristic is selected the clicked button become green, highlighting the selected choice.

*Figure 29 Example of configuration*



## 4.2.1.1. Work category

The work category button indicates the different types of works that can be undertake: New line, Upgrade, Rehabilitation and Signalling, Electrification and Telecommunication. Users can select only one work category. The selection of a category deselected automatically the previous selection.

*Figure 30 Work category box*



## 4.2.1.2. Country

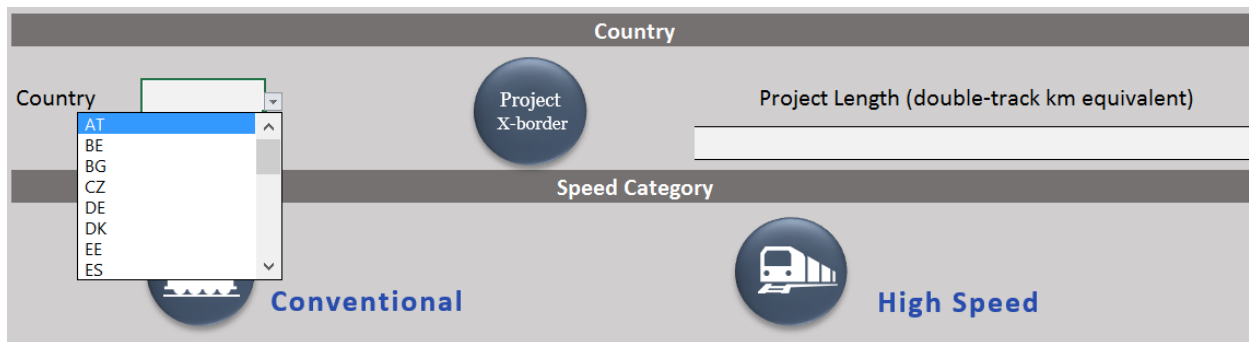The country selection box gives the possibility to the users to select the country of the project. The user requires to specify the country where the project is located (from a drop-down menu).

*Figure 31 Country selection*



In case of cross-border projects or projects located in more than one country, the user should select the button "Project X-border". Once the cross border button is selected the Tool will automatically change the country button and provides the possibility to indicate which countries the project is insisting on and the percentage of the project that has been deployed in those specific countries.

*Figure 32 Cross border selection*
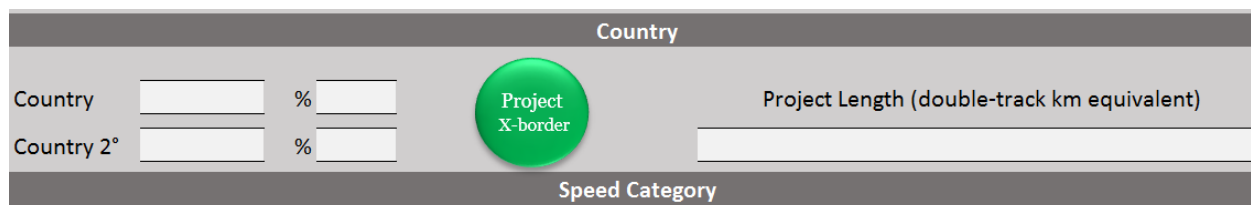


## 4.2.1.3. Project length

In the country box, in addition to the indication on the country of the project, users are required to insert the project length. The project length, which the user would like to estimate the cost for, needs to be provided in double track km equivalent.

*Figure 33 Project length box*



## 4.2.1.4. Speed category

The speed category box require users to indicate the speed category of the project that they would like to forecast. The two options are; Conventional or High speed.

*Figure 34 Speed category box*
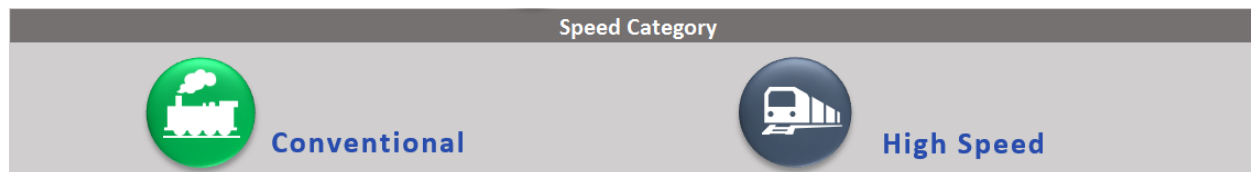


The selection of a category deselected automatically the previous selection.

## 4.2.1.5. Operation type

Users need to select the operation type of the investment they would like to forecast. Users can select one of the option of both, in case the rail infrastructure is mixed (passengers and freight). If the work category

selected is "Signalling, Electrification and Telecommunication" the operation type is not relevant. Therefore, users can select neither Passengers nor Freight. In case the user selects the operation type first, once the "Signalling, Electrification and Telecommunication" button is selected, the tool will automatically deselect the operation type button.

*Figure 35 Operation type box*



## 4.2.1.6. Type of environment

The information of the type of environment provide an indication of the environment and the terrain type. The information are not mandatory, therefore, users can leave the buttons unselected.



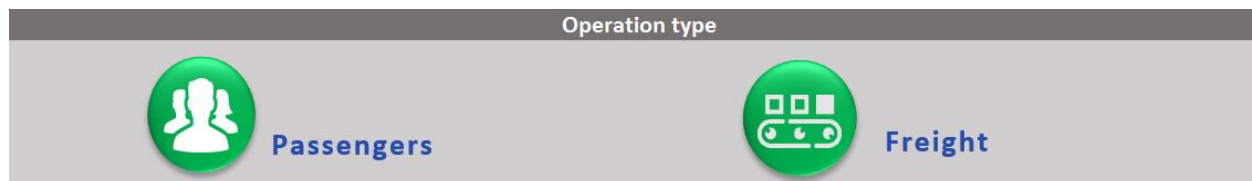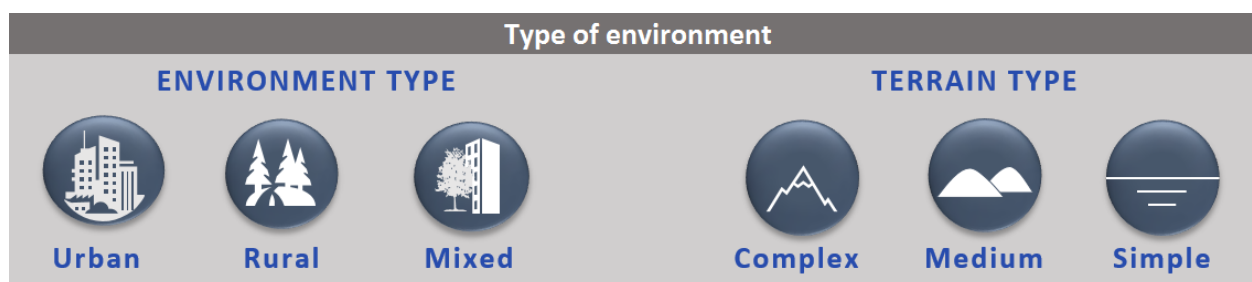**Environment type:** describes the different type of environment in which the line pass through. Three options are available, predominantly urban, predominantly rural and mixed. The selection of a category deselected automatically the previous selection.

**Terrain type:** the terrain type describes the complexity of the terrain in which the rail infrastructure is built. Also in this case three options are provided; complex, medium, and simple.

- The complex terrain is predominantly mountainous and/or has a particular characteristic that leads to the realization of the project particularly demanding.

- The medium terrain is predominantly hilly and/or has a particular characteristic that leads to the realization of the project averagely demanding.

- The simple terrain is predominantly flat and/or has particular characteristic that lead the realisation of the project easily.

The selection of a category deselected automatically the previous selection. If the work category selected is "Signalling, Electrification and Telecommunication" the type of environment is not relevant. Therefore, users can select neither Environment type nor Terrain type. In case the user selects the Type of environment first, once the "Signalling, Electrification and Telecommunication" button is selected, the tool will automatically deselect the Type of environment buttons.

# 5. Guide to output understanding

## 5.1. Benchmark output

Once all the inputs on the technical and cost data have been inserted, and it is selected whether to benchmark with estimated cost observations only or with both final and estimated costs, the Tool opens a new sheet with the results of the benchmark for the respective project. This section will explain how to read and understand those results. At this stage it is also possible to add the project to the database and thereby include it in the dataset for future benchmarks.

An example of the project benchmarking is reported in the paragraph (within the yellow boxes) to clarify the logic of the REGIO Rail Unit Cost Tool step-by-step and to help the user in the interpretation of the results. The example of the benchmarking is obtained by populating the Tool with the data of a fictional project (Example #1).

### 5.1.1. Summary overview

The initial interface that appears is depicted in Figure 36 below. It presents the share of the investment cost allocated to the different works/ elements of the project and the summary of the benchmark analysis.

*Figure 36 – Summary overview*
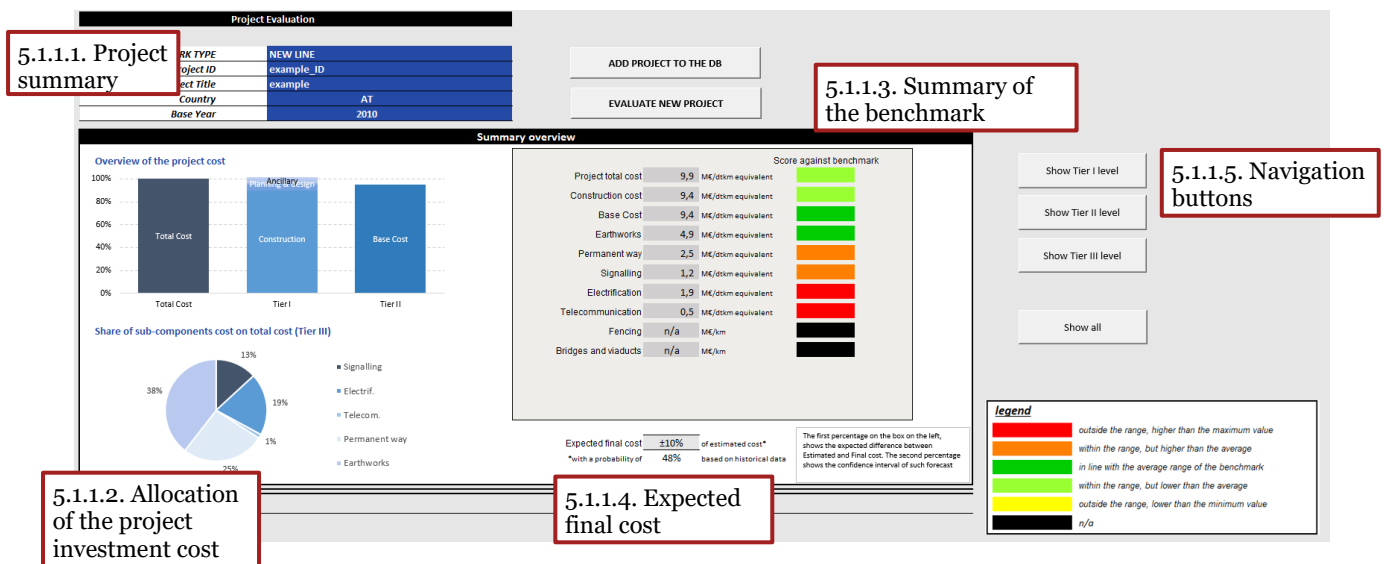


## 5.1.1.1. Project summary

The summary of the project's basic information (**Project Summary**) is reported in the upper left-hand side of the spreadsheet. In particular, the work type, the project ID, the project title, the country and the base year of the project are reported in the blue cells within the summary.

*Figure 37 – Project summary*

| Project Evaluation | |
|---|---|
| **Project Summary** | |
| *WORK TYPE* | NEW LINE |
| *Project ID* | Ex1 |
| *Project Title* | Example #1 |
| *Country* | it |
| *Base Year* | 2009 |

⚠

- **This box is not an input box and is not an editable field. Yet, in case**
    - o **the user wants to add the project to the database; and**
    - o **the project ID coincides to the project ID already included in the database; and**
    - o **the user does not want to overwrite the project already included in the database**

**the user has the possibility to modify the data in the project ID field.**

## 5.1.1.2. Allocation of the project investment cost

In the chart on the upper left-hand side (**Overview of the project cost**), in Figure 38, the user can see the percentage breakdown of the project costs into the different Tier I and Tier II elements, more specifically, how much of the total cost is attributed to ancillary, planning & design, and construction cost (Tier II), as well as how much of the construction cost is allocated to the construction of stations, tunnels, bridges and viaducts and to the base infrastructure.

*Figure 38 - Overview of the project cost bar chart*
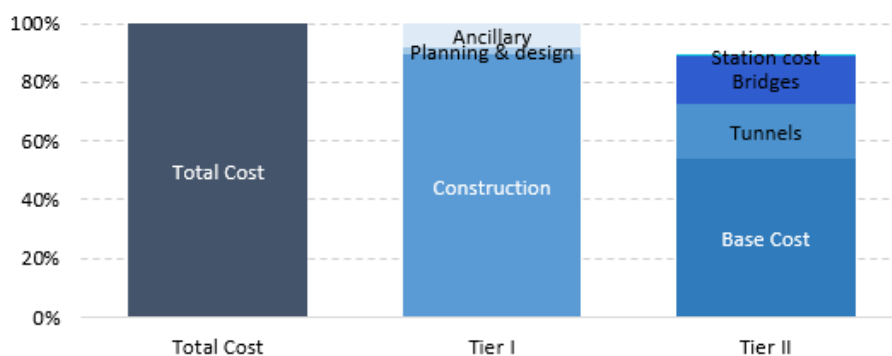
## Interpreting the results

For the project analysed (*Example #1*) the total cost is allocated as follows:

- 89 % to construction cost;

- 8% to ancillary cost;

- 3% to cost for planning and design activities.

The Tier II bar chart focuses on the percentage of the total cost allocated to big structures and to the base infrastructure cost;

- The base infrastructure cost represents 54% of the total cost;

- The tunnels cost represents 19% of the total cost;

- The bridges cost represents 16% of the total cost; and

- The station cost represents less than 1% of the total cost.

The sum of the abovementioned cost components is equal to the share of the construction cost on the total cost of the project (89%).

Below this chart, the share of the individual components of the base infrastructure cost is displayed in form of a pie chart to show their proportion among each other (**Share of sub-component costs on total cost**). The percentages do not have to add up to 100%, as they represent the percentage of each element of the total cost and not of their sum.

*Figure 39 - Share of Tier III components*
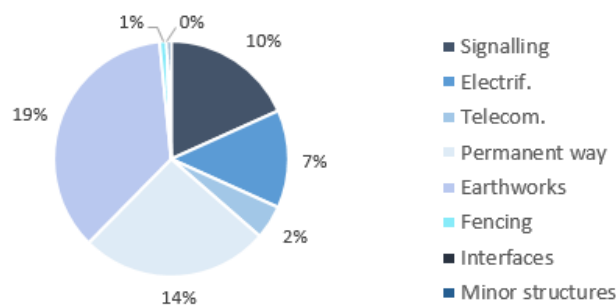


The aim of the pie chart is only to present visually the information that the user filled out, and therefore, no benchmark with similar projects is presented.

## 5.1.1.3. Summary of the benchmark analysis

On the right-hand side of those two graphs, the user can find the numerical values of the unit cost per double-track kilometre of the line along with a three-colour scale that functions as a quick indicator as to whether the unit cost is in line with the average range of the benchmark for comparable projects.

*Figure 40 - Unit Cost Quick Chart*
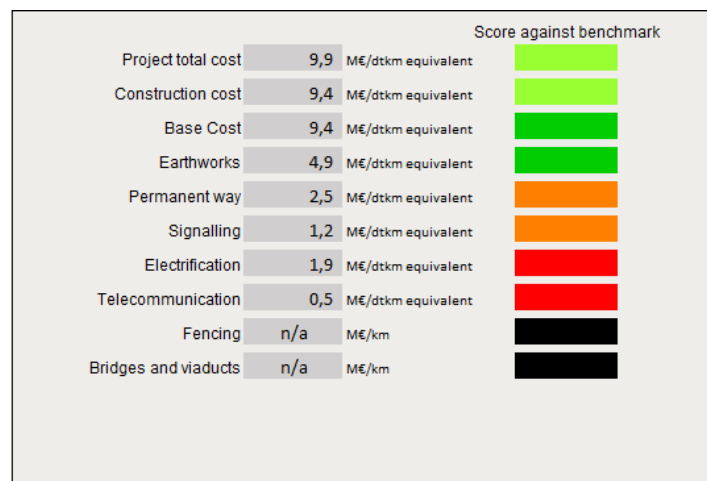


The RRUCT is able to perform an immediate benchmark analysis for each component, which results are presented by the following colours:

- **Green indicator:** the unit cost of the investment is included within the average range of the benchmark;

- **Light green indicator:** the unit cost of the investment is in the range but lower than the average range of the benchmark;

- **Orange indicator:** the unit cost of the investment is in the range but is higher than the average range of the benchmark;

- **Yellow indicator:** the unit cost of the investment assessed falls outside the cost range derived from the sample of similar projects analysed, the value is lower than the minimum value

- **Red indicator:** the unit cost of the investment assessed falls outside the cost range derived from the sample of similar projects analysed, the value is higher than the maximum value

- **Black indicator:** in case no detail is provided to assess the project component against the benchmark, the coloured box would be black.

The legend of the colour indicators is reported on the right-hand side of the box.

Additionally, a tolerance range is provided in which the final cost will most likely fall, along with the probability of that happening, which is measured on the data of estimated and final costs already in the database. To improve this data over time, the Tool has the functionality to add the final cost to a completed project at a later stage.

## Interpreting the results

The results of the evaluation performed by the REGIO Rail Unit Cost Tool represent **the positioning of the unit cost of the project assessed within the distribution of the unit cost of similar projects.**

These results do not provide a measure of the quality of the project or of the cost estimates (e.g. a red-coloured indicator for the category signalling does not imply that the cost of the signalling system of the project has been poorly estimated).

An overview on the interpretation of the results of the analysis is provided below:

- a green-coloured indicator means that the unit cost of the project assessed is close to the median of the unit cost of comparable projects carried out in the past. Thus, the unit cost is close to its expected value (calculated considering the cost of previous projects);

- a yellow-coloured indicator means that the unit cost of the investment evaluated diverges considerably from the median of the distribution, yet is comprised between its extreme values.

- The divergence may have different explanations. Firstly, the user should verify the values of the distribution and how far is the unit cost of the investment from the central share of the distribution. This way he/she can assess the magnitude of the divergence and consider if it can be considered negligible.

  Secondly, the user should check the characteristics of the sample used for the benchmark. To perform a reliable analysis, the REGIO Rail Unit Cost Tool may have disregarded some of the cost drivers that impact on the cost of the investment assessed (as outlined in section *Analysing uniform clusters of projects*). These may be the cause of the divergence.

  a red-coloured indicator means that the unit cost of the investment assessed is lower (or higher) than the minimum (or maximum) value encountered in the distribution of the unit cost of comparable projects. As for the other scores, this indicator does not imply that the cost has been poorly estimated. It is necessary to investigate the reasons for the unexpectedly low or high value which may be justified by specific conditions which were not encountered for the project included in the database. In case no possible reason is identified it may be necessary to ask further information to the project promoter to determine whether the cost has been under- (or over-) estimated.

## 5.1.1.4. Expected final cost

At the bottom of the *Summary of the benchmark analysis* there is a quick chart, which presents the *expected final costs*.

### *Figure 41 - Expected Cost Quick Chart*

| Expected final cost | ±10% | of estimated cost* |
| *with a probability of | 45% | based on historical data |

The Quick Chart presented above, provides the percentage of variation of the expected final costs compared to the estimated costs, and its probability. Such feature is useful as an indication of the likely final costs of the project assessed. The elaboration is based on the historic data of the distribution of final costs of projects of the geographical clusters. The result is the historical frequency of cost variation range.

A small variance indicates a small difference between the expected final costs and the estimated costs. On the other hand a higher probability presents a higher accuracy of the estimation of the Tool.

## 5.1.1.5. Navigation buttons

By clicking on these buttons, the user has the possibility to view the detailed outcomes of the analyses performed per Tier.

## *5.1.2. Analysis on Tier I*

This section provide the detailed outcome of the benchmark analysis as regards the unit total and construction cost of the project as well as further indication on the allocation of the total cost.

### *Figure 42 - Analysis on Tier I*
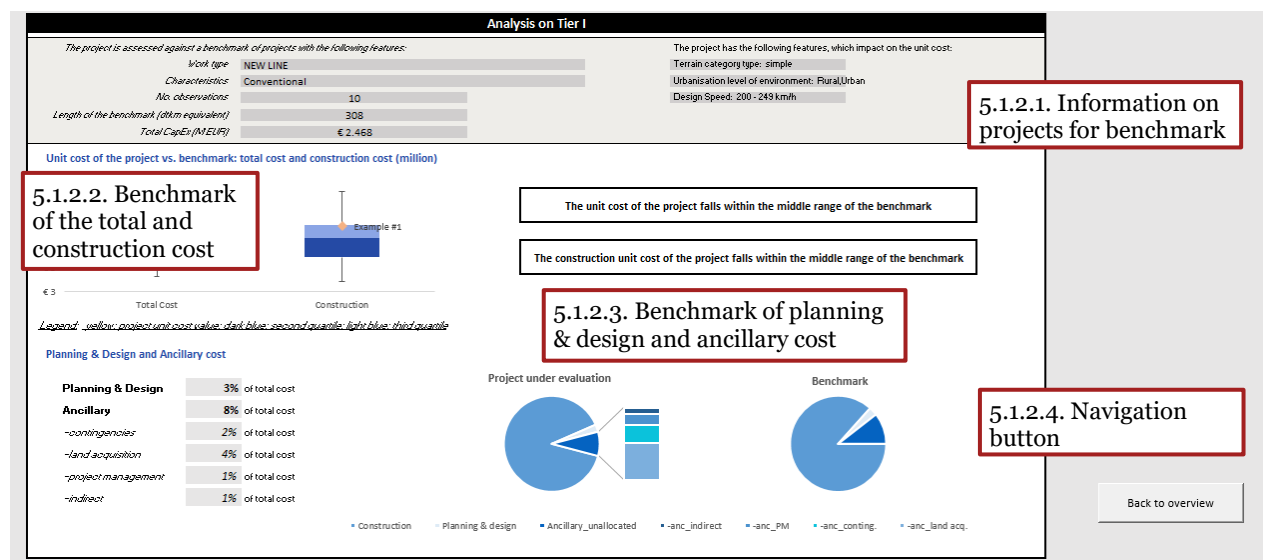


## 5.1.2.1. Information on projects included in the benchmark

In the upper part of this section the characteristics of the projects that have been used as a benchmark are reported.

### *Figure 43 - Information on projects for benchmark*



The database for this benchmark will grow over time as more projects are inserted into the database by the users.

On the upper rightmost part of the section the cost drivers which were not considered in the benchmark analysis are specified (e.g. terrain, environment, maximum speed, etc.). The impact of these factor is not considered in the analysis due to the limited number of projects in the database presenting all these features (the number of features non-considered in the analysis will reduce as new projects are included in the database).

## 5.1.2.2. Benchmark of the total and construction cost

In terms of the benchmarking, the section includes a boxplot graph that displays, where the projects falls on the spectrum of unit cost with comparable projects. Like for a common boxplot the interquartile ranges are included in the box while the range of the extreme values is displayed as whiskers. The difference in colours of the box marks the second and third quartiles, wherefore the median is displayed by the line in between the two. The project value is marked with a diamond as depicted on Figure 44.

*Figure 44 - Unit cost of the project vs. benchmark: total cost and construction cost*



*Legend: yellow: project unit cost value; dark blue: second quartile; light blue: third quartile*
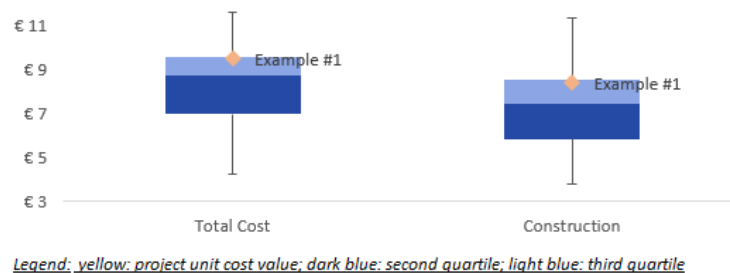
# Interpreting the results

**Figure 45 – Results of the assessment of total and construction unit cost**
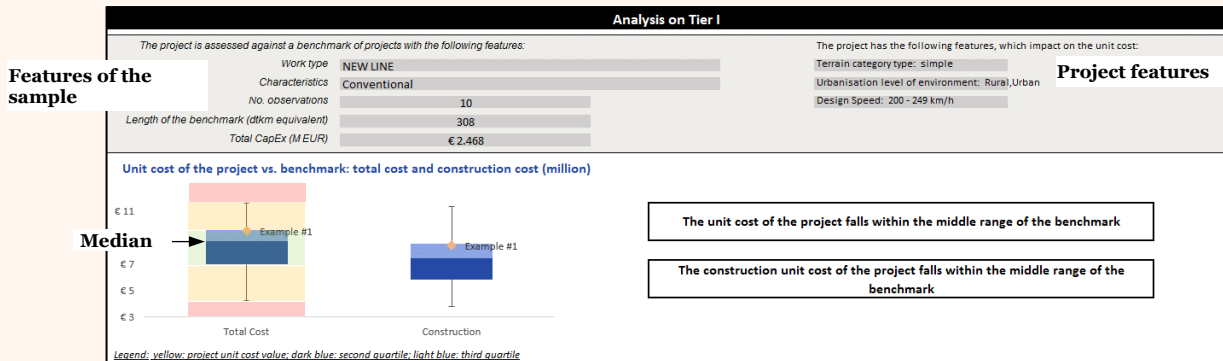


Would we wish to compare the summary results displayed in the *summary overview* ad the position of the project against the distribution of the benchmark shown in the figure for Tier I, we would consider that:

- o The median of the distribution corresponds to the line between the dark and the light blue area.

- o A green indicator in the summary overview corresponds to the unit cost of the project assessed falling within the dark or the light blue areas, which represent the two quartiles closer to the median value. Would the project fall in this range, it means that it is perfectly in line with the benchmark distribution.

- o A yellow indicator is displayed if the unit cost of the project assessed falls within the first or the fourth quartiles of the distribution. In this case, the user should compare the features of the sample and the project features. Possibly, not all the factors that impact on the cost of the project assessed are considered in the benchmark analysis.
  To be noted, the graphical representation of the figure enables not only to identify whether the project under assessment lies. It also enables to understand how far the unit cost is from the average values of the benchmark. To this end, one project positioned to the far side of the range (but still within the range) would be differentiated from another similar one, which is still in the "yellow" area, but closer to the median.

- o A red indicator in the summary overview corresponds to the unit cost of the project falling outside the cost range defined based on the unit cost of comparable projects included in the data background. It may be necessary to further investigate the reasons behind the out-of-range value, requiring information to the project promoter.

## 5.1.2.3. Benchmark of planning & design and ancillary cost

Furthermore, the section provides a detailed breakdown of the planning & design and the ancillary costs as a percentage of construction cost in form of a table.

**Figure 46 - Planning & Design and Ancillary Cost**
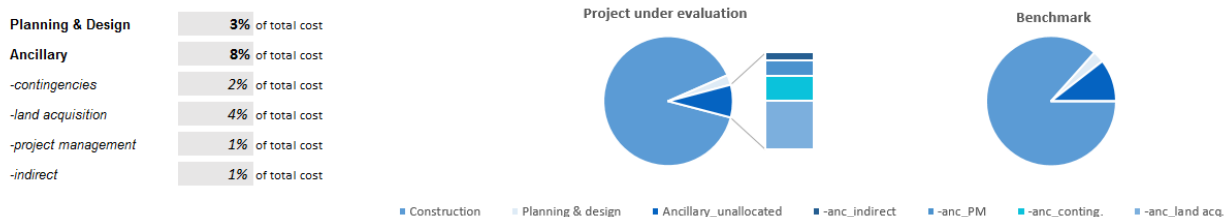


This table can potentially explain any extraordinary high or low total costs that are caused by complex design or extraordinary ancillary costs.

Lastly, the section provides a graph to easily benchmark this data by comparing the cost distributions of the project under review to the benchmark average.

## 5.1.2.4. Navigation button

By clicking on this button, the user can go back to the summary overview (section 5.1.1).

### *5.1.3. Analysis on Tier 2*

Coherently with the Tier structure it follows the analysis on Tier II, which predominantly provides the benchmark of the base cost to the projects with similar characteristics. The structure is displayed in the figure below.
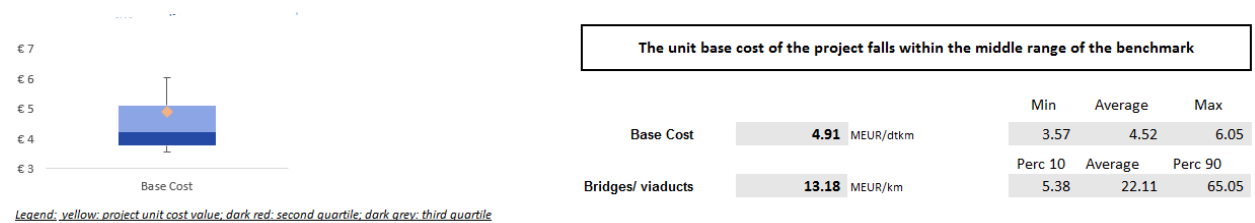
*Figure 47 - Analysis on Tier 2*
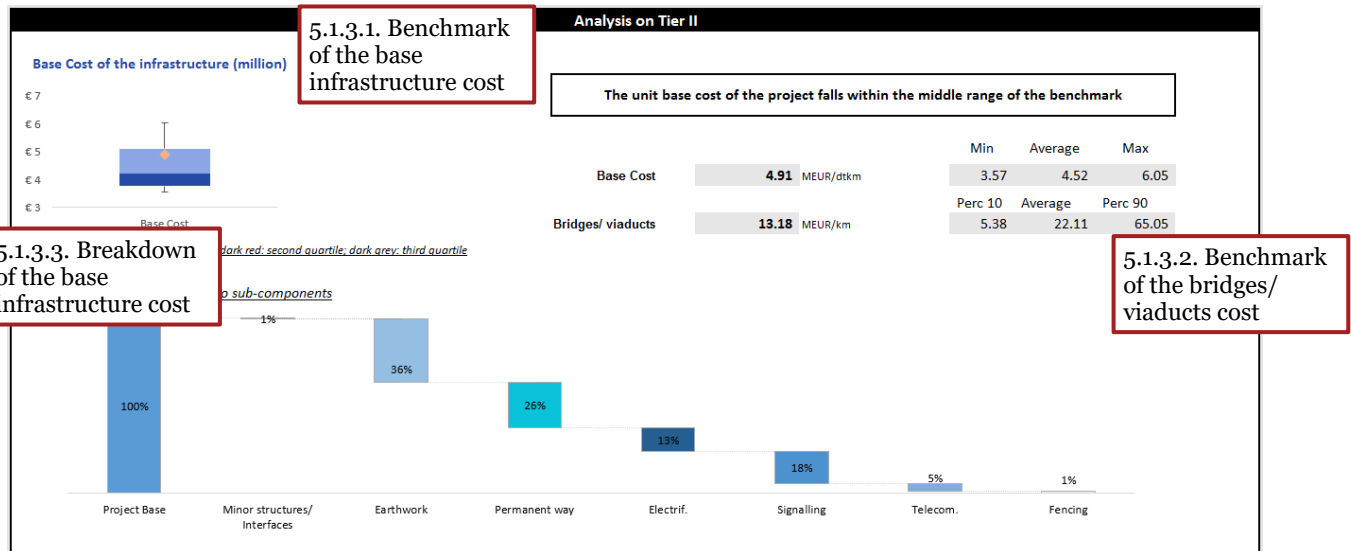


## 5.1.3.1. Benchmark of the base infrastructure cost

In the upper half of the section the analysis shows the benchmark of the base cost both in form of a boxplot and in text format.

*Figure 48 - Base cost of the infrastructure*



In the boxplot, again, the interquartile ranges are included in the box while the range of the extreme values is displayed as whiskers. The difference in colours of the box marks the second and third quartiles, wherefore the median is displayed by the line in between the two. The project under review is displayed as a diamond on the boxplot. The text format shows the base cost of the project under review per kilometre compared to the 10th percentile, the average and the 90th percentile encountered in the distribution of the unit costs of the investments included in the database or to the average and the maximum when the percentiles cannot be calculated with the data available.

## 5.1.3.2. Benchmark of the bridges/ viaducts cost

In case the project contains bridges or viaducts, the text displays the cost of these structures per kilometre compared to the 10th percentile, the average and the 90th percentile encountered in the distribution of the unit costs of the investments included in the database or to the average and the maximum when the percentiles cannot be calculated with the data available.

## 5.1.3.3. Breakdown of the base infrastructure cost

In the bottom half, a waterfall graph shows the percentage breakdown of the base cost into its sub-components. This way it is easily possible to view the allocation of the base infrastructure cost to its sub-components and identify which of them contribute most to the base infrastructure cost.

*Figure 49 - Breakdown of the base cost into sub-components*
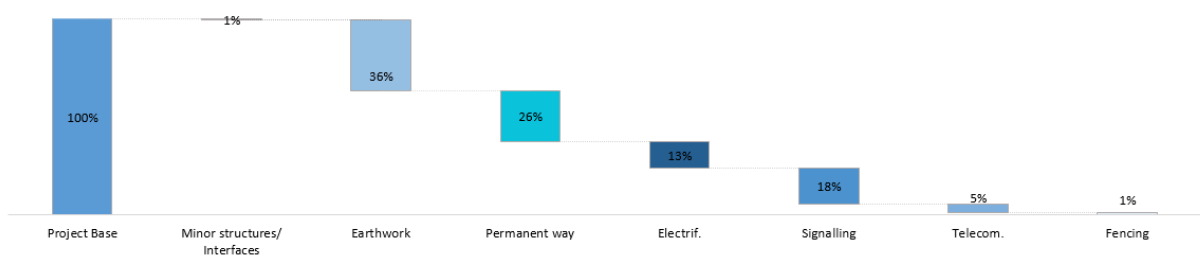


## *5.1.4. Analysis on Tier 3*

In the analysis on Tier 3, the breakdown of the Tier 2 level is elaborated and benchmarked for the individual elements.
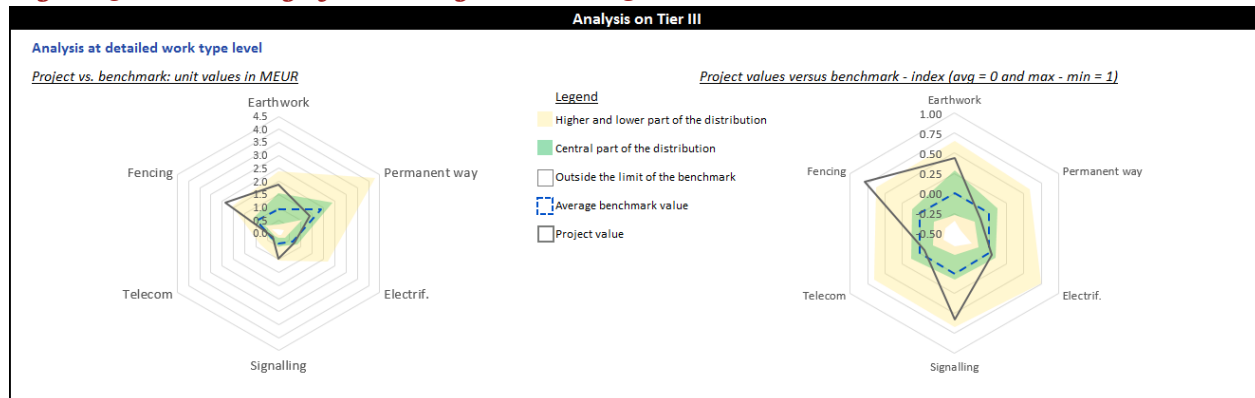
*Figure 50 – Analysis on Tier 3*



## 5.1.4.1. Summary of the analysis on Tier 3

The outcomes of the benchmark analysis on Tier 3 is summarised in two spider charts.

*Figure 51 - Summary of the analysis on Tier 3*



The first graph demonstrates the values of the individual elements in absolute values. As the different elements typically have differently large ranges, it is not always easy to see how the project ranks on the benchmark due to the scale of the graph. Therefore, a second graph has been included that scales all categories to the same size. In this chart, the average values correspond to zero. Negative variations indicate that the unit cost of the project assessed is lower than the average unit cost of the projects included in the sample. Positive values correspond to unit costs higher than the average.

## Interpreting the results

- Earthworks. The spider-chart of the example project shows that the costs of the element earthworks are within the higher part of the distribution. Considering that the distance between the unit cost of the project and the average unit cost is approximately 1 M EUR (and corresponds to approximately 100% of the average unit cost derived from the sample of projects analysed), the reasons for the divergence should be further investigated;

- Permanent way. The project value lies within the central part of the distribution. The value seems to be well within the interquartile range and therefore not extraordinary;

- Electrification. The value of the electrification as shown in the graph is very close to the median and average value of the benchmark. Therefore, the project seems closely in line with other projects with similar characteristics;

- Signalling. The project value lies outside of the interquartile range and is slightly lower than the maximum value. Therefore, it is more costly than the majority of other comparable projects. Considering the magnitude of the divergence (i.e. more than 100% of the unit cost of similar projects), it is worth searching further information which can explain this;

- Fencing. The project value lies outside the limit of the benchmark. Therefore it is more costly than all the projects included than the projects included in the benchmark. Further investigation on the driver of the cost are required.

## 5.1.4.2. Assessment of single elements

Below the spider graphs the different cost elements are analysed in detail and benchmarked. The analysis is presented in the same format as for the total and construction unit cost and is available for every single cost element. An example is provided below for the benchmark analysis of earthworks.

*Figure 52 – Example of the analysis of the elements of Tier 3*
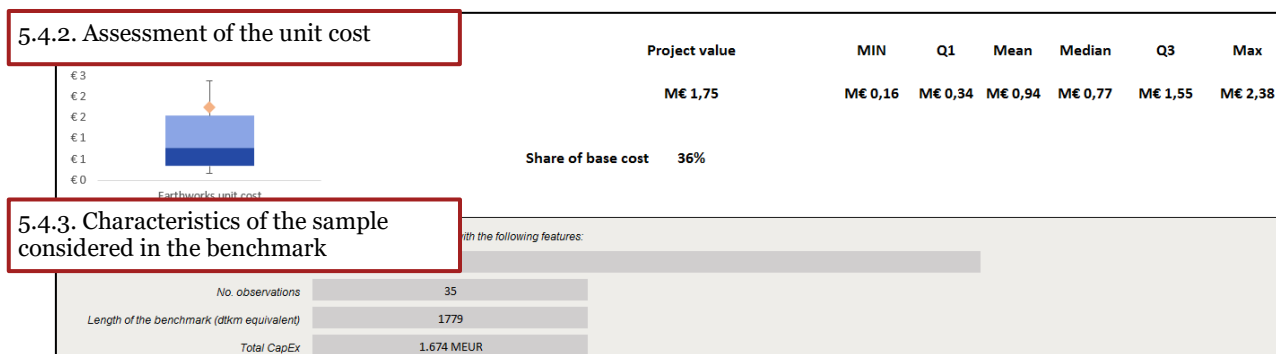
### 5.1.4.3. Assessment of the unit cost

The left part of the section presents a scatter plot which quickly allows to identify where this specific cost element stands in comparison to other similar projects present in the database.

In the middle and right part of the analysis it is possible to see:

- the unit cost for this specific project;

- its share compared to the overall project cost;

- how it ranks when compared to the distribution of the unit cost of the projects considered in the analysis (i.e. Minimum value, Q1, Mean, Median, Q3, Maximum Value).

### 5.1.4.4. Characteristics of the sample considered in the benchmark

The bottom part of the Tier 3 benchmark box presents the main features of the projects it is being compared against such as: Characteristics, No of observations, length of the benchmark (km) and Total CapEx.

## 5.2. *Forecast output*

Once all the inputs on the technical data have been inserted, the Tool opens a new sheet with the results of the forecast analysis for a project with the specified characteristics.

The Tool is designed to extrapolate statistical distributions from the observations in the database to support the forecasting of infrastructure investments. The Tool, following the main characteristics of the desired infrastructure, returns the average costs that projects with similar characteristics had. This section will explain how to read and understand those results.
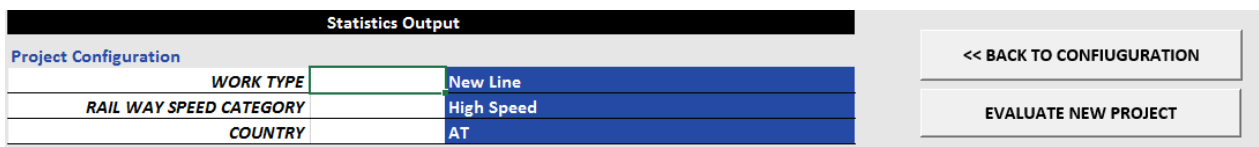
## 5.2.1. Forecast summary

*Figure 53 Forecast summary*
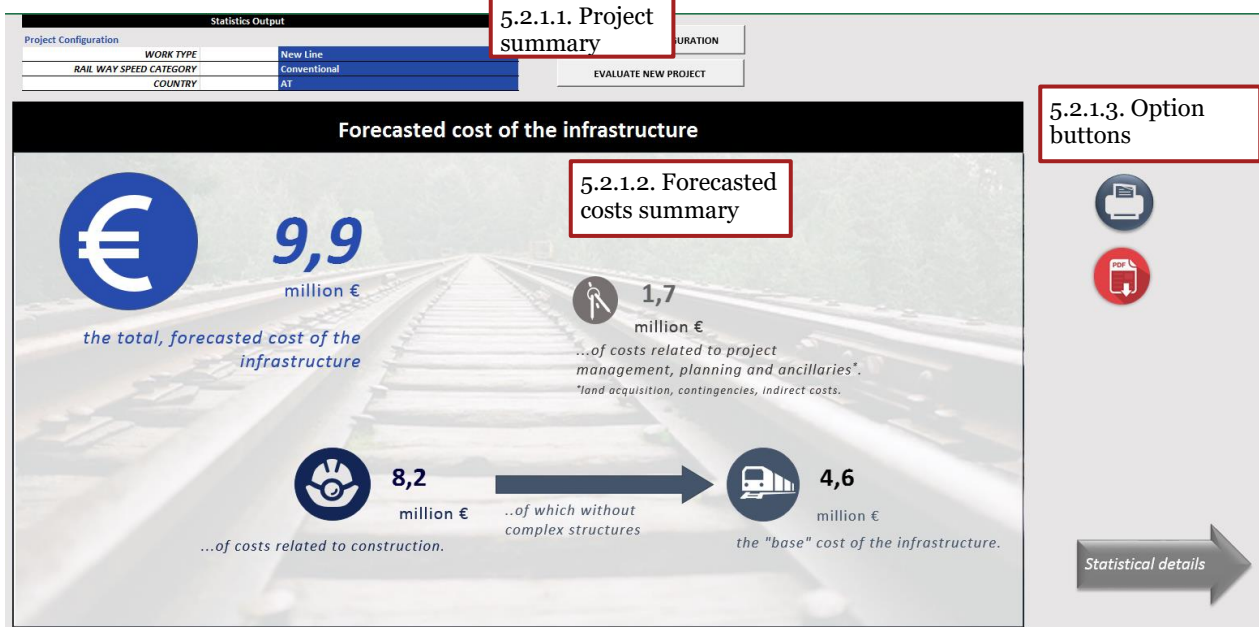


## 5.2.1.1. Project summary

The summary of the project's basic information is reported in the upper side of the spreadsheet. The project summary provides the description of project characteristic that will be used to forecast the cost of the project. In particular, the work type, the railway category and the country are reported in the blue cells within the summary.

*Figure 54 Project summary*



## 5.2.1.2. Forecast cost summary

The forecasted cost summary presents an overview of the estimated cost. Below are reported the following information:

- **Forecasted total cost:** presents the forecasted total cost of a project with the technical characteristic described in the Project summary.

- **Forecasted construction cost:** presents the forecasted construction cost of a project with the technical characteristic described in the Project summary.

- **Forecasted other costs:** includes costs related to project management, planning and ancillary that are expected for a project with the technical characteristic described in the Project summary.

- **Forecasted base cost:** represents the forecasted cost of the sum of the infrastructure components related to the development of a simple, complexity-free railway line with the technical characteristic described in the Project summary.

*Figure 55 Forecasted cost of the infrastructure*
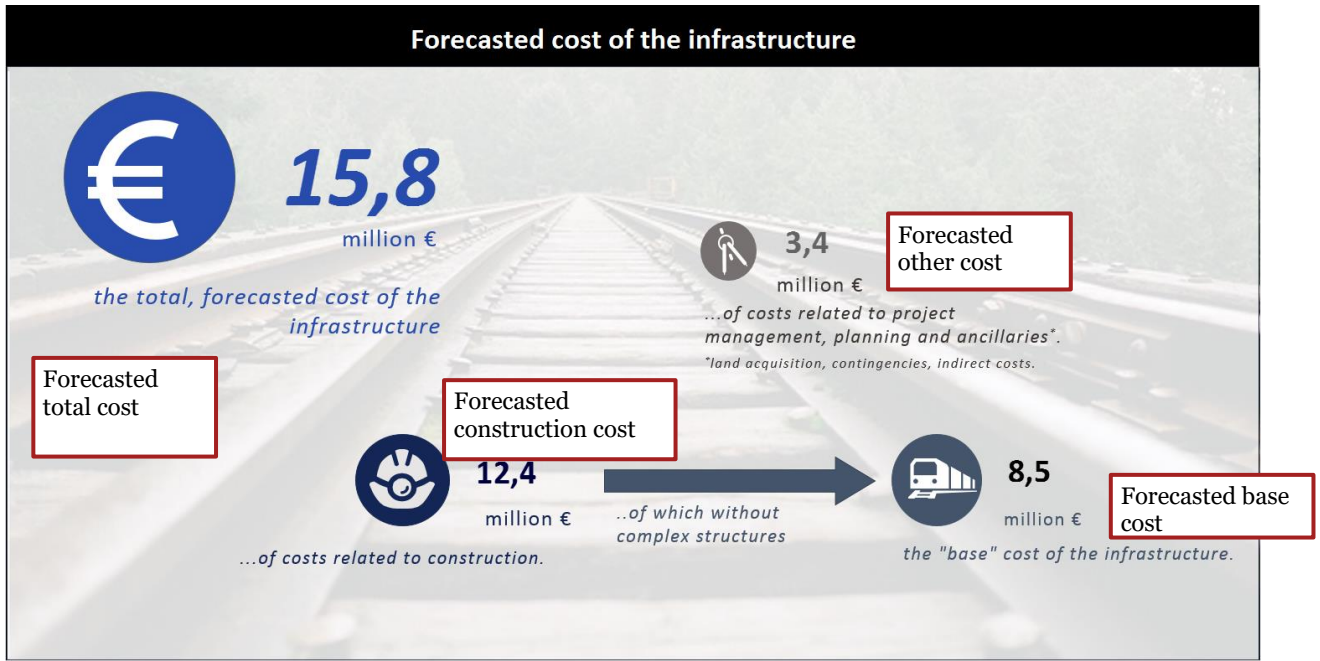


## 5.2.1.3. Option buttons

In addition to the estimations presented in the forecasting summary, is possible to export the information and/ or to explore detailed statistics on the forecasted cost.

- **Print option:** the print button allows the user to print the information displayed in the page.

- **Export in PDF:** the export in PDF button allows to export the information displayed in the page in a PDF format.

- **Statistical details:** the forecasting summary provides only the estimated overall information, users can access to the detailed description of the forecasted costs, by clicking on the statistical details arrow.

*Figure 56 Option buttons*
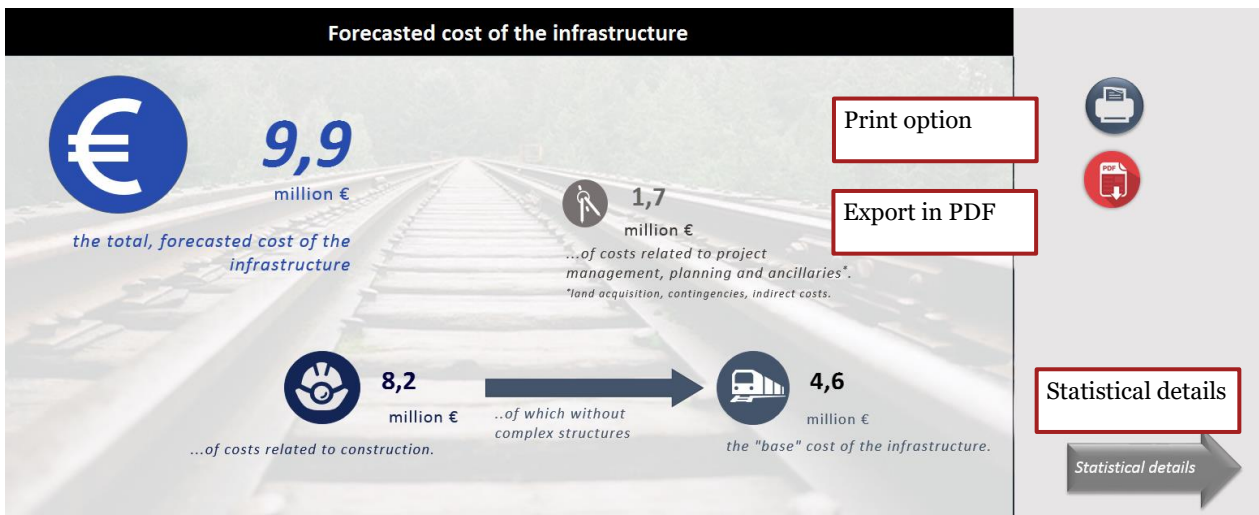
## 5.2.2. Statistical details

Once the user click on the statistical details arrow the Forecasted output page is displayed. The forecast output are presented with a structure similar to the one of the benchmarking analysis.

The main difference is that the forecast provide the cost distribution taking in consideration all the projects in the database with the technical characteristic indicated by the user. Hence, the forecast information is presented singularly and not in comparison with a provided project.

*Figure 57 Example of forecasted cost*
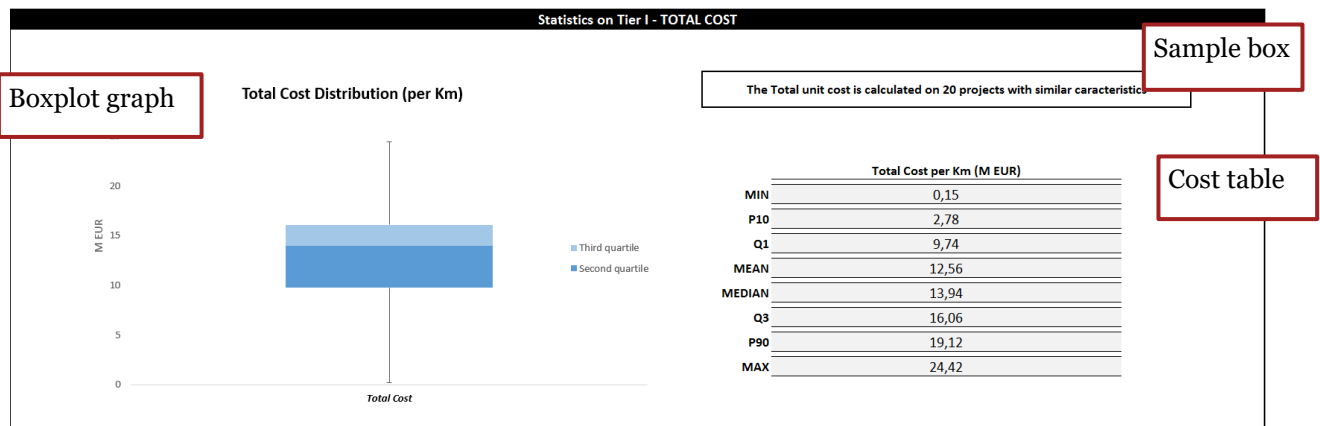


The estimated information on the different cost level is provided with a structure similar to the output of the benchmark. In order to clarify the information that is provided by the forecast, an example is provided. The figure above provides an example of the output representation of the forecasting, specifically of the estimated total cost.

The information is summarized in:

- **Cost table:** on the right side of the output page, it provides the distribution of the total cost of the projects in the database with the same technical characteristic. The following values are reported:
  - Minimum value;
  - 10th percentile distribution value;
  - 25th percentile (1st quartile) value;
  - Mean value;
  - Median value (or 50th percentile or 2nd quartile);
  - 75th percentile (3rd quartile) value;
  - 90th percentile value;
  - Maximum value.

  Depending on the number of data available some indicators may not display (i.e. 10th and 90th percentile in case of less than 10 observations)

- **Boxplot graph:** the boxplot graph, on the left side of the page, graphically represent the information provided in the Cost table. The structure of the graphs is the same as the one previously described in the Benchmark output.

- **Sample box:** the box above the Cost table describes the number of projects on which the forecast has been carried on. This number change based on the characteristic of the project and on the information available on this specific cost item.

The simple structure allows the user to understand intuitively the expected cost range of a project with the technical characteristic specify in the Project summary. In addition the Sample box provides the number of project on which the forecasting is undertaken, indicating the reliability of the estimation. Users are

able to observe the estimated cost ranges for all cost elements analysed. In case the number of observation are not enough to calculate the Percentiles and the Quartile, the space for this information is blank.

The information on the other cost elements follows the same structure of the example. The forecasted costs are presented with an increasing level of detail, from Tier 1 to Tier 3, and all cost elements are estimated.

*Figure 58 Forecasted overview*