Ex-ante GHG assessment of logistics investment projects

Manual of calculation tool

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This manual is prepared by:
Kerstin Dobers (Fraunhofer IML)
Eelco den Boer (CE Delft)
Matthijs Otten (CE Delft)

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Further information on this study can be obtained from the contact person, Eelco den Boer.

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Content

1 Introduction

1.1 Purpose of the manual

The tool enables

to assess prior to the investment (ex-ante) to what extent logistics infrastructure investment and fleet renewal contribute to an increase or decrease of GHG emissions resulting from the investment.

This manual will guide the user through the various stages of GHG emissions assessment. It provides guidance for setting customized parameters for describing project-specific logistics systems.

The manual is accompanied by the **framework on the ‘Methodology for ex-ante GHG assessment of logistics investment projects’.**

1.2 Intended users

The tool is intended to be used by experts involved in logistics investment decision making who have access to information requested from project applicants. Users can be EBRD staff, staff from other IFIs or contractors working on their behalf.

1.3 Structure of the manual, reading the manual

This manual first presents the architecture of the calculation tool (Chapter 2). Chapter 3 describes the modelling of an investment project step-by-step for calculating its GHG emissions impact. Here, the same structure as the tool is chosen and practical guidance and examples are given. The manual closes with overarching questions for using the tool (Chapter 4) as well as general definitions of terms that are given in Chapter 5. The Annexes provide further information on the emission factor database used in the tool.

Special symbols guide you through the steps and tool’s structure.

‘sheet’

Sheet symbols show the relevant sheet the manual’s information refers to.

Pointer symbols highlight issues that may require special attention during modelling. E.g. there is the possibility to:

– customize the calculation, e.g. override the suggested values; or
– integrate information on a more detailed level (e.g. cost change as average or on link level).

2 Architecture of the calculation tool

2.1 Objective and scope of the calculation tool

The tool together with this manual enables the assessment of GHG emissions of logistics investment projects prior to investment decisions. Therefore the calculation tool is intended to **evaluate GHG emissions of an investment project**.

Such evaluation may take place at different stages of an investment project, e.g. planning phase covering feasibility studies, design phase offering more detailed information on the planned investment, or implementation phase. The later in the process GHG emissions are evaluated, the more detailed information is available for the modelling of the project scenario.

The tool does not perform:
– corporate carbon footprints;
– supply chain carbon footprints;
– air pollutants assessment;
– transport flow simulation;
– logistics systems optimization.

2.2 Programming environment

The tool was developed in Microsoft Excel and includes macros (see also Section 2.4). The tool's language is English.

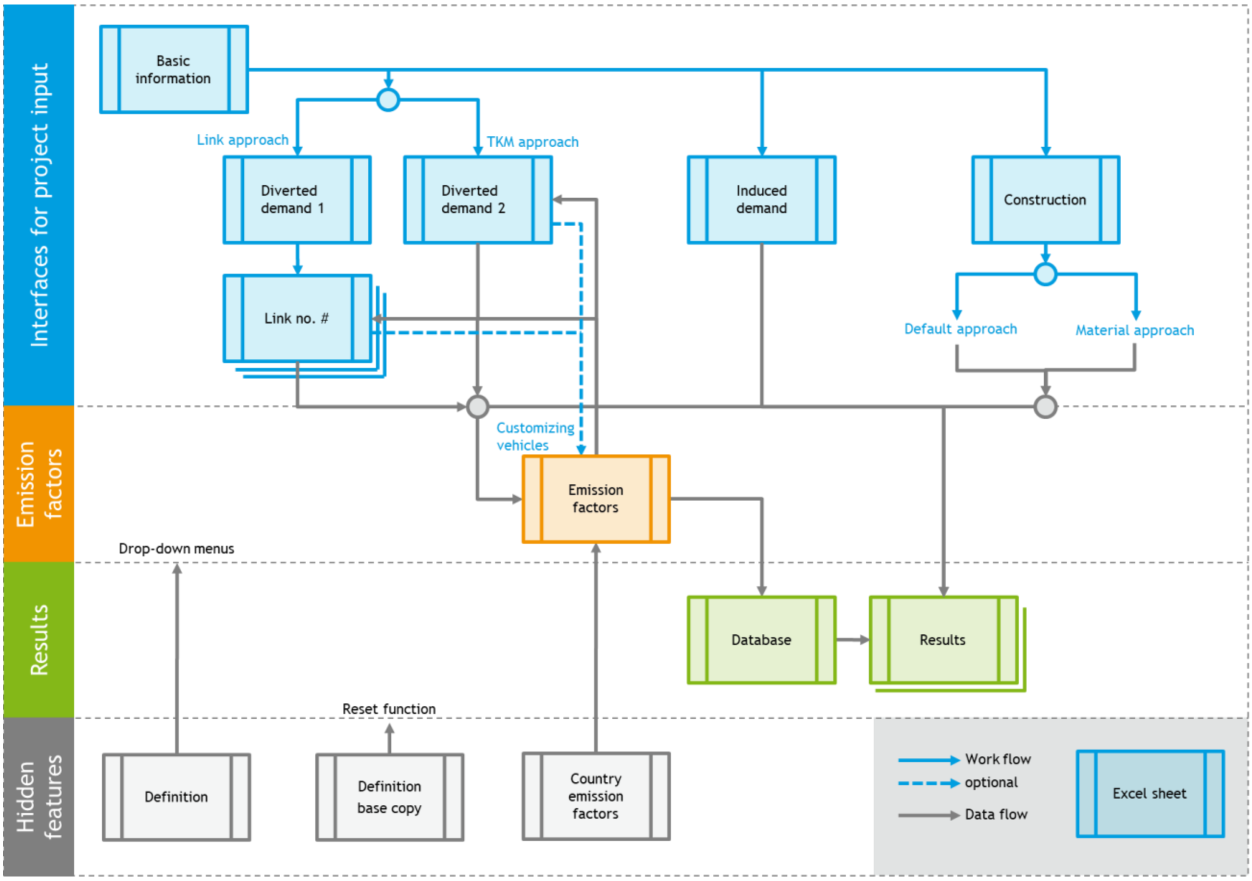
Cells not intended for data input are protected to avoid mistakes while using the tool by different users. The password is provided to the project team.

2.3 Tool structure

Figure 1 shows the general structure and modelling thread of the tool, including the main steps to take, data inputs and results.

The **blue area** covers all sheets offering input options for project data. Project data on diverted traffic is transferred to the **orange area** that covers the sheet 'Emission factors'. In this sheet all suggested emission factors used in the tool are listed; if required for the project at hand the user may customize these emission factors here. The **green area** shows all relevant results of the modelling: this is on the one hand an overview on the modelled transport system (sheet 'Database') and on the other hand the calculated GHG emissions (sheets 'Results in the project year', 'Results over time'). The modelling and calculations are also based on relevant information and factors that are set by the tool's authors and cannot be changed by the user (**grey area** with four sheets hidden).

Figure 1 General structure of the calculation tool



2.4 Data environment

The tool builds on general GHG principles and assumptions that are documented transparently in the framework of the methodology and this manual.

The tool requires a **minimum of data and information** (referred to as '**project data**') for specifying the investment project and deriving a baseline and project scenario (see Table 2 and Table 3). For collecting this data, dedicated input sheets are provided (see also Figure 1; blue area).

In addition to this, data used for calculating GHG emissions of the project covers:

– **set values** that are not changeable;
– **suggested values** cover state of the art emission and conversion factors required for the GHG emissions assessment of transport and infrastructure;
– **user-defined values** enables changing the database temporarily (project specific data).

Table 1 gives a short overview of the tool's database. For more details see annex A to this manual.

Table 1 Overview of database of tool

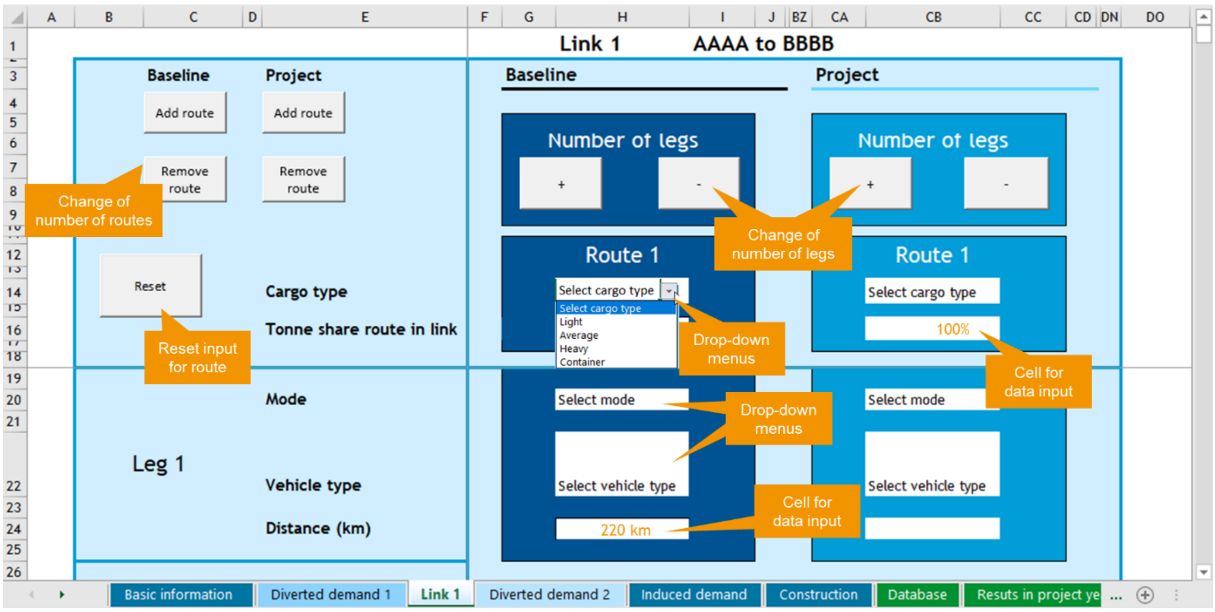
Type of values	Examples
Set values	– conversion factors between units (MJ/kWh); – vehicle capacities; – cargo types; – lifetime of infrastructure to allocate annual emissions (20 years).
Suggested values	– vehicle types with load factors and empty trip factors for set cargo types; – consumption factors for suggested vehicle types; – emission factors for fuels, electricity, material, infrastructure elements [g CO_2e/unit].
User-defined values	– new vehicle types, fuels; – varying consumption/emission factors for new vehicle types.

2.5 Data transparency and flexibility

The structure of the tool balances the variety of logistics infrastructure investment projects with simplicity as well as flexibility of use. Therefore, a number of special features (e.g. by using macros) is embedded in the tool, such as the following:

– Reset of data input in the tool is realised using a step-wise-reset per sheet for the time being.
  Note: It is not possible to undo a reset.
– Flexibility in number of links, routes, legs, vehicles types, and infrastructure items by adding or removing one element at a time.
– Drop-down menus for providing embedded default functions.

Figure 2 **The tool provides flexibility through buttons, drop-down menus, and cells for data input (example taken from sheet 'Link 1')**



The following tables summarise the minimum input data (project data) that is required for calculating the GHG impact of an investment project considering diverted and induced demand.

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Table 2 Overview of minimum input data and information using 'Link approach' (project data)

Focus	Input data	Reference to sheet
Investment project	Base year	Basic information
	Total transport activity in base year	
	Expected growth rate of transport	
	Project year	
	Maximum capacity of infrastructure	
Per link	Yearly transport activity	Diverted demand 1
Per leg	Cargo type	Link #
	Tonne share route in link	
	Mode	
	Vehicle type	
	Distance	

Table 3 Overview of minimum input data and information using 'tkm approach' (project data)

Focus	Input data	Reference to sheet
Investment project	Base year	Basic information
	Total transport activity in base year	
	Expected growth rate of transport	
	Project year	
	Maximum capacity of infrastructure	
Per vehicle type	Cargo type	Diverted demand 2
	Mode	
	Vehicle type	
	Distance	
	tkm	

3 Using the tool step-by-step

This chapter provides guidance for using the tool by describing the modelling of an investment project step-by-step. For this, each sheet of the tool is introduced and relevant activities (e.g. data input, choices) described.

3.1 Before starting modelling

Identify geographical boundaries

The tool is dedicated to model investment projects in:

– new, or the extension of existing, terminals at seaports or intermodal terminals, as well as port infrastructure;
– new, or the extension of existing, transport infrastructure;
– fleet renewal;

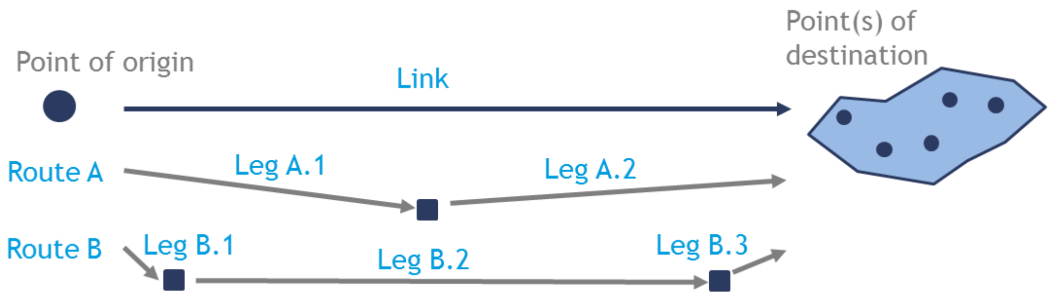
and to calculate the GHG emissions impact of the investment projects. The emissions are determined by comparing a baseline scenario (without investment) with a project scenario.

For modelling of the baseline and project scenarios the same geographical boundaries have to be defined by specifying relevant transport chains affected by the investment.

The origin – destinations relation are defined as links. The logistics system under study can consist of one or more links, depending on the number of point(s) of origin and destination.

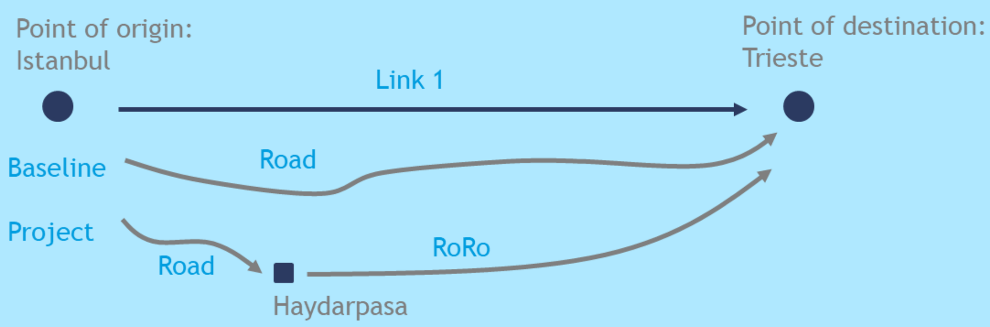
For this, select the most relevant links for both scenarios (in total max. 10). Describe those by identifying the relevant points of origin and destination (see Figure 3). The 'points' of origin/destination can be both detailed, e.g. selected cities, or less detailed, e.g. regions.

Figure 3 Differentiation of 'link', 'route' and 'leg' in the geographical boundaries of logistics chain (see also the Glossary for text definitions)



The consideration of future new points of origin/destination should only be included if this is distinctive of the project to be assessed. If this is relevant, further details on the modelling approach is given in Chapter 4 **'How to model future new points of origin/destination?'** (p. 43).

Example 1: Geographical boundaries of Turkish RoRo project (simplified)
The following simplified example is based on the EBRD investment in a new RoRo ship (Turkey, EBRD project code 46917, 2014), with road transport in the baseline scenario. The capacity of the ship is 200 trucks and it makes one round trip per week between Turkey and Italy. The distance by road from Istanbul to Trieste is 1,800 km by road in the baseline and 50 km by road in the project scenario, followed by a sea leg of 2,200 km. Products transhipped may be produced in the Turkish or Italian hinterland, but this does not differ between the scenarios and is therefore left out of scope.



3.2 Basic information

The user starts by specifying basic information on the investment project as well as the general framework of the modelling task.

For this, the sheet ‘Basic information’ asks for details concerning:
- general information;
- project type and investment focus;
- freight transport activity within the geographical boundaries.

General information

General information serves the documentation and transparency of the modelling. It is recommended that the user specifies the **operation name**, the **EBRD project reference number (OP ID)**, the **country** in which the investment is planned, the **investment budget (ABI)** as well as the **name of the user/modeller**. An additional field for **general notes by the user** is provided as well (e.g. relevant assumptions made).

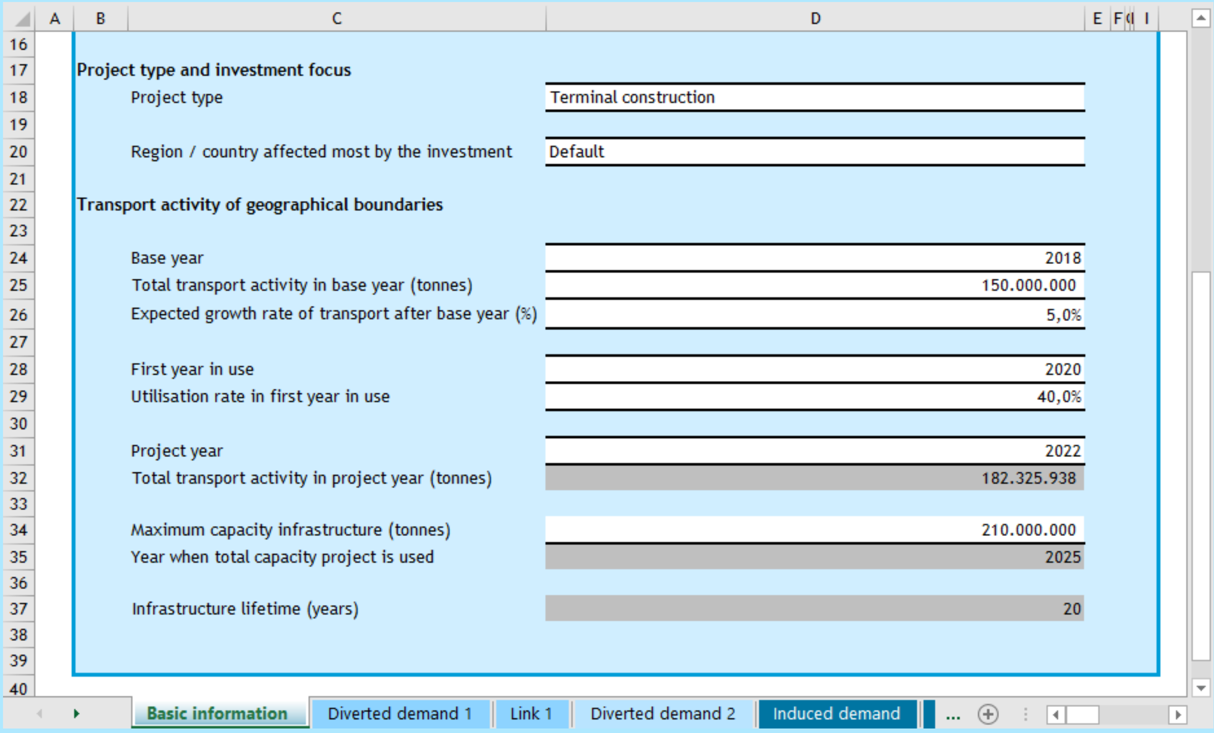
It is recommended to assess GHG emissions associated with construction of the investment only for larger projects. The user however may decide independently whether to in- or exclude construction emissions in the calculation (see Section 3.5). The tool does not use the specified investment budget except for documentation reasons.

Project type and investment focus

Project type
The general information is supplemented by the specification of the project type (see Example 2), so that a quick orientation is given by the user whether the investment refers to:
- new, or the extension of existing, terminals at seaports or intermodal terminals, as well as port infrastructure;
- new, or the extension of existing, transport infrastructure;
- fleet renewal for road, rail or water transport.

Region/country affected most by the investment
In addition, the user shall select the region or country affected most by the investment. This refers to the defined transport chains in this region or country (see also geographical boundaries).

Example 2: Basic information for terminal construction project



Project type and investment focus	
Project type	Terminal construction
Region / country affected most by the investment	Default
Transport activity of geographical boundaries	
Base year	2018
Total transport activity in base year (tonnes)	150.000.000
Expected growth rate of transport after base year (%)	5,0%
First year in use	2020
Utilisation rate in first year in use	40,0%
Project year	2022
Total transport activity in project year (tonnes)	182.325.938
Maximum capacity infrastructure (tonnes)	210.000.000
Year when total capacity project is used	2025
Infrastructure lifetime (years)	20

Transport activity of geographical boundaries

Base year
Please specify the base year used for the model. The base year is the most recent year for which transport data is available. It concerns transport that will be influenced by the project. In the base year no project investment is in place and the contract of the investment project has not been signed. Thus, the transport has not yet been influenced.

Total transport activity in base year
Specify the total transport activity in the base year. This total transport activity shall refer to all links covered by the geographical boundaries chosen (see also Sections 3.1 and 3.3.1).

The transport activity used refers to tonnes. If other units are more convenient e.g. twenty foot equivalent unit (TEU), Table 10 provides conversion factors recommended to be used.

Expected growth rate of transport after base year
The transport activity in the base year needs to be extrapolated to the expected transport activity in the project year. The extrapolation is based on an expected average market developments for the project. The transport activity to assess diverted transport is by definition equal for the baseline and the project scenario.

Project year
Please specify the project year used for the calculation. The project year represents a year of operation when the project investment has been finished and a typical operation can be expected.

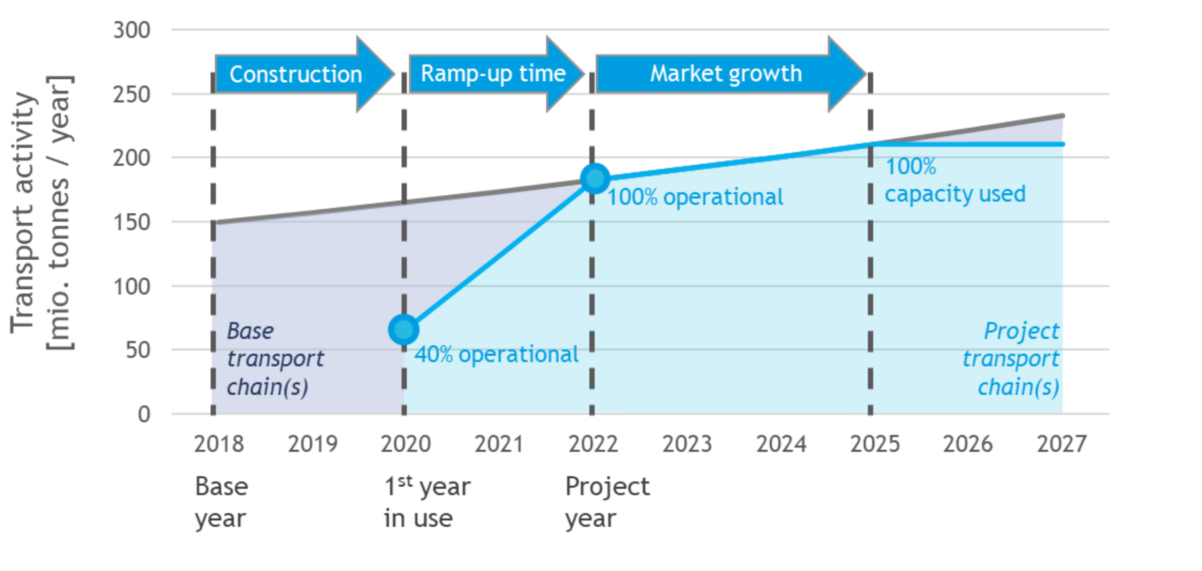
Total transport activity in project year
Using the specified base and project year as well as the growth rate, the tool extrapolates the total transport activity in the project year. The figure is not intended to be changed by the user (grey cell).

First year in use
Please specify the first year the new infrastructure is expected to be used.

This information is used to extrapolate the share of baseline and project scenario (with the respective transport chains and vehicles in operation) between first year in use and project year (see Example 3). This is used for displaying the annual emissions of the investment.

Utilisation rate in first year of use
Specify the utilisation rate in the first year of use. This will be used to account share-wise the initial and diverted transport chains (to be modelled at a later stage as described in Section 3.3), see also Example 3.

Example 3: Extrapolation of transport activity for assessment period using Example 2



Maximum capacity of infrastructure
Please specify, the maximum capacity of the invested infrastructure. Using the specified growth rate and project year, the tool calculates the expected year when the total capacity of the investment project is used. After this year (grey cell), no further transport activity growth is considered by the tool.

Infrastructure lifetime (years)
The total emissions caused by the construction refers to the lifetime emissions of the infrastructure. For comparison with annual operational emissions, the total infrastructure emissions are divided by the infrastructure lifetime to convert them to annual emissions. The tool uses a set value of 20 years (grey cell).

3.3 Diverted demand modelling

The primary operational effect of infrastructure or fleet investments is the diversion of traffic. The traffic accommodated by the new infrastructure or new equipment will mainly come from other routes benefitting from aspects such as time or cost reduction or reliability. By this, transport distances, modes and/or vehicle types may change and need to be specified as next step.

For this, the tool provides two options that are described in detail in the following. **Inputs for only one option should be used.** The tool does not prevent the user completing both input sections, which would lead to an incorrect result. This means that the user must reset one option if he decides to use the other one.

Table 4 Choice between two options for modelling diverted traffic

Modelling diverted traffic with...	Choose this option if….
Option 1 ‘Link approach’	– Knowledge of the routes and underlying legs is available
Option 2 ‘tkm approach’	– Information on route level is not available – Model investment projects for fleet renewal

3.3.1 Option 1: using ‘Link approach’

Diverted demand 1

Diverted demand 1: Specification of links
Sheet ‘Diverted demand 1’ focuses the geographical boundaries defined for the project (see Section 3.1). Here, the number of links as well as their origin, destination and transport activity need to be specified by the user.

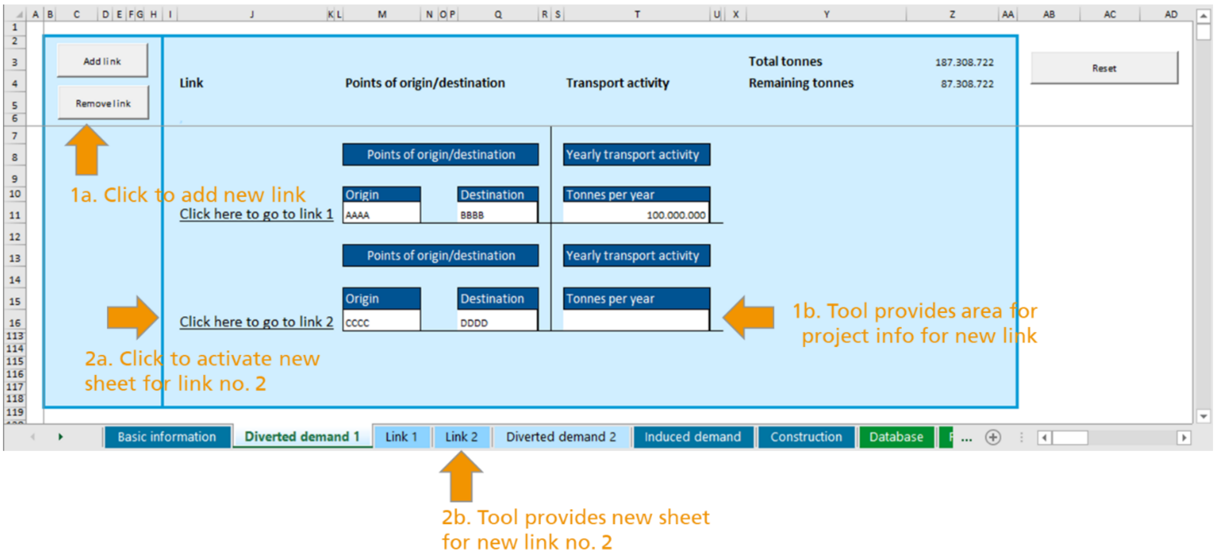
At the start, the tool provides one link.

Add new or remove last link
For adding a new link, press ‘Add new link’ button, as shown in Figure 4. This results in a new input area for the additional link as well as an additional sheet with the name ‘Link #’. The tool provides a maximum number of 10 links.

For removing the last link, press ‘Remove link’ button. It is not possible to remove a middle link.

For creating an additional sheet ‘Link #’ for the new link click on the hyperlink ‘link #’.

Figure 4 Adding new link induces the provision of new input cells and sheet for the new link (sheet: 'Diverted demand 1')



Point(s) of origin or destination
Specify the point of origin and destination for each link. This information is used in the relevant sheet 'Link #', however, no plausibility checks are programmed.

Yearly transport activity
Specify the annual transport activity per link in the project years. The sum of the transport activities of all links must equal the total transport activity as specified in sheet 'Basic information' (see Section 3.2). The extrapolated **total transport activity** (project year) is displayed at the top right side of this sheet. This amount is reduced by the amount specified per link, so that the user knows the **remaining transport activity** to be modelled in remaining links.

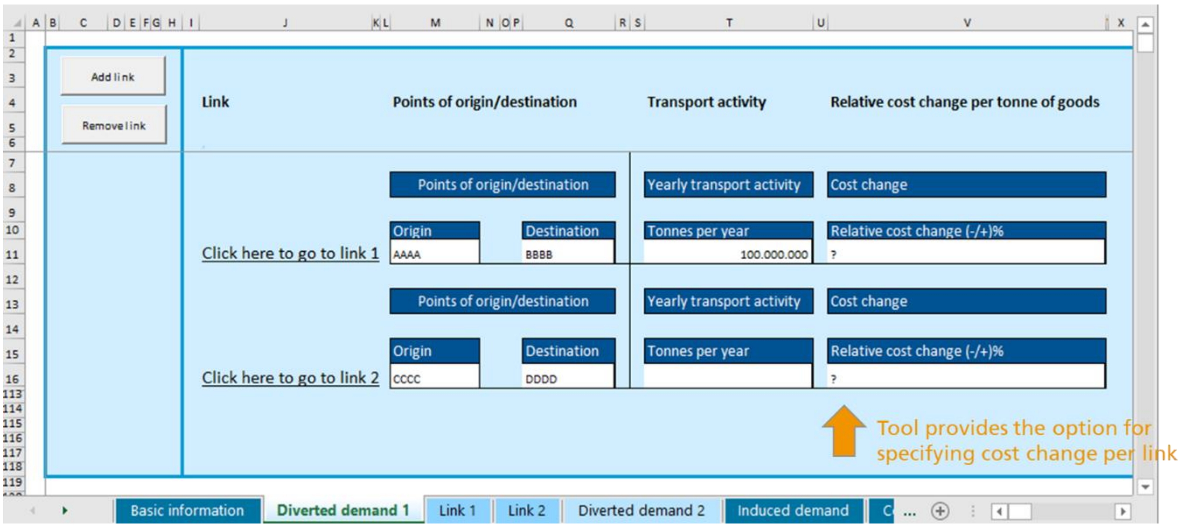
The transport activity used refers to tonnes. If other units are more convenient e.g. twenty foot equivalent unit (TEU), Table 10 provides conversion factors recommended to be used.

Relative cost change per tonne of goods
For modelling induced demand (see also Section 3.4) the tool provides the possibility for specifying relative cost changes at the link level. This may be required if regional transport market developments differ within the geographical boundaries.

For receiving the relevant input fields in sheet 'Diverted demand 1' (see Figure 5), use the button 'Provide cost change per link here!' in sheet 'Induced demand' (see also Figure 10). When using this option, the average defined value (sheet 'Induced demand') will be overwritten by the values on link level. For links with no specified values the average value will be used.

If you do not want to use the per link option any more, you have to put a question mark at the place where you have entered the value per link. Then the average value will apply again.

Figure 5 Optional specification of cost change (induced demand) on link level (sheet 'Diverted demand 1')

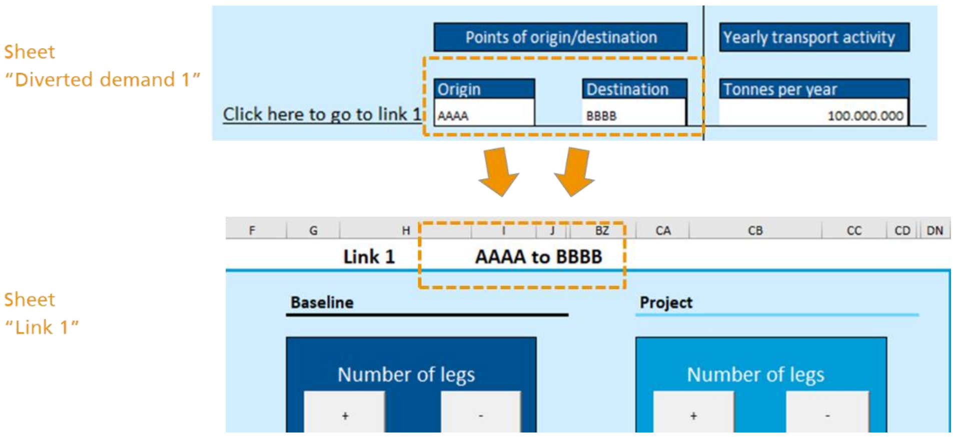


Link #: Specification of transport routes and modes for each link

As the next step, the user specifies in the sheet 'Link #' the relevant transport routes and modes for each link. This is done separately for the baseline and the project scenario. Here, '#' refers to the number of link (i.e. 1 to 20).

For better orientation the tool transfers the points of origin and destination (specified in sheet 'Diverted demand 1') of the link(s) to the headline of the relevant sheet 'Link #' (see Figure 6).

Figure 6 Use of specified points of origin/destination (sheet 'diverted demand 1') in sheet 'Link #'



For each link, various routes may be possible as shown in Figure 3.
For infrastructure investments new routes are established by e.g. the construction of a new port/terminal. Therefore the number of routes of the baseline scenario may differ from the project scenario.

Each route can be further specified by introducing one or more legs.
One route may consist of one or more legs, where a leg's beginning and end are defined by a change of mode, vehicle or transhipment.

Selection of link
For each link introduced in the previous step (sheet ‘Diverted demand 1’) the tool provides an extra sheet called ‘Link’ plus the relevant number as shown in Figure 4. Select the relevant link for further specification by choosing the relevant sheet.

If no additional sheet for the new link ‘Link #’ has been created yet, click on the hyperlink ‘link #’ in sheet ‘Diverted demand 1’ as shown in Figure 4 (step 2).

Differentiation between baseline and project scenario
The sheet ‘Link #’ offers a dark blue area which refers to the baseline scenario (left) and a light blue area which refers to the project scenario (right).

In each of those areas, the relevant routes are specified for both scenarios.

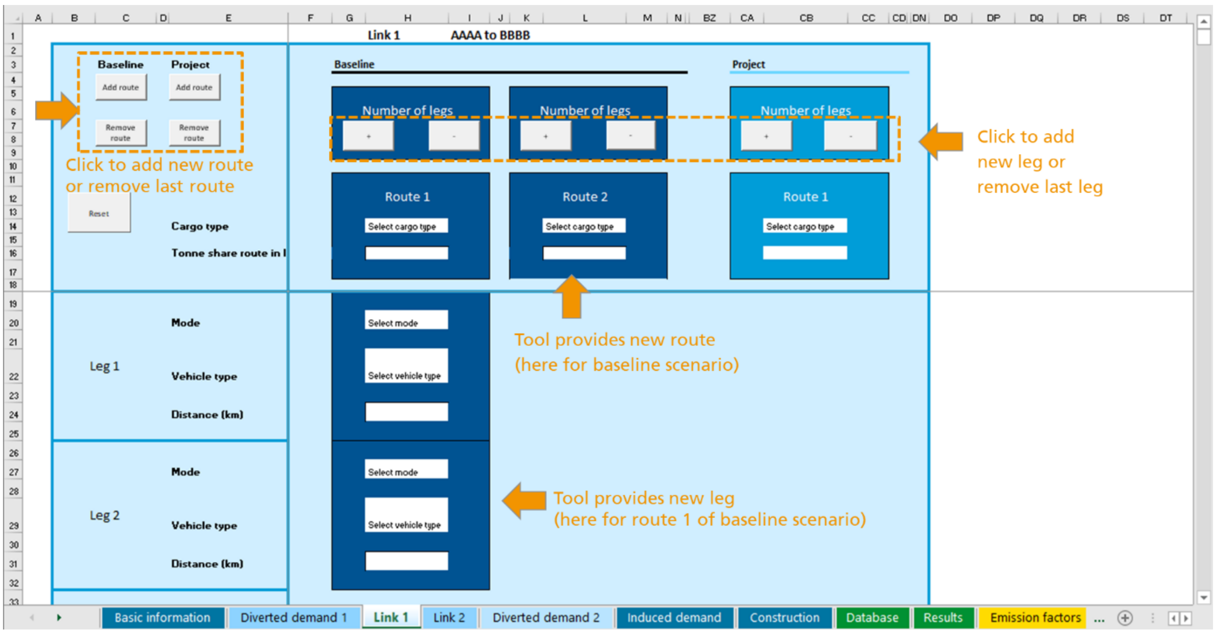
Add new or delete last route
For adding a new route, press the ‘Add route’ button, as shown in Figure 7. This results in a new input area for the additional route on the right hand of the previous route. The tool provides a maximum number of 10 routes for each scenario and link.

For removing the last route, press the ‘Remove’ button. It is not possible to remove a middle route.

Add new or delete last leg
For adding a new leg, press the ‘+’ button in the relevant route (see Figure 7). This results in a new input area for the additional leg below the previous leg. The tool provides a maximum number of 10 legs per route.

For removing the last leg, press ‘-’ button. It is not possible to remove a middle leg.

Figure 7 Adding new route or legs offers new input cells for the new route/leg (sheet: ‘Link #’)



The following description refers to the data input in the sheets ‘link #’ of all links, routes and legs that are within the geographical boundary of the investment project.

Cargo type
Select the relevant cargo type of the route. The tool provides the differentiation between four cargo types, i.e. light, average, heavy, and containerised. The following table gives an orientation for the different cargo types.

Check that the selection of cargo type is consistent for both scenarios.

Table 5 Cargo types used in the tool

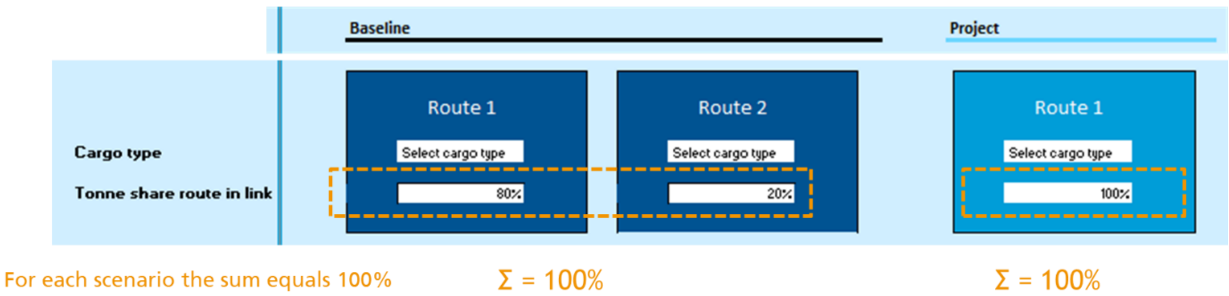
Cargo type	Description
Light	Light goods – E.g. appliances, furniture, mail, textiles, shaped products. – Approx. < 0.4 kg/litre in loading area.
Average	Medium-weight goods – E.g. food products, timber, paper, plastics, chemicals, metal products, cars, waste. – Approx. 0.5-1.2 kg/litre in loading area.
Heavy	Heavy goods – E.g. ores, minerals, coal, coke, oil. – Typically for liquids and cargo > 1.3 kg/litre.
Container	Containerised goods – 10 tonnes per TEU; empty weight container 1.95 tonnes per TEU.

Tonne share route in link
Allocate the expected transport activity for the selected routes of the relevant link for both the baseline and the project scenario by specifying the route’s share.

The allocation of the transport activity in the baseline scenario will follow the allocation shares of the base year, unless there is good reason to deviate from this (e.g. stronger growth on certain links or routes). The allocation in the project scenario should follow from the project plans.

Check that for each scenario the sum of tonne share is equal 100%, see also Figure 8.

Figure 8 Specification of tonne share of the route in each link (sheet ‘Link #’)



Mode
Select the relevant mode of the leg. The tool provides differentiation between four modes, i.e. road, rail, inland waterway (IWW), and maritime/short sea.

Select the mode for each leg first, since the selection list for vehicle types (next step) is adjusted dependent on the chosen mode.

Vehicle type
Select the relevant vehicle type for the leg. Table 12 (p. 43) gives an overview on which vehicles types per mode are embedded in the tool.

The tool provides the option to define a new vehicle type for any mode. This may refer to other vehicle classes, different consumption factors or new fuel types (e.g. LNG, CNG). This customizing step is done in the sheet 'Emission factors' and is described in more detail in Chapter 4.

Distance
Specify the transport distance of the selected leg in [km]. For more information, see general chapter on '**How to measure distance of freight transport**' (p. 41).

Transhipment between modes is modelled by default by the tool. Whenever cargo is transhipped between modes the emissions caused are calculated by multiplying the relevant transport activity by an emission factor [g CO_2e/tonne].

Example 4: DCT Gdansk expansion (Poland, EBRD project code 45805, 2014)

Using the 'Link approach', the following table shows the input data for routes in the baseline and project scenario on two example links, i.e. from Rotterdam to (1) Finland and (2) Hungary, with relevant modes and distances for both scenarios. The transport capacities are defined as follows: large maritime vessel (18,340 TEUs), feeder (small vessel, 4,400 TEUs), rail (28 platform train, 56 TEUs), and road (truck 40 t, 1.7 TEUs[1]). Terminal capacity is 1,5 million TEU per year.

Link #		**Link 1: Rotterdam - Finland**		**Link 2: Rotterdam - Hungary**		
Scenario		Baseline	Project	Baseline	Project	Project
Cargo type		Container	Container	Container	Container	Container
Tonne share		100%	100%	100%	36%	64%
Leg 1	**Mode**	Maritime	Maritime	Rail	Maritime	
	Vehicle type	Container (1-5 kTEU)	Container (>14.5 kTEU)	Train - 32 wagons	Container (>14.5 kTEU)	
	Distance	1.749 km	800 km	949 km	800 km	
Leg 2	**Mode**	-	Maritime	Road	Rail	Road
	Vehicle type		Container (1-5 kTEU)	AT/TT 34-40 t, Euro I-VI	Train - 32 wagons	AT/TT 34-40 t, Euro I-VI
	km		785 km	579 km	926 km	926 km

3.3.2 Option 2: using 'tkm approach'

Diverted demand 2

Diverted demand 2: Specification of vehicle types
Sheet 'Diverted demand 2' focuses the geographical boundaries defined for the project (see Section 3.1). Here, the used vehicles as well as the transported distance, transport activity and cargo type need to be specified by the user.

[1] Average utilisation.

At the start, the tool provides one vehicle type.

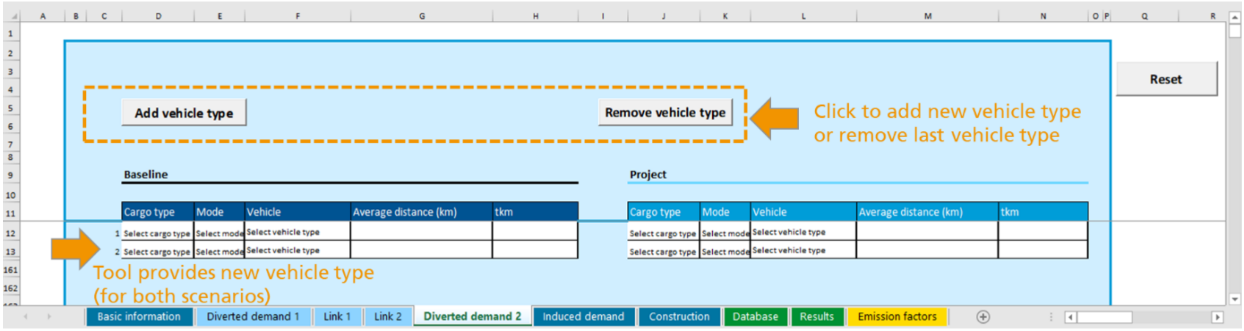
Add new or remove last vehicle type

For adding a new vehicle type, press ‘Add vehicle type’ button, as shown in Figure 9. This results in a new input row for the additional vehicle type. The tool provides a maximum number of 149 vehicle types.

For removing the last vehicle type, press ‘Remove vehicle type’ button. It is not possible to remove a middle vehicle type. Always the last entry is removed.

The tool provides the same number of vehicles for both scenarios. If the baseline and the project scenario don’t have the same number of vehicles, leave the input fields blank where necessary.

Figure 9 Adding new vehicle types offers new input cells for both scenarios (sheet: ‘Diverted demand 2’)



The following description refers to the data input in the sheets ‘Diverted demand 2’ for both the baseline and the project scenario.

Cargo type

Select the relevant cargo type transported by the vehicle type. The tool provides the differentiation between four cargo types, i.e. light, average, heavy, and containerised. Table 5 gives an overview for the different cargo types.

Mode

Select the relevant mode. The tool provides the differentiation between four modes, i.e. road, rail, inland waterway (IWW), and maritime/short sea.

Select the mode first, since the selection list for vehicle types (next stept) is adjusted dependent on the chosen mode.

Vehicle type

Select the relevant vehicle type. Table 12 gives an overview on which vehicles types per mode are embedded in the tool.

The tool provides the option to define a new vehicle type for any mode. This may refer to other vehicle classes, different consumption factors or new fuel types (e.g. LNG, CNG). This customizing step is done in the sheet ‘Emission factors’ and is described in more detail in Chapter 4.

Average distance (km)
Specify the average distance the relevant vehicle type travels in [km].
For more information, see general chapter on **'How to measure distance of freight transport'** (p. 41).

tkm
Specify the relevant annual tonne-kilometre per vehicle type.

This is done by multiplying the average transport distance [km] of the vehicle type by the annual freight transport activity [tonne].

The transport activity used refers to tonnes. If other units are more convenient e.g. twenty foot equivalent unit (TEU), Table 10 provides conversion factors recommended to be used.

In case of ferry transport (Ro-Ro) the embedded emission factors consider the transported gross weight of the vehicle (i.e. truck plus cargo weight). For this a truck size AT/TT 34-40 t is assumed and the emission factor already refers to the emissions per cargo weight. The equivalent has been done for containerised transport.

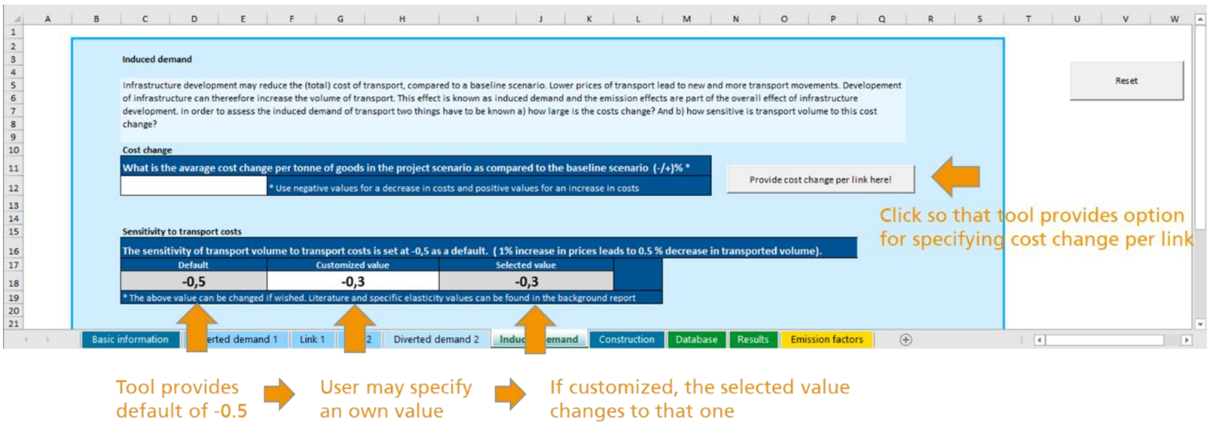
3.4 Prediction of induced demand

Induced deman

Infrastructure development may reduce the (total) cost of transport, compared to a baseline scenario. Lower prices of transport lead to new and more transport movements. Development of infrastructure can therefore increase the amount of transport. This effect is known as induced demand and related emission changes are part of the overall effect of infrastructure development. In order to assess the induced demand of transport two things have to be known

a. How large is the cost change?
b. How sensitive is transport activity to this cost change?

Figure 10 Modelling of induced demand in sheet 'Induced demand'



Cost change on project level
Specify, what the average cost change per tonne of goods is. This is done for the project scenario compared to the baseline scenario by specifying a positive or negative percentage [+/- %]. Use negative values for a decrease in costs and positive values for an increase in costs.

Cost change per link

The tool provides the possibility for specifying relative cost changes at link level. This may be required if regional transport market developments differ within the geographical boundaries.

If you want to choose this option, use the button ‘Provide cost change per link here!’ (see also Figure 10). Thus, the relevant input fields in sheet ‘Diverted demand 1’ are created (see Figure 5).

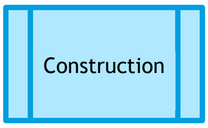
Further information on ‘**How to estimate the cost change?**’ is given on page 45.

Sensitivity to transport costs

The sensitivity of transport volume to transport costs is set at -0.5 as a default. This means that an increase in prices of 1% leads to a decrease in transported volume of 0.5 %.

The default value of -0.5 can be customized as shown in Figure 10. Literature and specific elasticity values can be found in the annex of the framework report.

3.5 Construction impact modelling



Additional environmental effect of infrastructure investments is associated with the construction of the infrastructure itself. The emissions are caused by the production and supply of used material as well as the use of energy during construction.

It is recommended to assess GHG emissions associated with construction of the investment only for larger projects. The user however may decide independently whether to in- or exclude construction emissions in the calculation.

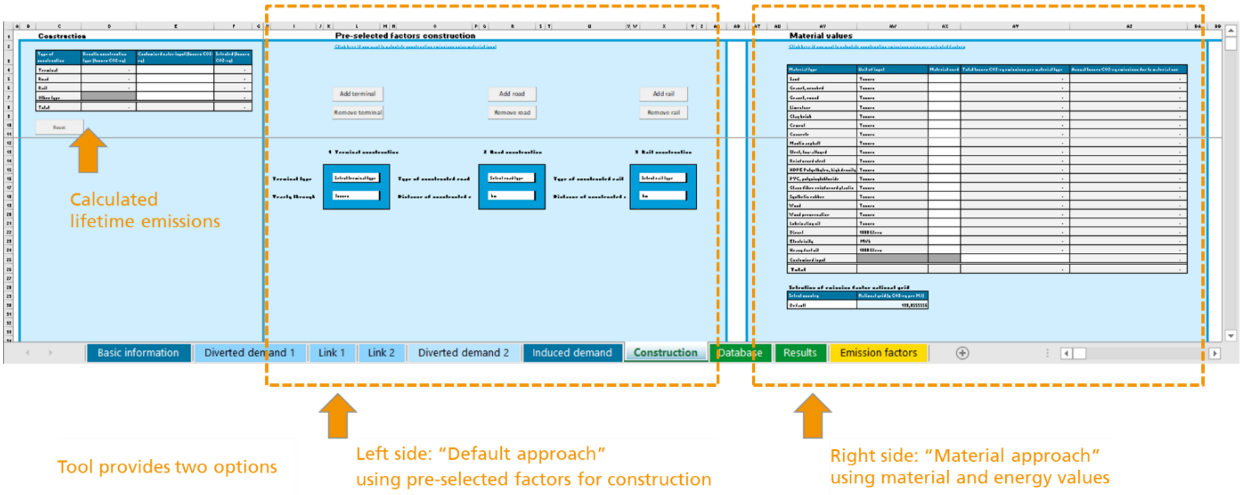
For estimating construction emissions, the tool provides two options that are described in detail in Table 6.

Table 6 Choice between two options for modelling construction emissions

Modelling diverted traffic with…	Choose this option if….
Option 1 ‘Default approach’	– You do not have any detailed information on the infrastructure design and relevant material use. – You want to calculate initial GHG emissions without any further information.
Option 2 ‘Material approach’	– You have detailed information on the infrastructure design and relevant material use.

Both options are covered by the sheet ‘Construction’: option 1 ‘Default approach’ on the left hand, option 2 ‘Material approach’ on the right hand side (see Figure 11).

Figure 11 Modelling of construction emissions

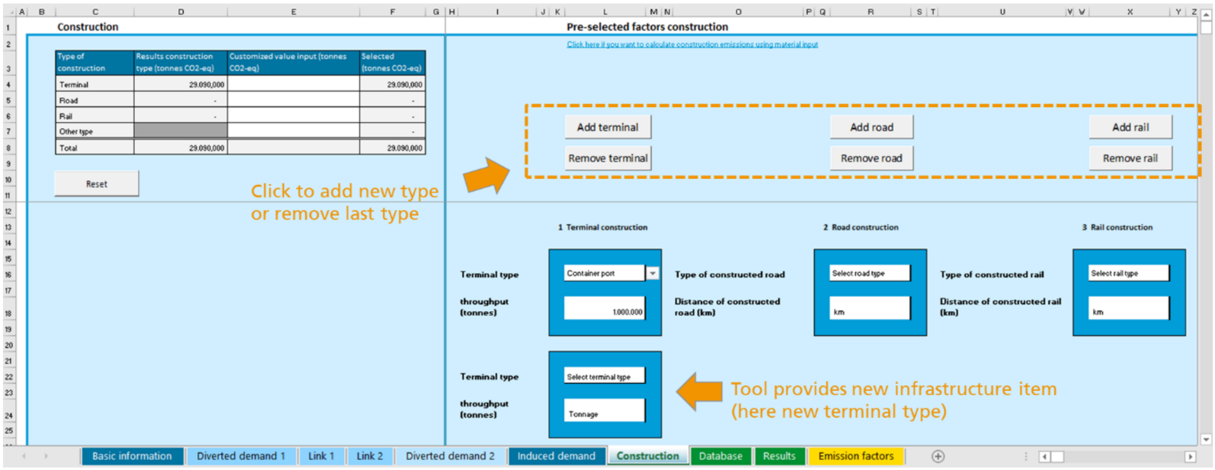


At the very left of this sheet a table summarizes the calculated lifetime emissions of the constructed infrastructure. **The user must choose between the two approaches. Note: if any data is included for the default approach then the material approach is ignored.**

3.5.1 Option 1: Using 'Default approach'

The tool provides a default approach for the construction of terminals, road and railways. Here, an average design is assumed and literature values are used for estimating the GHG emissions caused by the infrastructure construction.

Figure 12 Input area for 'Default approach' (sheet 'Construction')



Add new or remove last terminal, road or rail type

For adding a new infrastructure item (item = terminal, road, or rail), press 'Add item' button, as shown in Figure 12. This results in a new input area for the additional infrastructure item. The function of adding new infrastructure items is unlimited.

For removing the last item, press 'Remove item' button. It is not possible to remove a middle item.

Table 7 **Overview of provided types of terminals, roads and railways (sheet 'Construction'). For more information see following paragraphs**

Terminal types	Road types		Rail types
Container port	Expressway	New alignment	Rail line
Oil port	National road	Widening	Rail track
RoRo port	Provincial road	New alignment	Single track
	Rural road - gravel		Double track
	Rural road - DBST		Tunnel
			Bridge
			Electrification single track
			Electrification double track

Terminal type and yearly throughput

Select the relevant terminal type. The tool provides the following terminal types: Container port, oil port, RoRo port.

Specify the planned total capacity of the terminal.

The transport volume used refers to tonnes. If other units are more convenient e.g. twenty foot equivalent unit (TEU), Table 10 provides conversion factors recommended to be used.

Road type and length

Select the relevant road type out of the list as shown in Table 7.

Specify the total length of the road to be constructed or widened (km).

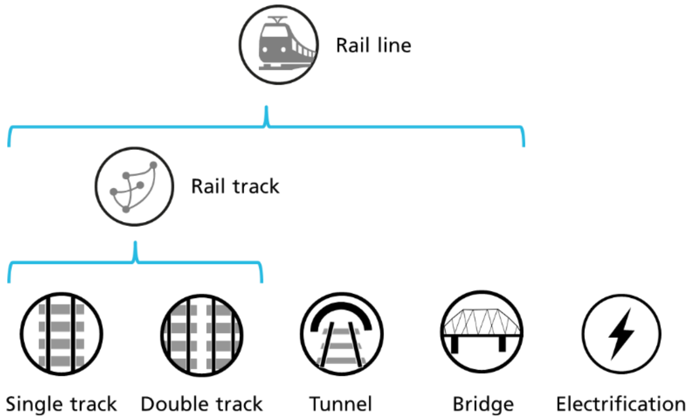
Rail type and length

Select the relevant rail type. The tool provides the following rail types with the hierarchy as shown in Figure 13:

- rail line with default share of tracks, tunnels, and bridges;
- rail track only with default share of double and single tracks;
- single track only with default share of sleeper and track types;
- double track only with default share of sleeper and track types;
- tunnel with default share of open pit and mining, excl. tracks in tunnel;
- bridge with default share of bridge types, excl. tracks on bridge;
- electrification of single track;
- electrification of double track.

Note, that the provided tunnels and bridges do not include the track running through resp. on them. Note, that the provided rail line or tracks do not include the electrification that needs to be modelled separately using the relevant electrification module.

Figure 13 Hierarchy of provided default rail types (sheet 'Construction')

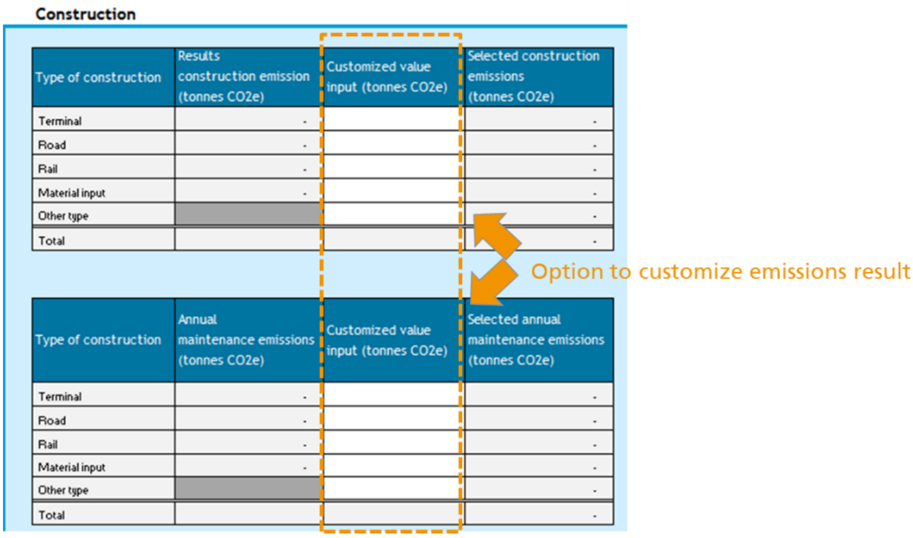


Specify the total length of the rail to be constructed (km).

The calculated emissions are shown at the very left side of the sheet (see Figure 14). In the first table, the lifetime construction emissions per infrastructure type (default approach) and in total (either default approach or material approach) are listed. In the second table, the relevant annual maintenance emissions are listed.

In both tables, the user may customize the calculated emissions for the constructed terminal(s), road(s) or rail(s).

Figure 14 Customizing emission factors for 'Default approach'


Construction

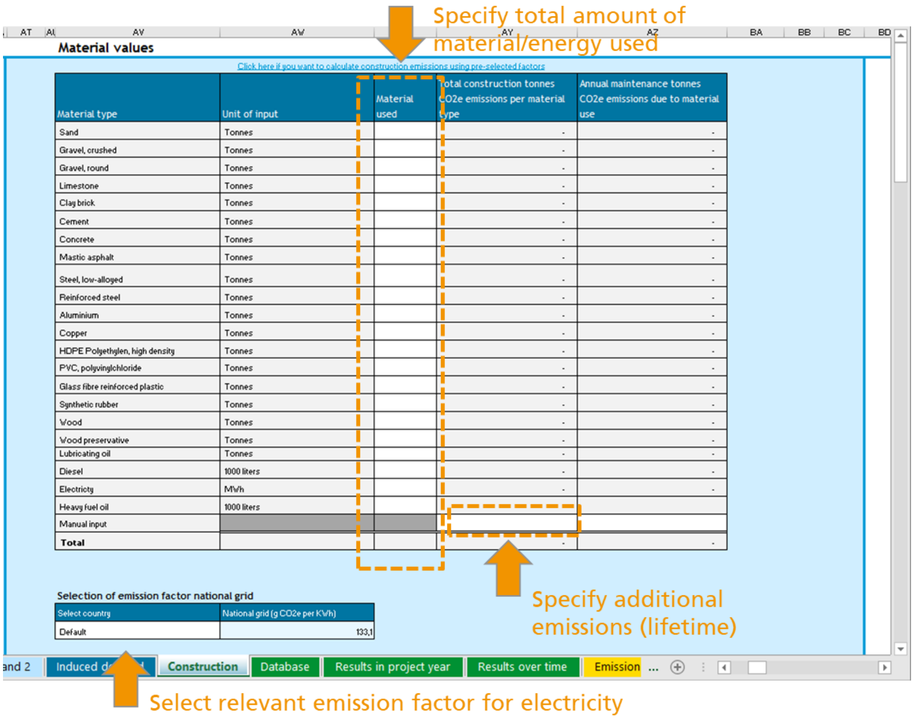
Type of construction	Results construction emission (tonnes CO2e)	Customized value input (tonnes CO2e)	Selected construction emissions (tonnes CO2e)
Terminal	-		-
Road	-		-
Rail	-		-
Material input	-		-
Other type			-
Total			-

Type of construction	Annual maintenance emissions (tonnes CO2e)	Customized value input (tonnes CO2e)	Selected annual maintenance emissions (tonnes CO2e)
Terminal	-		-
Road	-		-
Rail	-		-
Material input	-		-
Other type			-
Total			-

3.5.2 Option 2: Using ‘Material approach’

If detailed information on the infrastructure design and relevant material and/or energy use is available, the material approach can be used.

Figure 15 **Input area for construction emissions using ‘Material approach’ (sheet ‘Construction’)**



Material used

For each relevant material type and energy carrier, specify the amount estimated to be needed for constructing the infrastructure.

The tool also offers the possibility to include emissions associated with other types of materials or energy carriers than those listed. To do this the user specifies the estimated amount of total emissions (lifetime) as shown in Figure 15.

In addition, the emission factor for electricity used during construction may be selected by the user from a drop down menu, as shown in Figure 15.

The tool calculates a 10% surcharge of emissions associated to maintenance of the infrastructure.

On the right of the input cells (material approach), all lifetime and annual emissions are displayed per material/energy type as well as in total.

Example 5: Yuzhny Grain Terminal (Ukraine, EBRD project code 47383, 2016)

Using the ‘Material approach’ the construction emissions are estimated for the development of a modern greenfield grain transhipment terminal in the Port of Yuzhny. The material balance for the following selected areas are given in this example:

– quay: 440 m length; water depth of 16 m;
– ship loader: two with a capacity of 2,000 tonnes/hour;
– rail connection: rail station on berth with a capacity of 16,250 tonnes/day.

Element	Steel [t]	Concrete [m³]	Gravel [m³]	…
Quay		4,398		
Ship loader	1,281			
Rail connection	30	111	270	
…				
Total project	**1,311**	**4,509**	**270**	

Since some detailed data is lacking, the following assumptions are used for establishing the above material input matrix:

– quay: 20 m width with 10 m³ of concrete per m length of quay (Stripple & Uppenberg, 2010);
– ship loader: Height/length/depth loader 20 m/2 m/2 m, density steel 8 tonne/m³;
– rail connection: Length wagon 15 m; with material input for single tracks with concrete sleepers as published by Stripple & Uppenberg (2010), i.e. 60 kg steel/m rail, 250 kg concrete/sleeper, 1,7 sleeper / m rail, 10 m³ base material/m rail.

Material type	Unit of input	Material used	Total tonnes CO2-eq emissions per material type	Annual tonnes CO2-eq emissions due to material use
Sand	Tonnes		-	-
Gravel, crushed	Tonnes	756	15,291	0,765
Gravel, round	Tonnes		-	-
Limestone	Tonnes		-	-
Clay brick	Tonnes		-	-
Cement	Tonnes		-	-
Concrete	Tonnes	10.776	1.121,508	56,075
Mastic asphalt	Tonnes		-	-
Steel, low-alloyed	Tonnes	1.311	2.704,590	135,230
Reinforced steel	Tonnes		-	-
HDPE Polyethylen, high density	Tonnes		-	-
PVC, polyvinylchloride	Tonnes		-	-
Glass fibre reinforced plastic	Tonnes		-	-
Synthetic rubber	Tonnes		-	-
Wood	Tonnes		-	-
Wood preservative	Tonnes		-	-
Lubricating oil	Tonnes		-	-
Diesel	1000 liters		-	-
Electricity	MWh		-	-
Heavy fuel oil	1000 liters		-	-
Customized input				-
Total			3.841,390	192,069

3.6 Emission factors

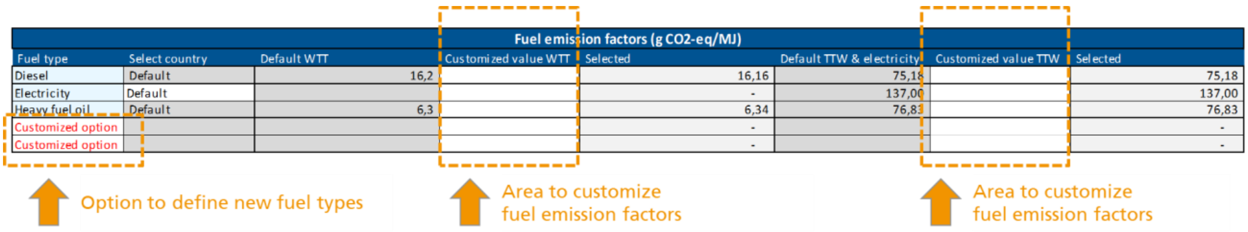
Emission factors

The sheet ‘Emission factors’ covers the following topics:
- fuel emission factors;
- vehicle emission factors.

3.6.1 Fuel emission factors

The tool provides the option to customize fuel emission factors. In the current version this refers to the following fuel types:
- diesel (road, rail and IWW transport, use for construction equipment);
- electricity (rail grid, national grid);
- heavy fuel oil (maritime transport).

Figure 16 List of fuel emission factors (sheet ‘Emission factors’)



Fuel emission factors (g CO2-eq/MJ)							
Fuel type	Select country	Default WTT	Customized value WTT	Selected	Default TTW & electricity	Customized value TTW	Selected
Diesel	Default	16,2		16,16	75,18		75,18
Electricity	Default			-	137,00		137,00
Heavy fuel oil	Default	6,3		6,34	76,83		76,83
Customized option				-			-
Customized option				-			-

For customizing the fuel emission factors, specify the relevant values in [g CO_2e/MJ] for fuel types and/or for WTT and TTW in the relevant cells as highlighted in Figure 16.

This information is used for the preliminary selection of the carbon content of fuels or electricity (rail grid) used in the assessment. For the time being, the tool provides the following suggested values for:
- Diesel:
  - 75.18 g CO_2e/MJ (TTW);
  - 16.16 g CO_2e/MJ (WTT).
- Heavy fuel oil:
  - 76.83 g CO_2e/MJ (TTW);
  - 6.34 g CO_2e/MJ (WTT).
- Electricity: national electricity grid factors (source: IFI).

3.6.2 Vehicle emission factors

The tool provides the following features for analysing and customizing vehicle emission factors:

- analysis of vehicle types used in the modelled scenarios;
- customizing suggested vehicle types and connected emission factors;
- definition of new vehicle type to be used in the model.

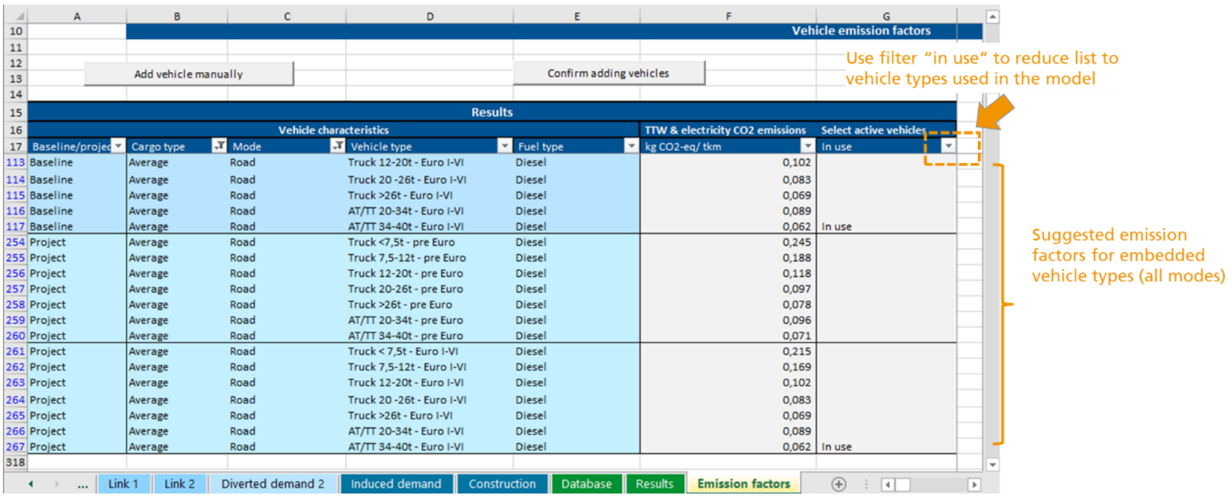
Analysis of vehicle types used in the modelled scenarios

To get an overview of which vehicle type are used in the modelled scenarios so far, the tool provides a list by using the filter feature in the sheet 'Emission factors' (see Figure 17).

Click on the filter function of the column 'In use' and select 'In use'. Thus, the list is reduced to the vehicle types used in the baseline and project scenarios. For each vehicle type, the suggested emission factor used for calculating transport emissions is listed in column 'g CO_2e/tkm'.

If relevant, this value can be customized. For this step, see description in the following section, i.e. '**Customizing of suggested vehicle types and connected emission factors**'.

Figure 17 List of vehicle types used in the model (sheet 'Emission factors', modified)



Row	Baseline/project	Cargo type	Mode	Vehicle type	Fuel type	kg CO2-eq/ tkm	In use
113	Baseline	Average	Road	Truck 12-20t - Euro I-VI	Diesel	0,102	
114	Baseline	Average	Road	Truck 20 -26t - Euro I-VI	Diesel	0,083	
115	Baseline	Average	Road	Truck >26t - Euro I-VI	Diesel	0,069	
116	Baseline	Average	Road	AT/TT 20-34t - Euro I-VI	Diesel	0,089	
117	Baseline	Average	Road	AT/TT 34-40t - Euro I-VI	Diesel	0,062	In use
254	Project	Average	Road	Truck <7,5t - pre Euro	Diesel	0,245	
255	Project	Average	Road	Truck 7,5-12t - pre Euro	Diesel	0,188	
256	Project	Average	Road	Truck 12-20t - pre Euro	Diesel	0,118	
257	Project	Average	Road	Truck 20-26t - pre Euro	Diesel	0,097	
258	Project	Average	Road	Truck >26t - pre Euro	Diesel	0,078	
259	Project	Average	Road	AT/TT 20-34t - pre Euro	Diesel	0,096	
260	Project	Average	Road	AT/TT 34-40t - pre Euro	Diesel	0,071	
261	Project	Average	Road	Truck < 7,5t - Euro I-VI	Diesel	0,215	
262	Project	Average	Road	Truck 7,5-12t - Euro I-VI	Diesel	0,169	
263	Project	Average	Road	Truck 12-20t - Euro I-VI	Diesel	0,102	
264	Project	Average	Road	Truck 20 -26t - Euro I-VI	Diesel	0,083	
265	Project	Average	Road	Truck >26t - Euro I-VI	Diesel	0,069	
266	Project	Average	Road	AT/TT 20-34t - Euro I-VI	Diesel	0,089	
267	Project	Average	Road	AT/TT 34-40t - Euro I-VI	Diesel	0,062	In use

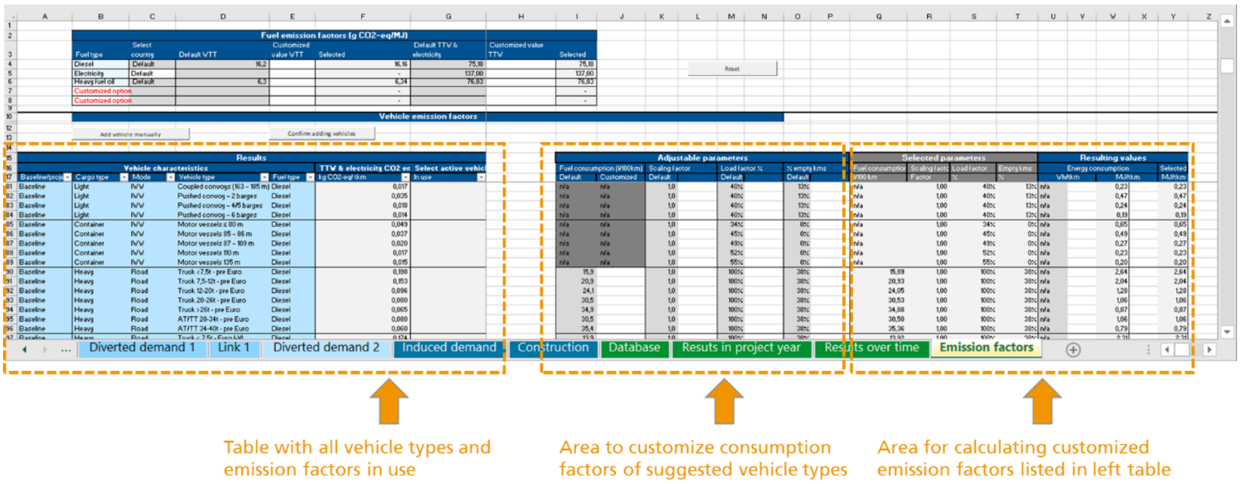
Customizing of suggested vehicle types and connected emission factors

Starting with suggested energy consumption factors for embedded vehicle types, the user can further customize the energy consumption of the vehicles depending on e.g. the relevant market and its predicted or assumed development.

For this, the sheet 'Emission factors' provides three main areas to be aware of (see Figure 18).

- table with all vehicle types and emission factors (columns A-G);
- area to customize consumption factors of suggested vehicle types (columns I-P);
- area for processing customized emission factors listed in first table (columns U-Y).

Figure 18 Overview of sheet ‘Emission factors’ as regards vehicle emission factors



The current energy consumption is declared in the following columns:

- column I: litres diesel per 100 km (road);
- column U: Wh per tkm (rail);
- column W: MJ per tkm (all modes).

For customizing the energy consumption of suggested vehicle types, the user has the following four options that can be used separate or in combination (see also Figure 19):

- fuel consumption (l/100 km); Note: option only for mode ‘road’;
- scaling factor;
- loading factor;
- %empty trip factor.

Figure 19 Area for customizing suggested vehicle types (sheet ‘Emission factors’, modified)

Results					Adjustable parameters							
Vehicle characteristics			GHG emissions		Fuel consumption (l/100km)		Scaling factor		Loading factor		% empty trip factor	
Baseline/project	Cargo type	Vehicle type	g CO2e / tkm	In use	Default	Customized	Default		Default		Default	
Baseline	Average	AT/TT 34-40 t - Euro I-VI	61,5	In use	30,8		1,0		0,6		0,2	
Project	Average	AT/TT 34-40 t - Euro I-VI	61,5	In use	30,8		1,0		0,6		0,2	

White cells to be used to customized suggested vehicle types and their emission factors

Fuel consumption (l/100 km)

For road transport, the tool lists the suggested fuel consumption factor that depends on the vehicle type, cargo type and other parameters that are described in more detail in annex A.

For customizing the emission factor for road vehicles, specify the fuel consumption in column J. The consumption factor refers to litres per 100 km.

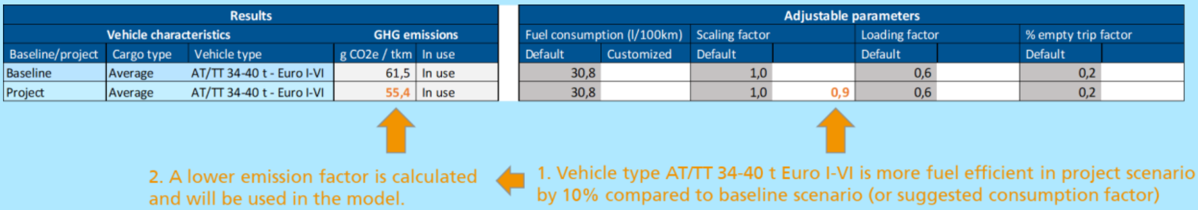
Scaling factor

For customizing the efficiency of the vehicle type, specify the scaling factor (column L). 100% refers to the suggested consumption factor. Allocate a scaling factor <100% for vehicles with a higher efficiency. (See following paragraphs for an example.)

Loading factor
For customizing the loading factor of the vehicles, specify the relevant figure in column N. The annex provides further information on the suggested loading factors.

%empty trip factor
For customizing the empty trip factor of the vehicles, specify the new value in column P. The annex provides further information on the suggested loading factors.

Example:
Definition of a 10% higher fuel efficiency for one suggested vehicle type used in project scenario



Definition of new vehicle type

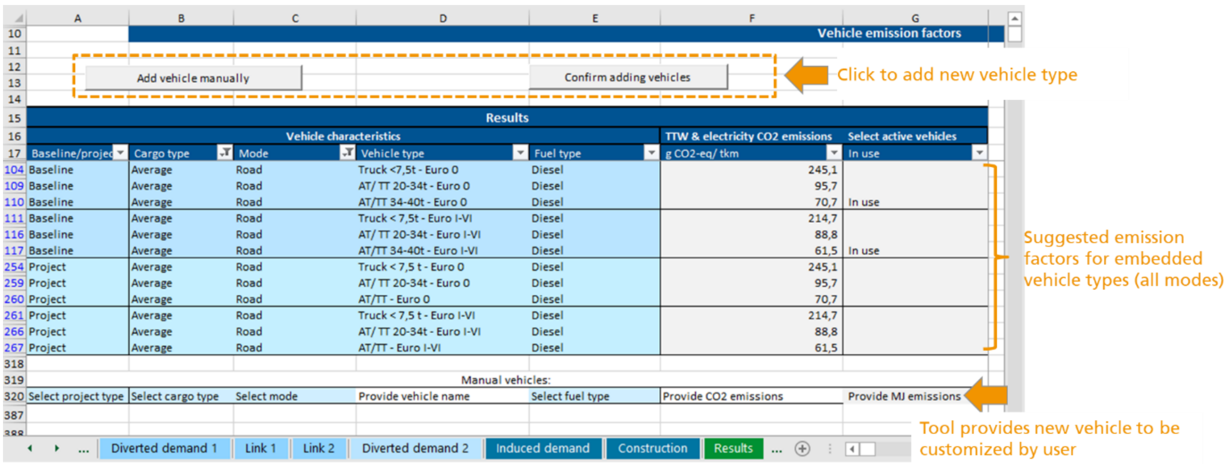
The user may want to define a new vehicle type if e.g.:

– a new vehicle technology (e.g. renewable fuels) shall be modelled (see also **Example 6** on specification of an electric truck, p. 32);
– a regional fleet mix shall be modelled by using a fictional vehicle type.

Add new vehicle type
At the start, the tool provides no input area.

For adding a new vehicle type, press 'Add vehicle manually' button, as shown in Figure 20. This results in a new input area for the additional vehicle below the main table with suggested emission factors for embedded vehicle types. The function of adding new vehicle types is unlimited.

Figure 20 Definition of a new vehicle type (sheet 'Emission factors', modified)



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Select scenario
Specify for which scenario (baseline/project) this vehicle type shall be used. Thus, this vehicle type will be provided in the relevant drop-down menu.

Select cargo type
Select the relevant cargo type transported by the new vehicle type. The tool provides the differentiation between four cargo types, i.e. light, average, heavy, and containerised. Table 5 gives an overview for the different cargo types.

Select mode
Select the relevant mode (Note: the drop-down menu is active after selecting cargo type). The tool provides the differentiation between four modes, i.e. road, rail, inland waterway (IWW), and maritime/short sea.

Provide vehicle name
Specify a descriptive term for the new vehicle name.

Select fuel type
Select the relevant fuel type of the vehicle. The tool provides the differentiation between diesel, electric (for rail), heavy fuel oil and 2 customized options that can be inserted by the user (see Section 3.6.1).

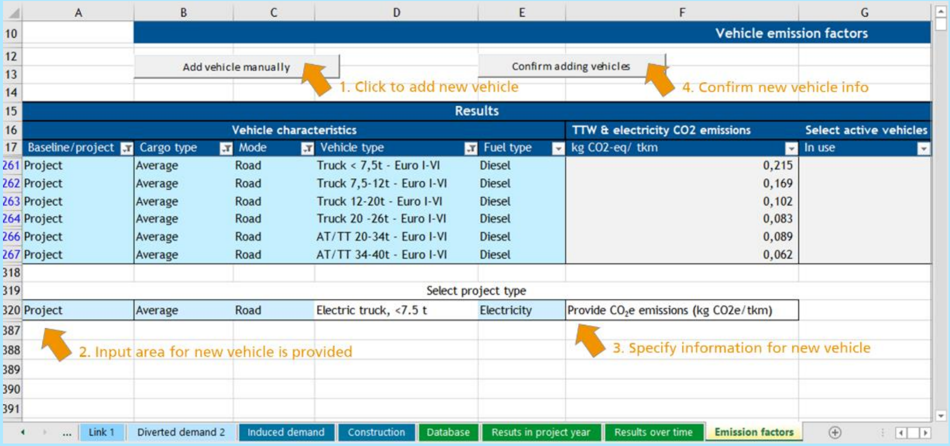
The selection of the fuel is necessary for converting TTW GHG emissions to WTT GHG emissions.

k CO_2e/tkm
If possible, specify the relevant emission factor for the vehicle type in [kg CO_2e/tkm]. Consider the principles of GHG emissions factors as outlined in the annex to guarantee comparable emissions calculation. If you use other assumptions, conversion factors or other, it is recommended to transparently document any deviation and reasons.

Confirm adding vehicles
When you have finished the specification of relevant new vehicle types, complete this step by pressing 'Confirm adding vehicles' button. Only then, the input can be used in the relevant sheets of the tool.

It is possible to adjust existing customized new vehicles again later in the modelling, or remove them, if necessary. Then, change the relevant data and reconfirm the input by pressing 'Confirm adding vehicles' button.

Example 6: Definition of an electric truck



The emission factor [kg CO_2e/tkm] may be calculated as follows.

Assumptions:

– maximum capacity of 3.5 t;
– consumption factor of 85 kWh/100 km (full) and 90% if empty;
– average load factor of 60% and empty trip factor of 20%;
– electricity factor (default) of 137 g CO_2e/MJ (see Section 3.6.1).

$$electricity\ use = \frac{60\%\times\left(0.85\frac{kWh}{vkm}-0.765\frac{kWh}{vkm}\right)+0.765\frac{kWh}{vkm}\times(1+20\%)}{60\%\times 3.5t} = 0.4614\,\frac{kWh}{tkm}$$

$$emission\ factor = 0.4614\frac{kWh}{tkm}\times 3.6\frac{MJ}{kWh}\times 0.137\ \frac{kg\ CO_2e}{MJ} = 0.228\ \frac{kg\ CO_2e}{tkm}$$

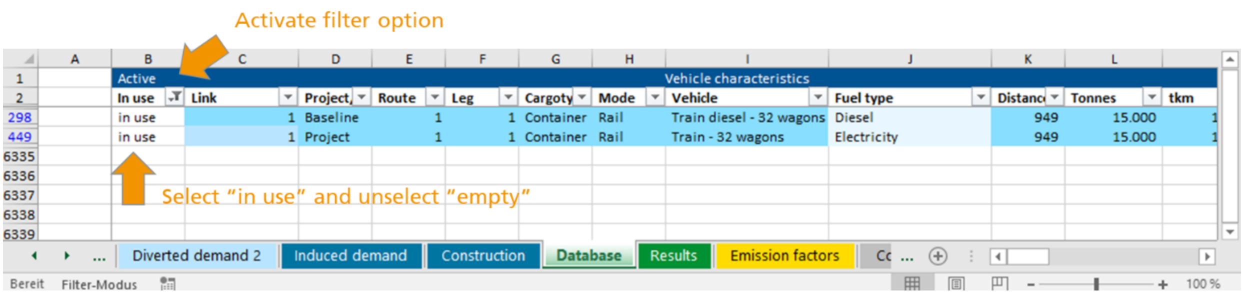
3.7 Database

Database

The sheet 'Database' provides an overview of the modelled scenarios leg-by-leg with all relevant input data as well as the calculated emissions.

To reduce the initial list to the legs in use, select in column B the filter option 'in use' (see Table 21). If you have changed transport chains after first selection, you may need to re-select 'in use' to have all legs and vehicles types shown.

Figure 21 Creating a list of all legs modelled for baseline and project scenario (sheet 'Database')



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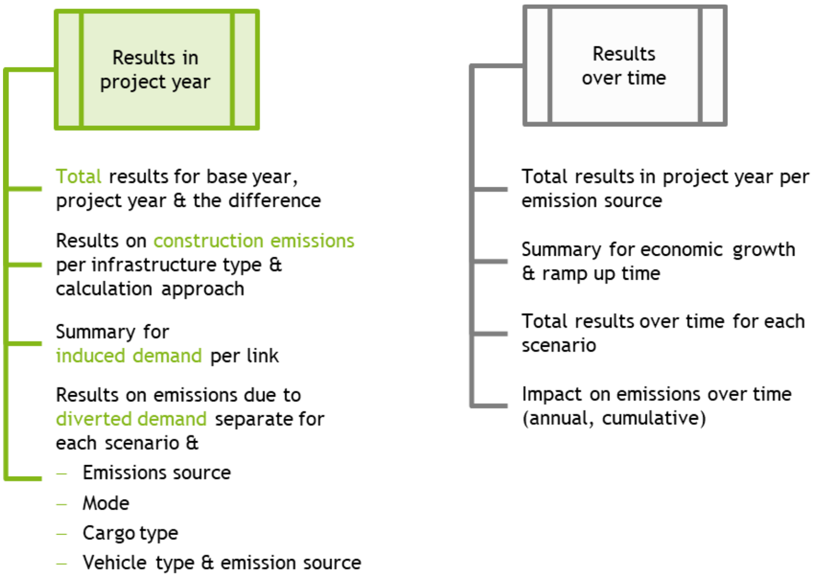
3.8 Results in project year

The tool provides two sheets on calculated results on greenhouse gas emissions caused by the modelled investment project, as shown in the figure below. The sheet ‘Results in project year’ provides the total GHG emissions results calculated for the investment project.

Figure 22 Overview on provided results in sheet ‘Results in project year’



Note: The user may chose the unit of the displayed emissions in sheet ‘Results in project year’, i.e. kilogrammes, tonnes, kilo-tonnes, mega-tonnes, giga-tonnes.

Total impact of the investment project relative to the baseline

Separate tables provide GHG emissions results in the base year, the project year as well as the difference by the investment, as a total and differentiating the following types of emissions;

- tank-to-wheel emissions of diverted traffic;
- well-to-tank emissions of diverted traffic;
- emissions of electricity used for transport;
- emissions of induced demand;
- annualised construction emissions;
- emissions of infrastructure maintenance;
- transhipment emissions.

The total annual GHG impact of the investment project is calculated as:

$$EM_{tot} = EM_{diverted} + EM_{induced} + EM_{transhipment} + EM_{construction} \quad (1)$$

With:

EM_{tot}	Total annual GHG impact in the base or project year
$EM_{diverted}$	Annual GHG effect of diverted traffic (covering TTW, WTT and electricity use)
$EM_{induced}$	Annual emissions due to induced transport
$EM_{transhipment}$	Annual emissions due to transhipment
$EM_{construction}$	Annual emissions due to construction and maintenance of infrastructure

The impact (difference) of the investment project is calculated as:

$$EM_{impact} = EM_{project} - EM_{baseline} \tag{2}$$

With:

EM_{impact}	Total GHG impact of the investment project
$EM_{project}$	Total GHG emissions in the project year
$EM_{baseline}$	Total GHG emissions in the base year

Figure 23 Total results for base year, project year and the difference (sheet 'Results in project year')

Results

Baseline

Type of emissions	kg CO2e/a
Diverted traffic TTW	3.806.379
Diverted traffic WTT	437.234
Electricity used for transport	157.589
Transhipment	150.028
Induced demand	
Annualized construction	
Maintenance	
Total	4.551.230

Project

Type of emissions	kg CO2e/a
Diverted traffic TTW	2.561.109
Diverted traffic WTT	293.236
Electricity used for transport	67.094
Transhipment	295.289
Induced demand	321.673
Annualized construction	111.882
Maintenance	37.510
Total	3.687.792

Difference

Type of emissions	kg CO2e/a
Diverted traffic TTW	-1.245.270
Diverted traffic WTT	-143.998
Electricity used for transport	-90.495
Transhipment	145.260
Induced demand	321.673
Annualized construction	111.882
Maintenance	37.510
Total	-863.438

Diverted demand 2 | Induced demand | Construction | Database | Results in project year | Results over time | Emission fa...

Results on construction emissions

Construction emissions are displayed separately for

- default approach: emissions due to the construction of terminal, road or rail infrastructure
- material approach: material input (incl. energy use during construction) or other type of emissions
- the sum of emissions

Both, the lifetime emissions (20 years) as well as annualized emissions for construction and maintenance of the infrastructure are listed.

Figure 24 Results on construction emissions (sheet 'Results in project year')

Construction

Infrastructure lifetime
20

Type of construction	Results construction per type (kg CO2e)	Results construction annualized (kg CO2e/a)	Results maintenance (kg CO2e/a)
Terminal	2.237.640	111.882	37.510
Road	-	-	-
Rail	-	-	-
Material input	-	-	-
Other type	-	-	-
Total	2.237.640	111.882	37.510

Diverted demand 2 | Induced demand | Construction | Database | Results in project year | Results over time | Emission fa...

Summary for induced demand per link

The calculated GHG emissions due to induced demand are given next.

First, the relevant assumptions of the modelled investment project are given on a link level. Figure 25 shows an example of an infrastructure investment project covering six links. In addition to the summary of modelled diverted

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transport demand, the link specific cost change, induced effect and induced demand are listed.

The total GHG emissions due to diverted demand and induced demand are listed afterwards.

Figure 25 Summary for induced demand per link (sheet 'Results in project year')

Induced demand

Sensitivity of transport
-0,50

Link	Tonnes diverted demand	Cost change	Induced effect (%)	Induced demand (tonnes)
1	5.502	-10%	5%	275
2	5.502	-10%	5%	275
3	7.336	-10%	5%	367
4	47.687	-10%	5%	2.384
5	25.677	-10%	5%	1.284
6	11.005	-10%	5%	550
7	-	-10%	5%	-
8	-	-10%	5%	-
9	-	-10%	5%	-
10	-	-10%	5%	-
Non link specific method	102.709	-10%	5%	5.135

Result	Diverted demand	Induced demand
Tonnes transport volume	102.709	5.135
kg CO2e	3.216.728	160.836,38

Results on emissions due to diverted demand

The calculated results on emissions due to diverted demand are given as a total, per mode, per cargo type as well as vehicle type.

Figure 26 Summary for induced demand per link (sheet 'Results in project year')

Diverted demand - total

	Tkm	Emissions TTW & electricity (kg CO2e)	Emissions WTT (kg CO2e)	Transhipment emissions (kg CO2e)	Total emissions (kg CO2e)
Baseline	178.992.707	3.963.968	437.234	150.028	4.551.230
Project	167.653.963	2.628.203	293.236	295.289	3.216.728
Difference	-11.338.744	-1.335.765	-143.998	145.260	-1.334.502
Difference %	-6%	-34%	-33%	97%	-29%

Diverted demand - per mode

	Baseline				Project			
	Road	Rail	IWW	Maritime	Road	Rail	IWW	Maritime
Tkm	11.884.320	10.442.796	-	156.665.591	7.904.100	4.446.056	-	
Emissions TTW & electricity (kg CO2e)	929.336	157.589	-	2.877.043	618.089	67.094	-	
Emissions WTT (kg CO2e)	199.764	-	-	237.470	132.860	-	-	
Transhipment emissions (kg CO2e)	14.672	8.803	-	126.553	9.390	5.282	-	
Total emissions (kg CO2e)	1.143.772	166.392	-	3.241.067	760.339	72.376	-	

Diverted demand - per cargo type

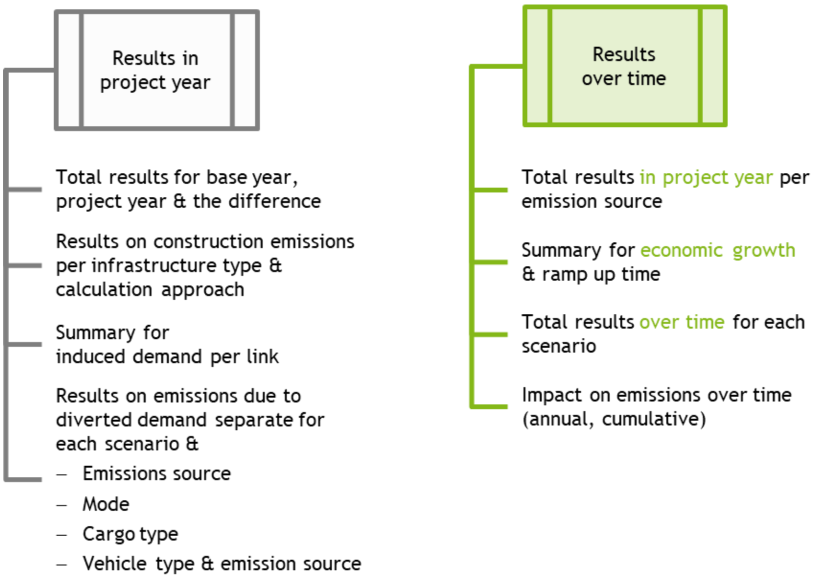
	Baseline				Project			
	Light	Average	Heavy	Container	Light	Average	Heavy	Container
Tkm	-	-	-	178.992.707	-	-	-	
Emissions TTW & electricity (kg CO2e)	-	-	-	3.963.968	-	-	-	
Emissions WTT (kg CO2e)	-	-	-	437.234	-	-	-	
Transhipment emissions (kg CO2e)	-	-	-	150.028	-	-	-	
Total emissions (kg CO2e)	-	-	-	4.551.230	-	-	-	

3.9 Results over time

Results over time

The second results sheet, ‘Results over time’, provides:
- Annual GHG emissions in the project year;
- Annual GHG emissions for a period of 20 years starting with first year in use:
  1. Separate.
  2. Accumulated.
- GHG emissions per scope.

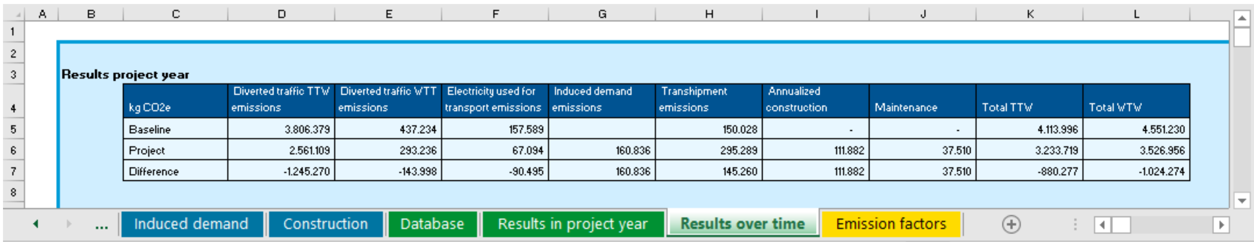
Figure 27 Overview on provided results in sheet ‘Results in project year’



Total results in project year per emission source

At the top of this results sheet, all calculated GHG emissions are shown for the project year. The emissions are shown into the relevant emissions sources for the baseline and the project scenario as well as for the difference between both scenarios. The results are summarised in a table (see Figure 28) as well as a diagram (see Figure 29).

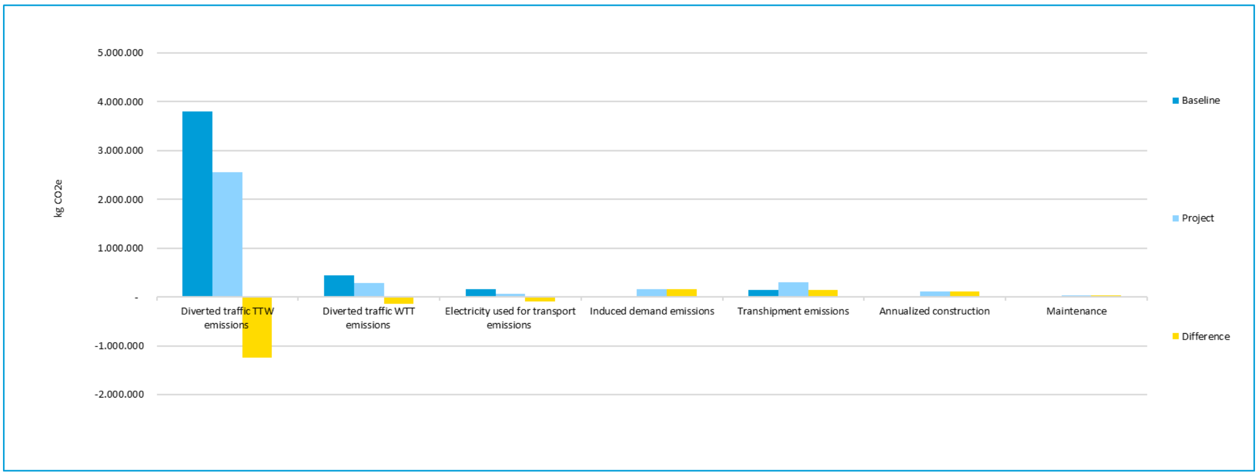
Figure 28 Results in project year, table (sheet ‘Results over time’)



Results project year

kg CO2e	Diverted traffic TTW emissions	Diverted traffic WTT emissions	Electricity used for transport emissions	Induced demand emissions	Transhipment emissions	Annualized construction	Maintenance	Total TTW	Total WTW
Baseline	3.806.379	437.234	157.589		150.028	-	-	4.113.996	4.551.230
Project	2.561.109	293.236	67.094	160.836	295.289	111.882	37.510	3.233.719	3.526.956
Difference	-1.245.270	-143.998	-90.495	160.836	145.260	111.882	37.510	-880.277	-1.024.274

Figure 29 Results in project year, diagram (sheet 'Results over time')



Summary for economic growth

Next, a summary of the assumed economic growth is given in sheet "Results over time". Two tables summarise

– The used parameters on economic growth, utilisation rate in the first year of use, the project year as well as the year when the total capacity is used
– the economic growth and rate of operational use of the planned infrastructure in the respective years.

Figure 30 Summary for economic growth (sheet 'Results over time')

Economic growth and ramp up time

Economic growth after base year	Utilisation rate in first year in use	Project year	Year when total capacity project is used	Selected unit
7%	40%	2025	2027	kg CO2e

Click here to change the selected GHG unit

Year	Economic growth	Ramp up operational use
Construction		
2021	74%	40%
2022	80%	55%
2023	86%	70%
2024	93%	85%
2025	100%	100%
2026	107%	100%
2027	115%	100%
2028	115%	100%
2029	115%	100%
2030	115%	100%
2031	115%	100%
2032	115%	100%
2033	115%	100%
2034	115%	100%
2035	115%	100%
2036	115%	100%
2037	115%	100%
2038	115%	100%
2039	115%	100%
2040	115%	100%

Results in project year | Results over time | Emiss ...

Total results over time

This is followed by the calculated GHG emissions over time. Differentiating the emissions sources, the results are given both per year and cumulative. This is done for each scenario and the total impact of the investment in three separate tables.

Using the same example as in Figure 30, the results for the baseline scenario are given in the figure below. In this example the total capacity of the new infrastructure is used in year 2027. As such, no additional diverted demand is calculated, but it stays with 4,374,230 kg CO_2e/a (diverted traffic TTW).

Figure 31 Total results over time (sheet 'Results over time')

Results over time

Baseline								
kg CO2e emissions								
Year	Construction and maintenance emissions	Diverted traffic TTW	Diverted traffic WTT	Electricity used for transport emissions	Induced demand	Transhipment	Cumulative emissions (WTW)	Cumulative results (TTW & electricty)
Construction							-	-
2021		1.129.182	129.708	46.750	-	44.507	1.350.146	1.220.438
2022		1.673.087	192.185	69.268	-	65.945	3.350.631	3.158.446
2023		2.294.595	263.577	94.999	-	90.441	6.094.244	5.830.667
2024		3.002.472	344.890	124.306	-	118.342	9.684.254	9.339.364
2025		3.806.379	437.234	157.589	-	150.028	14.235.484	13.798.250
2026		4.080.438	468.715	168.935	-	160.831	19.114.403	18.645.688
2027		4.374.230	502.462	181.099	-	172.410	24.344.604	23.842.141
2028		4.374.230	502.462	181.099	-	172.410	29.574.805	29.072.342
2029		4.374.230	502.462	181.099	-	172.410	34.805.005	34.302.543
2030		4.374.230	502.462	181.099	-	172.410	40.035.206	39.532.744
2031		4.374.230	502.462	181.099	-	172.410	45.265.407	44.762.945
2032		4.374.230	502.462	181.099	-	172.410	50.495.608	49.993.145
2033		4.374.230	502.462	181.099	-	172.410	55.725.809	55.223.346
2034		4.374.230	502.462	181.099	-	172.410	60.956.009	60.453.547
2035		4.374.230	502.462	181.099	-	172.410	66.186.210	65.683.748
2036		4.374.230	502.462	181.099	-	172.410	71.416.411	70.913.949
2037		4.374.230	502.462	181.099	-	172.410	76.646.612	76.144.149
2038		4.374.230	502.462	181.099	-	172.410	81.876.813	81.374.350
2039		4.374.230	502.462	181.099	-	172.410	87.107.013	86.604.551
2040		4.374.230	502.462	181.099	-	172.410	92.337.214	91.834.752

Results in project year | Results over time | Emission factors

Impact of infrastructure investment over time

The overall impact of the project is summarised starting in row 68 in sheet "Results over time". Here a table gives an overview on all calculated emissions per emission source, both per year and cumulative.

In addition, the calculated emissions are summarised in three diagrams:

- The difference emissions over time (per year)
  - Including construction emissions
  - Excluding construction emissions
- The difference emissions cumulated.

Figure 32 Impact of infrastructure investment over time, annual with construction emissions (sheet 'Results over time')

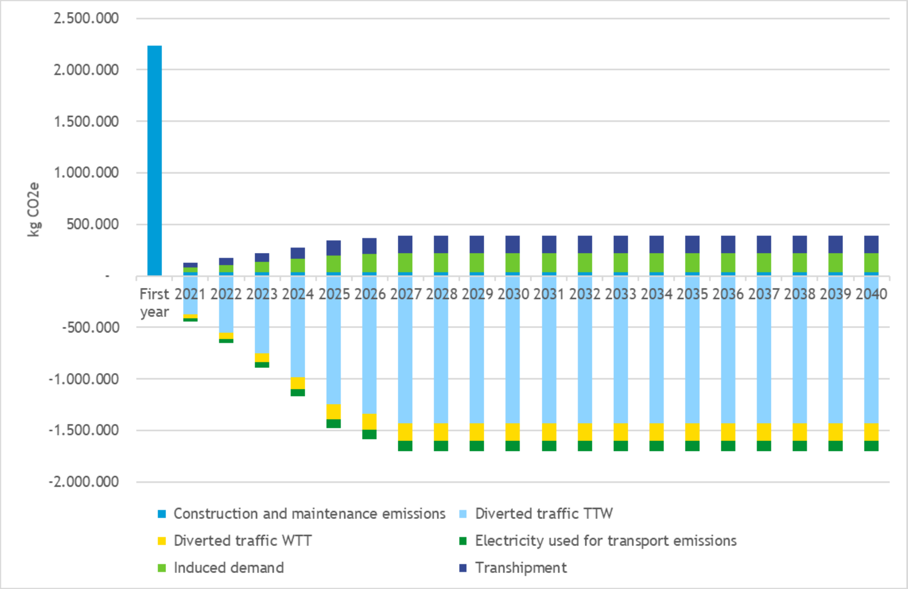


Figure 33 Impact of infrastructure investment over time, annual without construction emissions (sheet 'Results over time')

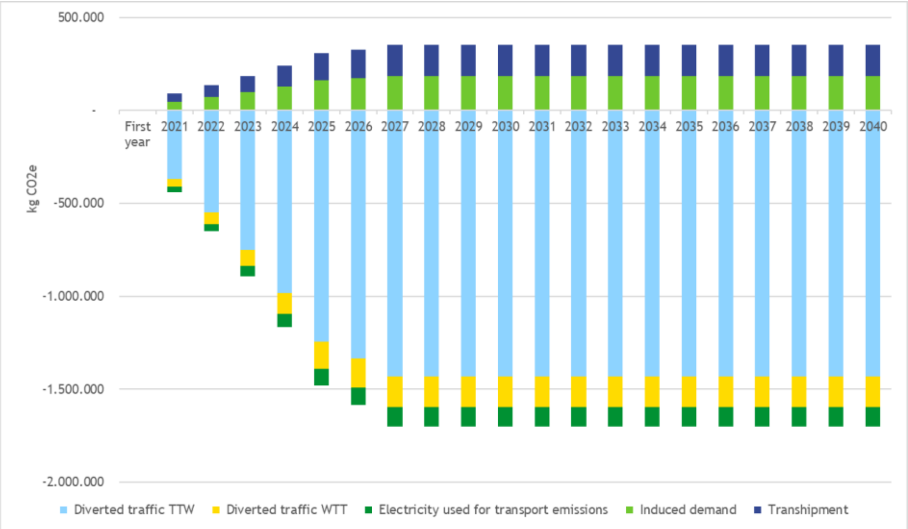
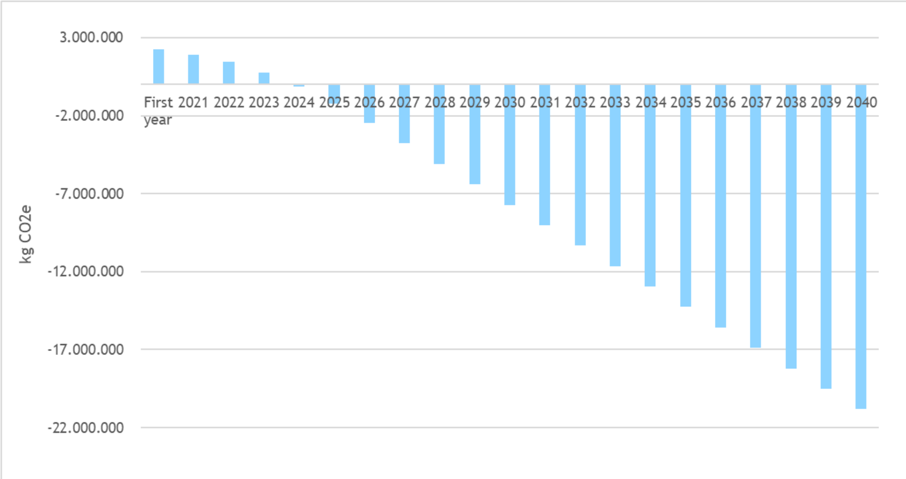


Figure 34 Impact of infrastructure investment over time, cumulative (sheet ‘Results over time’)

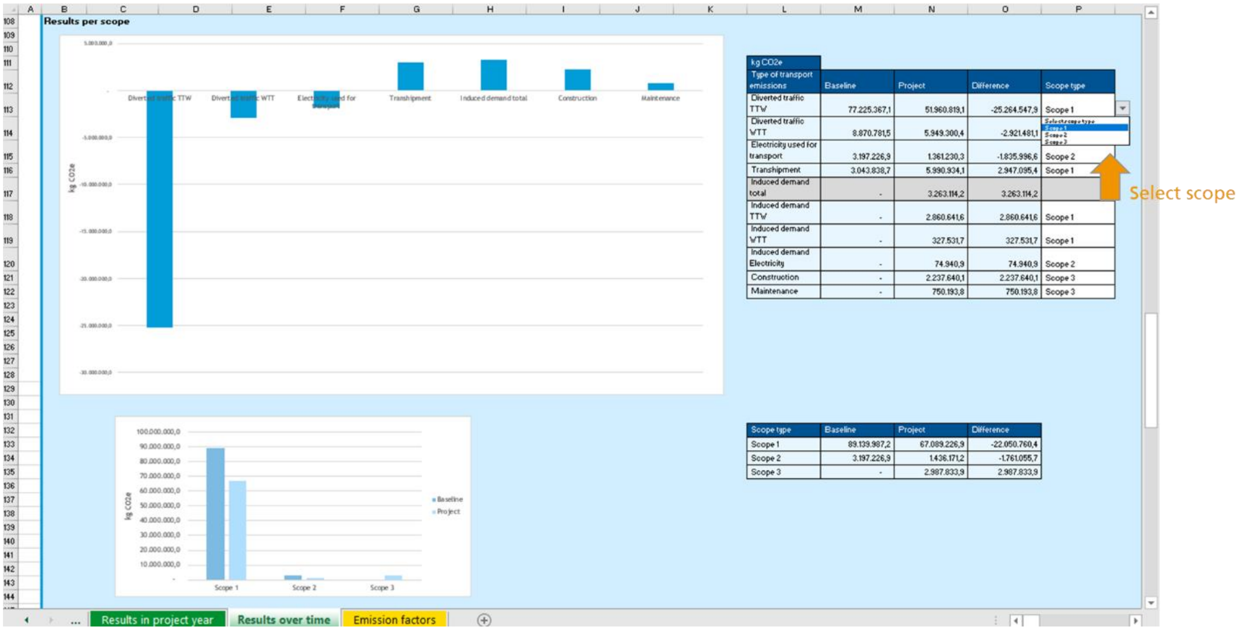


Impact of infrastructure investment per scope

The total GHG impact of the infrastructure investment is finally shown for a period of 20 years starting in the first year in use, i.e. in the example given from 2021 to 2040. The emissions are shown for the relevant emission sources.

Furthermore, the user may allocate the relevant scope for each of the emissions sources, as shown in the following figure. An additional diagram, then, shows the total emissions per scope.

Figure 35 GHG emissions of construction and 20 years of use of the new infrastructure (sheet ‘Results over time’)



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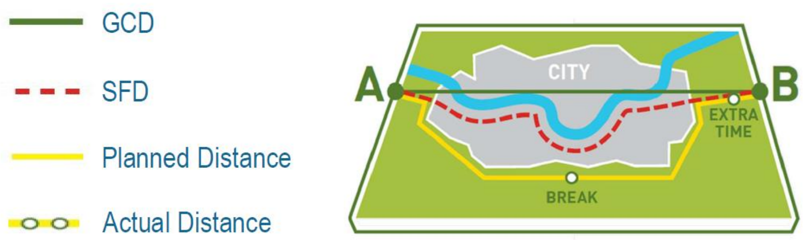
4 Overarching questions

This chapter covers general questions that may arise while using the tool.

How to measure distance of freight transport
Different approaches exist to express the distance of freight transport as shown in Figure 36. The GLEC Framework v1.0 defines the different approaches as follows (Greene & Lewis, 2016, p. 26).

Figure 36 Types of distance calculation (Greene & Lewis, 2016)



The GLEC Framework v1.0 defines the different approaches as follows (GLEC 2016, p. 26).]

- Great circle distance (GCD), also known as direct distance 'as the crow flies'
- Shortest feasible distance (SFD), as produced by a route planning software package, which may or may not take account of physical restriction on a vehicle for example weight and height restrictions
- Planned distance: the shortest planned distance related to real operating conditions. This is a modification of the theoretical SFD. For road, this takes into account weight and height restrictions and typical operational choices taken to avoid congestion hotspots such as urban centres or local/small rural roads by using highways, unless required for a collection or delivery.
- Actual distance travelled, e.g. based on knowledge of actual routings or odometer readings.

In general the other approaches underestimate the distance travelled in comparison to the actual distance. Therefore, a correction factor may be applied to GCD, SFD or planned distances as an approximation of actual distance travelled where it is not known. The correction factor should be mode-specific to reflect how direct the route network is. The appropriate approach for calculating distance varies by mode […]

The GLEC Framework acknowledges that different, well-established conventions exist for different modes that make complete alignment of approach across all modes impossible at this point. For example, for road transport the recommendation is to use planned between the point(s) of origin and destination, with a mode-specific correction factors, as listed in Table 8, if the transport operator only has actual distance travelled available.

Table 8 **Mode-specific recommended approach and correction factors**

Mode	Preferred approach	Correction factor
Road	Planned distance	Actual distance = 1.05 * planned distance
Rail	Planned network distance	
Inland waterway	Planned network distance	
Maritime/short sea shipping	Transport operator: actual distance Customer: shortest port to port distance	Actual distance = 1.15 * shortest port to port distance

The distance refers to kilometres. For converting other units see Table 9.

How to convert between different units?

The following conversion factors are recommended to be used.

Table 9 **Conversion factor for distances**

To convert from	to	Multiply by	Source
Mile	Kilometre [km]	1.61	
Nautical mile [nmi]	Kilometre [km]	1.852	(Greene & Lewis, 2016)

In this tool, the freight transport activity refers to tonne. If twenty foot equivalent unit (TEU) is more convenient to use for the assessment (e.g. in case of containerised freight transport), a conversion factor as published by Greene & Lewis (2016) shall be used, i.e. 10 tonne/TEU. If the user decides to use a different conversion factor, it is recommended to report this e.g. in the general notes field (see sheet 'Basic information', general information).

Table 10 **Conversion factors for weight and volume**

To convert from	to	Multiply by	Source
Kilogram [kg]	[metric] tonne [t]	0.001	(Greene & Lewis, 2016)
Twenty-foot equivalent TEU	[metric] tonne [t]	10	(Greene & Lewis, 2016)

Table 11 **Conversion factors for density**

Type	Density
Concrete	2,390 kg/m³
Mastic asphalt	1,775 kg/m³
Gravel	2,800 kg/m³
Wood	720 kg/m³
Diesel	0.832 kg/l

Which vehicle types are given as default by the tool?

Table 12 provides an overview, which vehicle types per mode are embedded in the tool.

The tool provides the option to define a new vehicle type for any mode. This may refer to other vehicle classes, different consumption factors or new fuel types (e.g. LNG, CNG). This customizing step is done in the sheet 'Emission factors' and is described in more detail in Section 3.6.2 '**Definition of new vehicle type**' (p. 30).

Table 12 Vehicle types provided by the tool

Mode	Vehicle type		Max. capacity
Road	Truck < 7.5 t	Fuel: diesel – pre-Euro – Euro I-VI	3.5 t
	Truck 7.5-12 t		6.0 t
	Truck 12-20 t		11.0 t
	Truck 20-26 t		17.0 t
	Truck > 26 t		24.0 t
	AT/TT 20-34 t		17.2 t
	AT/TT 34-40 t		27.0 t
Rail	Train - 11 wagons	Traction: • Diesel • Electric	500 t
	Train - 21 wagons		1,000 t
	Train - 32 wagons		1,500 t
	Train - 42 wagons		2,000 t
	Train > 51 wagons		5,000 t
IWW	Motor vessels ≤ 80 m	Fuel: diesel	365 t
	Motor vessels 85-86 m		1,537 t
	Motor vessels 87-109 m		2,041 t
	Motor vessels 110 m		3,013 t
	Motor vessels 135 m		3,736 t
	Coupled convoys 163-185 m)		4,518 t
	Pushed convoy - push boat + 2 barges		5,150 t
	Pushed convoy - push boat + 4/5 barges		11,181 t
	Pushed convoy - push boat + 6 barges		16,444 t
Maritime	Oil tanker <5 dwkt	Fuel: HFO	
	Oil tanker 5-60 dwkt		
	Oil tanker 60-200 dwkt		
	Oil tanker >200 dwkt		
	General Cargo <10 dwkt		
	General Cargo 10-20 dwkt		
	Bulk carrier <10 dwkt		
	Bulk carrier 10-100 dwkt		
	Bulk carrier >100 dwkt		
	Ro-Ro 0-4999		
	Ro-Ro 5000-+		
	Container (<1 kTEU)		
	Container (1-5 kTEU)		
	Container (5-14,5 kTEU)		
	Container (>14,5 kTEU)		

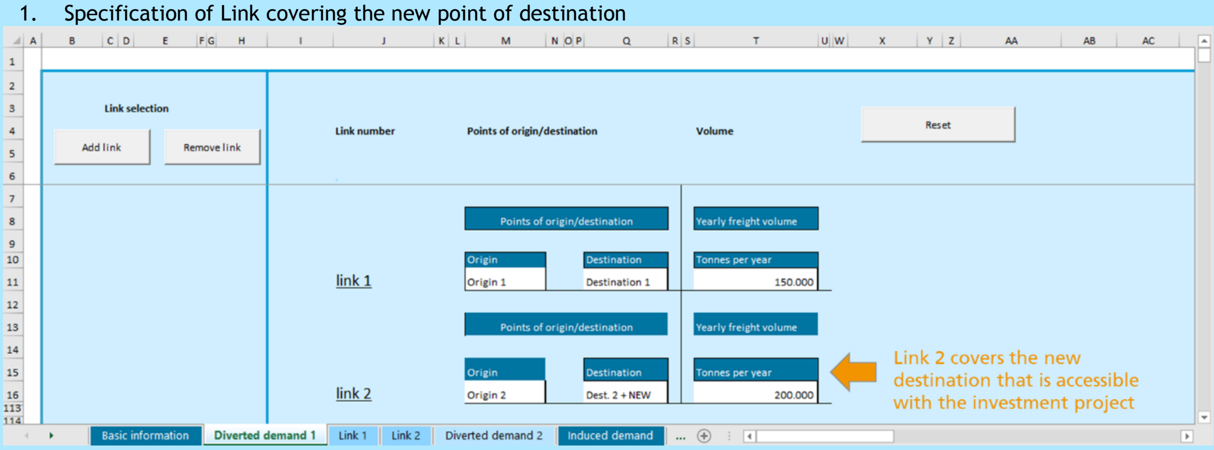
How to model future new points of origin/destination?

The consideration of future new points of origin/destination should only be included if this is distinctive of the project to be assessed. An example is, if a new terminal is installed that provides access by new modes (e.g. maritime vessels) and, thus, new regions are accessible for the goods.

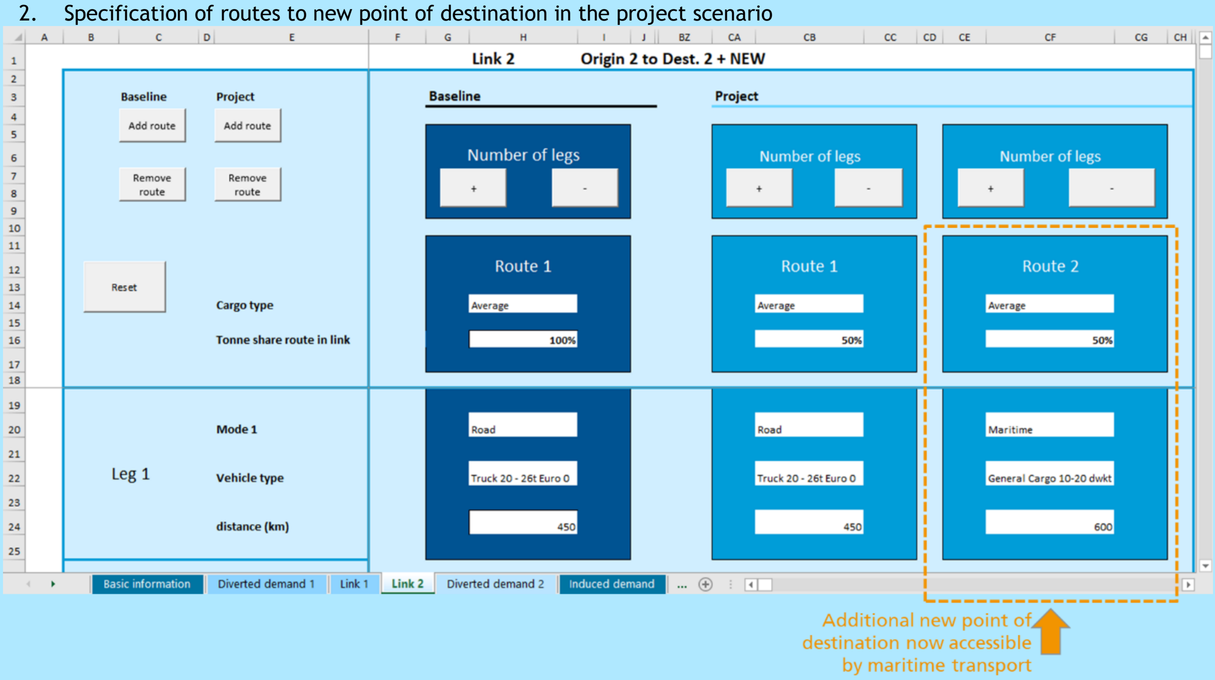
In this case, define a link covering also this new point of origin or destination. On a route level, the new point of origin or destination, then, can be specified in the project scenario.

Example: modelling of future new point of destination

1. Specification of Link covering the new point of destination



2. Specification of routes to new point of destination in the project scenario



How to estimate the cost change?

Costs that play a role in the assessment are all the carrier's costs during transport: fuel, maintenance, insurance, handling and storage costs, services directly linked to a transport, labour, capital invested in vehicles, plus all residual indirect costs like those of administrative services. Transport distance and time impact on the inventory cost of transported goods proportional to their value, a part of the shipper's logistic cost, is also included.

These costs should be evaluated both for the baseline and the project scenario per fixed amount of goods (tonne). From the total costs in the baseline and project scenario the relative cost change can be calculated as follows:

$$CostChange\ (\%) = \frac{Cost_p - Cost_b}{Cost_b} \times 100\% \tag{3}$$

With

$Cost_p$	Total transport costs after project implementation [€/tonne]
$Cost_b$	Total transport costs in the baseline scenario [€/tonne]
$CostChange\ (\%)$	Relative cost change [%]

This information is needed in the sheet ‘Induced demand’, see Section 3.4.

5 Terms/Glossary

Assessment period	Is the time horizon over which the GHG impact of the logistics investment project is assessed. It starts at the time of the baseline, where no project investment is in place and the contract of the investment project has not been signed. The project scenario is the end of the assessment period and represents a reasonable year of operation, where the project investment has been finished and a typical operation can be expected.
Baseline scenario	No project investment is in place and the contract of the investment project has not been signed.
Empty trip factor	Refers to the ratio of empty transport: distance empty / distance loaded, i.e. km_{empty} / km_{loaded} [%].
Leg	Is the smallest unit to specify a route in detail. A leg's beginning and end are defined by a change of mode, vehicle or transhipment (see also Figure 3).
Link	Connect point(s) of origin with point(s) of destination (see also Figure 3).
Load factor	Refers to the share of freight capacity [tonne] used when loaded of the vehicle type (truck, train, and vessel). In this tool, the load factor refers to weight capacity [tonne], not to volume capacity.
Project input	Covers the minimum amount of data and information necessary for calculating the GHG impact of a project.
Route	Specifies a link geographically. One link may be realised by different routes. One route may consist of one or more legs (see also Figure 3).
Point(s) of destination	Description of the boundary at the finishing point of the transport chain, until which point the new/extended terminal/port infrastructure most likely affects the transport flows, e.g. change of mode, other routing (see also Figure 3).
Point(s) of origin	Description of the boundary at the starting point of the transport chain, from which point on the new/extended terminal/port infrastructure most likely affects the transport flows, e.g. change of mode, other routing (see also Figure 3).
Project scenario	Represents a reasonable year of operation, where the project investment has been finished and a typical operation can be expected.

6 Abbreviations

AT	Articulated truck
CNG	Compressed natural gas
CO_2e	Carbon dioxide equivalents
DBST	Double bituminous surface treatment
dwkt	Deadweight tonnage in kilo tonnes: total mass a shipping vessel can carry (load, fuel, ballast water)
FSU	Former Soviet Union
GCD	Great circle distance
GHG	Greenhouse gases
GLEC	Global Logistics Emissions Council
GTW	Gross tonne weight
HDV	Heavy duty vehicles
HFO	Heavy fuel oil
IWW	Inland waterways
kTEU	1,000 TEU
LNG	Liquefied natural gas
SFD	Shortest feasible distance
TEU	Twenty foot equivalent unit
tkm	Tonne-kilometre
TT	Truck train
TTW	Tank to wheel
vkm	Vehicle-kilometre
WTW	Well to wheel
WTT	Well to tank

7 References

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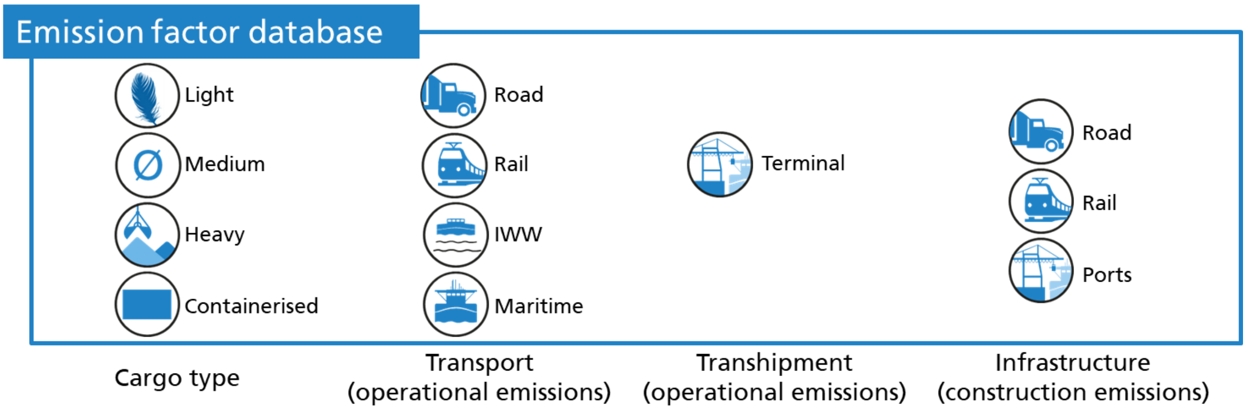
Annex A Emission factor database

For realising alignment with the GLEC framework, the current status of work of the default factor action group of GLEC has been taken into account. In some cases, the GHG emissions assessment of EBRD investment projects in logistics infrastructure requires more detailed, differently focussed and/ or additional emission factors, that are provided with the tool and are described in the following chapters.

Figure 37 Overview on contents of emission factor database



A.1 Road transport

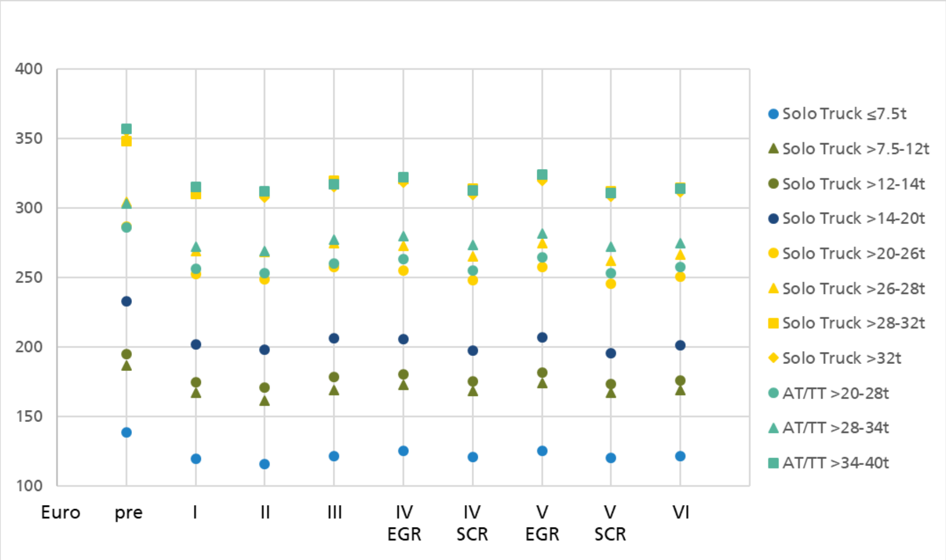
Emissions accounting of road transport base on consumption factors published by the 'Handbook Emission Factors for Road Transport' (HBEFA)[2]. The handbook differs between 11 heavy duty vehicle (HDV) classes and 9 exhaust emission standards and provides consumption factors for empty and full load transport in different traffic situations.

Figure 38 shows consumption factors of HDVs with full load on motorways for the different vehicle classes and exhaust emission standards. One can see that fuel consumption changed decisively after introduction of exhaust emission standards in 1992, i.e. 12-18% less fuel consumption per km. However, afterwards the consumption factors stay almost constant, as the main focus of the exhaust emission standards is air quality, i.e. NO_x, SO_2 emissions or particulate matters (see also Annex A.1.1).

Therefore, two truck generations are defined for the EBRD tool, i.e. pre-Euro (before 1992) and Euro (1992 an onwards).

2 See: Handbook Emission Factors for Road Transport

Figure 38 Consumption factors of HDVs with full load on motorway [g diesel/vkm]



Source: HBEFA v3.3.

Using the consumption factors of full and empty trucks (see Table 13) as well as assumptions on load factor and empty trip factors (see Table 14) the consumption factor per vehicle class and generation is calculated as follows:

$$EF_{LF,ET} = LF * (EF_{100} - EF_0) + EF_0 * (1 + ETF) \tag{4}$$

With

$EF_{LF,ET}$	Fuel consumption with LF & ETF [l diesel/100 km]
LF	Load factor
ETF	Empty trip factor
EF_{100}	Fuel consumption (full load)
EF_0	Fuel consumption (empty)

Table 13 Vehicle fuel consumption factors used for emissions calculation

Vehicle class	Generation	[l/100 km]
Truck <7,5 t	Pre Euro	15,89013
Truck 7,5-12 t		20,93032
Truck 12-20 t		24,05499
Truck 20-26 t		30,53270
Truck >26 t		34,87981
AT/ TT 20-34 t		30,50420
AT/TT 34-40 t		35,35820
Truck <7,5 t	Euro I-VI	13,91758
Truck 7,5-12 t		18,75391
Truck 12-20 t		20,77325
Truck 20-26 t		26,29373
Truck >26 t		30,55348
AT/ TT 20-34 t		28,28171
AT/TT 34-40 t		30,76376

Table 14 Load factor and distance empty of road transport for cargo types

Cargo type	Load factor	Distance empty
Light	30%	9%
Average	60%	17%
Heavy	100%	38%
Container	72%	30%

A.1.1 Reduction potentials of air pollutants within road transport

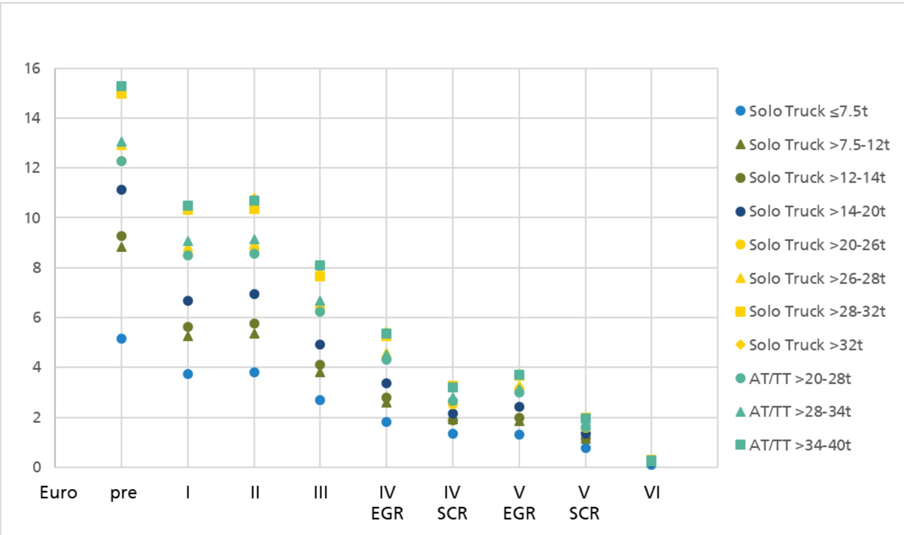
In addition to greenhouse gases, the investment projects may have a positive impact on local air quality, triggering the use of low emission technologies and modes.

Air quality is a major problem in developing as well as developed regions, specifically in and around ports and areas with concentrated freight transport and handling activities. This topic is even higher on the agenda in case of proximity to urban areas (e.g. urban ports).

The assessment of air quality impacts, however, cannot be based on fuel use as it is done for greenhouse gas emissions. Air quality is a more complex issue. Along with air pollutants emitted (depending on i.a. technology used), it needs to be linked to weather conditions, local topography as well as the concentration of pollutant from other sources. Therefore, the methodological approaches for the assessment of air quality are far more complex than GHG emissions accounting and cannot be generalized in terms of impact resulting from a given action.

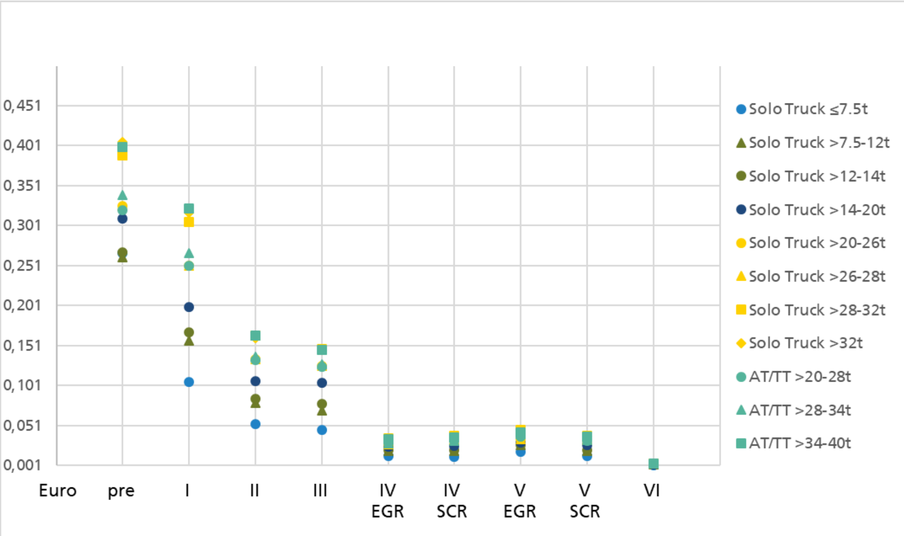
Hence, air quality is not addressed by the tool and the accompanying manual and methodological framework. The following figures give an overview on the reduction potential of air pollutants by Euro classes for road transport.

Figure 39 Emission factors of HDVs with full load on motorway [g NO_x/vkm]



Source: HBEFA v3.3.

Figure 40 Emission factors of HDVs with full load on motorway [g PM/vkm]



Source: HBEFA v3.3.

A.2 Rail transport

Emissions accounting of rail transport base on consumption modelling and assumptions as published by EcoTransIT World[3] as follows:

$$EF_{spec} = 1{,}200 * GTW^{-0.62} \quad (5)$$

With

EF_{spec}	Specific energy consumption [Wh/Gtkm]
GTW	Gross tonne weight

Relevant load factors and empty trip factors of rail transport are given in Table 15.

Table 15 Load factor and distance empty of rail transport for cargo types

Cargo type	Load factor	Distance empty
Light	30%	17%
Average	60%	33%
Heavy	100%	44%
Container	50%	17%

Assuming an empty weight per wagon of 23 t (21 t for containerised transport) and a capacity per waggon of 61 t (65 t), an average load resp. gross weight per wagon is calculated as summarized in Table 16.

Table 16 Parameters used for estimating energy consumption of rail transport for cargo types

Parameter	Light	Average	Heavy	Container
Average load per wagon [t]	15.25	24.40	33.89	27.08
Average GTW per wagon [t]	38.25	47.40	56.89	48.08
Nt/Gt	0.40	0.51	0.60	0.56

3 www.ecotransit.org/index.de.html

Table 17 **Consumption factors of rail transport (e-traction) used for emissions calculation [MJ/tkm]**

Train class	Light	Average	Heavy	Container
Train - 11 wagons	0.2626	0.1780	0.1374	0.1613
Train - 21 wagons	0.1708	0.1158	0.0894	0.1049
Train - 32 wagons	0.1329	0.0901	0.0695	0.0816
Train - 42 wagons	0.1112	0.0754	0.0604	0.0683
Train > 51 wagons	0.0993	0.0699	0.0604	0.0639

For calculating consumption factors of diesel trains an efficiency of the diesel-electricity conversion for final energy consumption of 37% is used.

Table 18 **Consumption factors of rail transport (diesel traction) used for emissions calculation [MJ/tkm]**

Train class	Light	Average	Heavy	Container
Train - 11 wagons	0.7096	0.4812	0.3713	0.4359
Train - 21 wagons	0.4617	0.3131	0.2416	0.2836
Train - 32 wagons	0.3591	0.2435	0.1879	0.2206
Train - 42 wagons	0.3004	0.2037	0.1633	0.1845
Train > 51 wagons	0.2683	0.1890	0.1633	0.1727

A.3 IWW transport

The emission for inland waterways follows the modelling as applied in STREAM Freight 2016, which has been slightly modified to allow to model the effect of different load factors in the tool. The ship categories are aligned with GLEC.

As in STREAM freight, the energy consumption per kilometre has been modelled by using the model of the Dutch Pollutant Release and Transfer Register. A description of the model is given in AVV (2003). The model estimates energy consumption using waterway parameters (depth, width, flow), vessel parameters (length/width, full and empty vessel draught), and operational parameters (sailing speed, load). Load factor affects draught and thus energy consumption.

With the model, the energy consumption on a river for an empty ship and two emission factors for a loaded ship have been calculated:

- Empty ship: EF_{empty};
- 0% loaded ship: EF_0; and
- 100% loaded: EF_{100}.

These energy consumption factors are for the empty ship and the (hypothetically) 0% loaded ship are not the same, because a different speed is assumed for an empty and a loaded ship.

Given these energy consumption factors in the tool, the average energy consumption per kilometre ($EF_{LF,EKF}$) for a ship is calculated as follows:

$$EF_{LF,EKF} = EKF * EF_{empty} + (1 - EKF) * (EF_0 + (EF_{100} - EF_0) * LF) \quad (6)$$

With

$EF_{LF,EKF}$	Average energy consumption per kilometre
EKF	Empty kilometre factor
EF_{empty}	Energy consumption of an empty ship
EF_0	Energy consumption of an 0% loaded ship
EF_{100}	Energy consumption of an 100% loaded ship
LF	Load factor

The applied load factors (LF) and empty kilometre factor (EKF) are given in Table 19.

Table 19 Load factor and distance empty of IWW transport for cargo types

<table>
<tr><th rowspan="2">IWW vessel class</th><th colspan="2">Light</th><th colspan="2">Average</th><th colspan="2">Heavy</th><th colspan="2">Container</th></tr>
<tr><th>LF</th><th>EKF</th><th>LF</th><th>EKF</th><th>LF</th><th>EKF</th><th>LF</th><th>EKF</th></tr>
<tr><td>Motor vessels ≤ 80 m</td><td rowspan="2">45%</td><td rowspan="2">25%</td><td rowspan="2">75%</td><td rowspan="2">30%</td><td rowspan="2">90%</td><td rowspan="2">40%</td><td>36%</td><td>0%</td></tr>
<tr><td>Motor vessels 85-86 m</td><td>45%</td><td>0%</td></tr>
<tr><td>Motor vessels 87-109 m</td><td rowspan="7">40%</td><td rowspan="7">13%</td><td rowspan="7">65%</td><td rowspan="7">15%</td><td rowspan="7">80%</td><td rowspan="7">30%</td><td>49%</td><td>0%</td></tr>
<tr><td>Motor vessels 110 m</td><td>52%</td><td>0%</td></tr>
<tr><td>Motor vessels 135 m</td><td>55%</td><td>0%</td></tr>
<tr><td>Coupled convoys 163-185 m</td><td></td><td></td></tr>
<tr><td>Pushed convoy - push boat + 2 barges</td><td></td><td></td></tr>
<tr><td>Pushed convoy - push boat + 4/5 barges</td><td></td><td></td></tr>
<tr><td>Pushed convoy - push boat + 6 barges</td><td></td><td></td></tr>
</table>

The resulting emission factors per tkm for the default load factor and empty kilometre factor are given in Table 20.

Table 20 Consumption factors of IWW transport used for emissions calculation [MJ/tkm]

IWW vessel class	Light	Average	Heavy	Container
Motor vessels ≤ 80 m	0.5326	0.4203	0.4187	0.6529
Motor vessels 85-86 m	0.5288	0.4018	0.3995	0.4860
Motor vessels 87-109 m	0.3788	0.2743	0.2797	0.2688
Motor vessels 110 m	0.2914	0.2143	0.2192	0.2292
Motor vessels 135 m	0.2570	0.1884	0.1936	0.2019
Coupled convoys 163-185 m	0.2324	0.1728	0.1768	
Pushed convoy - push boat + 2 barges	0.4708	0.3867	0.3929	
Pushed convoy - push boat + 4/5 barges	0.2420	0.1920	0.1956	
Pushed convoy - push boat + 6 barges	0.1927	0.1501	0.1530	

A.4 Maritime transport and short sea shipping

Emission factors for Maritime transport have been calculated according to the methodology applied in STREAM (2016). As STREAM only report on ship types used in short sea shipping, ship types have been added for deep sea shipping. The Figures in STREAM are based on the results of the 3rd IMO GHG study, supplemented with data on ship characteristics from IMO (2015)[4].

[4] The existing Shipping Fleet CO_2 Efficiency; IMO/UCL, UK, March 2015, MEPC 68/INF.24

With the methodology energy consumption per kilometre is calculated for ships in ballast with 0% load (EF_0) and 100% loaded ships (EF_{100}). Given these consumption factors, in the tool the average energy consumption ($EF_{LF,EKF}$) is calculated according to the formula below:

$$EF_{LF,EKF} = LF * (EF_{100} - EF_0) + EF_0 * (1 + EKF) \tag{7}$$

With

$EF_{LF,EKF}$	Average energy consumption per kilometre
LF	Load factor
EF_{100}	Energy consumption of an 100% loaded ship
EF_0	Energy consumption of an 0% loaded ship
EKF	Empty kilometre factor

With the load factors (LF) and empty kilometre factors (EKF) as given in Table 21.

Table 21 Load factor and distance empty of maritime transport for cargo types

Vessel class	Light		Average		Heavy		Container	
Oil tanker <5 dwkt					89%	25%		
Oil tanker 5-60 dwkt					82%	25%		
Oil tanker 60-200 dwkt					79%	56%		
Oil tanker >200 dwkt					89%	52%		
General Cargo <10 dwkt	35%	13%	85%	31%	89%	31%		
General Cargo 10-20 dwkt	35%	13%	83%	37%	86%	37%		
Bulk carrier <10 dwkt			86%	25%	90%	25%		
Bulk carrier 10-100 dwkt			85%	43%	88%	43%		
Bulk carrier >100 dwkt			86%	43%	90%	43%		
Ro-Ro 0-4999	40%	0%	40%	0%	40%	0%	40%	0%
Ro-Ro 5000-+	40%	0%	40%	0%	40%	0%	40%	0%
Container (<1 kTEU)							62%	0%
Container (1-5 kTEU)							51%	0%
Container (5-14,5 kTEU)							47%	0%
Container (>14,5 kTEU)							45%	0%

The resulting consumption factors (MJ/tkm) for the default load factor and empty kilometre factor are given in Table 22.

Table 22 Consumption factors of maritime transport used for emissions calculation [MJ/tkm]

Vessel class	Light	Average	Heavy	Container
Oil tanker <5 dwkt			0.7207	
Oil tanker 5-60 dwkt			0.2495	
Oil tanker 60-200 dwkt			0.1047	
Oil tanker >200 dwkt			0.0309	
General Cargo <10 dwkt	0.3737	0.2249	0.2177	
General Cargo 10-20 dwkt	0.2451	0.1597	0.1555	
Bulk carrier <10 dwkt		0.3905	0.3747	
Bulk carrier 10-100 dwkt		0.0883	0.0856	
Bulk carrier >100 dwkt		0.0342	0.0329	
Ro-Ro 0-4999	4.8026	5.3731	7,7805	6,8099
Ro-Ro 5000-+	0.4791	0.4791	0.4791	0.4791
Container (<1 kTEU)				0.3624

Vessel class	Light	Average	Heavy	Container
Container (1-5 kTEU)				0.2390
Container (5-14,5 kTEU)				0.1619
Container (>14,5 kTEU)				0.0950

A.5 Transhipment

For transhipment processes only limited data is published so far. Therefore, initial values are used as summarised in Table 23.

Table 23 Emission factors for transhipment of cargo

Transhipment	Emission factor	Source
Container (water/land)	1.500 kg CO_2e per tonne cargo	Fraunhofer IML
Container (rail/road)	0.800 kg CO_2e per tonne cargo	internal information
Oil terminal	0.025 kg CO_2e per tonne oil product	(Stripple, et al., 2016)
RoRo terminal	0.321 kg CO_2e per tonne cargo	

A.6 Construction emissions

Emission factors for the construction of infrastructure is limited.
However, some comprehensive studies for selected terminals, road and rail infrastructure could be identified. These studies may use different approaches but general principles are aligned and, thus, they are used as reasonable base for the default approach (see Section 3.5.1).

A.6.1 Terminal infrastructure

Terminal infrastructure has been comprehensively studied by Stripple et al. (2016) covering a container terminal, energy/oil terminal and RoRo terminal at the studied port of Gothenburg. No bulk terminal is covered by the study.

The following elements are covered by the study and related emission factors:
- port foundation construction;
- construction of the bearing surfaces in ports;
- quay construction;
- buildings in ports;
- dredging of harbours and fairways.

The authors specify the life time emissions as shown Table 24. Here, they assume a calculation period of 60 years which is a typical assumption in life cycle analysis studies.

Table 24 GHG emissions of terminals (60 years) [kg $CO_2e/t/a$] (Stripple, et al., 2016)

Terminal type	Construction	Maintenance	Operation	Total
Container terminal	0.3631	0.3652	1.5730	2.3010
Energy/oil terminal	0.1772	0.1572	0.02514	0.3596
RoRo terminal	0.1595	0.09144	0.3212	0.5721

For the EBRD tool a calculation period of 20 years was chosen by the project team. Therefore, the initial emissions associated by the construction needs to be multiplied by 3, maintenance and operation are annual emissions and, thus, independent of the calculation period.

Table 25 GHG emissions of terminals (20 years) [kg CO_2e/t/a] (basing on Stripple et al. 2016)

Terminal type	Construction	Maintenance	Operation	Total
Container terminal	1.0893	0.3652	1.5730	3.0275
Energy/oil terminal	0.5316	0.1572	0.02514	0.7139
RoRo terminal	0.4785	0.09144	0.3212	0.8911

Emission factors resulting from this approach and used by the tool are summarised in the following tables.

Table 26 Emission factors for terminal infrastructure (annual) (basing on Stripple et al. 2016)

Terminal type	Construction emissions [kg CO_2e/t/a]	Maintenance emissions [kg CO_2e/t/a]
Container terminal	1.08935	0.3652
Energy/oil terminal	0.5316	0.1572
RoRo terminal	0.4785	0.0914

Table 27 Emission factors for terminal infrastructure (lifetime of 20 years) (basing on Stripple et al. 2016)

Terminal type	Construction emissions [kg CO_2e/t]	Maintenance emissions [kg CO_2e/t]
Container terminal	21.79	7.30
Energy/oil terminal	10.63	3.14
RoRo terminal	9.57	1.83

A.6.2 Road infrastructure

Emission factors used for road infrastructure construction base on a World Bank tool 'Roadeo' (ASTAE, 2011)[5]. In the executive summary (The World Bank ; ASTAE, 2010) on the tool, emission factors for five road categories are published. However, no details on the underlying assumptions (e.g. number of lanes, width, or design) are given by the authors, see Table 28.

Table 28 GHG emissions for road types [t CO_2e/km]

Road type	Transport	Material	Machines	Total
Expressway	1,003.71	2,121.83	108.58	3,234.12
National road	235.00	522.62	36.19	793.81
Provincial road	66.08	111.52	28.96	206.56
Rural road – gravel	19.83	55.51	14.48	89.82
Rural road - DBST	25.91	62.35	14.48	102.74

With view on the tool's construction one can assume, that an average share of bridge and tunnel infrastructure is covered, however, no emissions associated with maintenance of the infrastructure. Therefore, 10% for maintenance is surcharged.

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Moreover, the modelling of a new alignment compared to widening an existing road by 2 lanes results in an approximately share of 40% of the total emissions of a new alignment. This share is used to estimate emission factors for widening an average expressway and a national road.

For providing separate maintenance emissions, an average surcharge for maintenance emissions of 10% is assumed.

Emission factors resulting from this and used by the tool are summarised in the following tables.

Table 29 **Emission factors for road infrastructure (annual) (basing on Roadeo, (ASTAE, 2011))**

Road type	Work	Construction emissions [t CO_2e/km/a]	Maintenance emissions [t CO_2e/km/a]
Expressway	New	161.71	16.17
National road		39.69	3.97
Provincial road		10.33	1.03
Rural road - gravel		4.49	0.45
Rural road - DBST		5.14	0.51
Expressway	Widening by 2 lanes	64.68	6.47
National road		15.88	1.59

Table 30 **Emission factors for road infrastructure (lifetime of 20 years) (basing on Roadeo (ASTAE, 2011))**

Road type	Work	Construction emissions [t CO_2e/km]	Maintenance emissions [t CO_2e/km]
Expressway	New	3,234.12	323.41
National road		793.81	79.38
Provincial road		206.56	20.66
Rural road - gravel		89.82	8.98
Rural road - DBST		102.74	10.27
Expressway	Widening by 2 lanes	1,293.65	129.36
National road		317.52	31.75

A.6.3 Rail infrastructure

Rail infrastructure has been comprehensively studied by Tuchschmid et al. (2011). The underlying assumptions on material consumption per type of infrastructure have been transparently documented in this study. As the study bases on an older version of LCA-data (ecoinvent v2.1) GHG emissions have been re-calculate using ecoinvent v3.3 (see also Table 36) and summarised in Table 31.

The following types of rail infrastructure components are focus of the study:
- project type (renewal of existing lines, new constructed lines);
- track type (single track, double track);
- sleeper type (concrete sleeper, wooden sleeper, iron sleeper);
- rail type (UIC 60, S 54, S 49);
- substructure and earthwork;
- bridge type (concrete viaduct (> 200 m), other concrete bridges, iron bridge);
- tunnel type (open pit construction, mining construction);
- construction and maintenance.

Table 31 **Emission factors for new construction of rail tracks [kg CO_2e/km] (basing on Tuchschmid et al. (2011) and ecoinvent v3.3)**

Type of infrastructure	Single track	Double track
Concrete sleeper; UIC 60	595,331.55	1,446,064.25
Concrete sleeper; S 54	573,310.89	1,402,022.93
Concrete sleeper; S 49	553,966.88	1,363,221.01
Wooden sleeper; UIC 60	644,354.19	1,548,474.96
Wooden sleeper; S 54	622,333.54	1,504,433.65
Wooden sleeper; S 49	602,989.53	1,465,631.73
Iron sleeper; UIC 60	702,644.90	1,670,361.93
Iron sleeper; S 54	680,624.24	1,626,320.62
Iron sleeper; S 49	661,280.23	1,587,518.70
Concrete viaduct (>200 m);	9,930,890.97	16,551,484.95
Other concrete bridge	4,292,817.28	7,154,695.47
Iron bridge	8,150,956.22	13,584,927.03
Tunnel: Open pit construction	15,600,858.89	26,001,431.49
Tunnel: Mining construction	9,209,995.54	15,349,992.56
Electrification	20,149.44	40,298.87

For providing of flexible set of emission factors balanced with a sufficient level of detail, 6 default rail types have been derived (see also Figure 13):

- rail line with default share of tracks, tunnels, and bridges;
- rail track with default share of double and single tracks;
- single track with default share of sleeper and track types;
- double track with default share of sleeper and track types;
- tunnel with default share of open pit and mining, , excl. tracks in tunnel;
- bridge with default share of bridge types, , excl. tracks on bridge.

For this, UIC data on rail infrastructure in various countries has been used (Tuchschmied et al. (2011)) as summarised in the following tables.

Table 32 **Assumed share of rail track types for deriving average emission factors**

Type of infrastructure	Single track		Double track	
Concrete sleeper; UIC 60	17,5%		12,4%	
Concrete sleeper; S 54	10,4%		7,4%	
Concrete sleeper; S 49	17,4%		12,3%	
Wooden sleeper; UIC 60	3,7%		2,6%	
Wooden sleeper; S 54	2,2%	100%	1,5%	100%
Wooden sleeper; S 49	3,6%		2,6%	
Iron sleeper; UIC 60	1,5%		1,0%	
Iron sleeper; S 54	0,9%		0,6%	
Iron sleeper; S 49	1,4%		1,0%	

Table 33 **Assumed share of types of rail bridges tunnels for deriving average emission factors**

Type of infrastructure	Single track	Double track	
Concrete viaduct (>200 m);	13,6%	7,7%	
Other concrete bridge	28,4%	20,5%	100%
Iron bridge	17,5%	12,2%	
Tunnel: Open pit construction	13,5%	10,9%	100%
Tunnel: Mining construction	42,9%	32,7%	

For providing separate maintenance emissions, an average share for maintenance emissions of 10% is assumed.

Emission factors resulting from this and used by the EBRD tool are summarised in the following tables.

Table 34 Emission factors for rail infrastructure (annual)

Rail type	Construction emissions [kg CO_2e/km/a]	Maintenance emissions [kg CO_2e/km/a]
Rail line	68,196.02	7,577.34
Rail track	42,332.30	4,703.59
Single track	26,518.84	2,946.54
Double track	64,590.25	7,176.69
Bridge	377,989.22	41,998.80
Tunnel	625,672.13	69,519.13
Electrification, single track	18,134.49	2,014.94
Electrification, double track	36,268.98	4,029.89

Table 35 Emission factors for rail infrastructure (lifetime of 20 years)

Rail type	Construction emissions [kg CO_2e/km]	Maintenance emissions [kg CO_2e/km]
Rail line	1,363,920.49	151,546.72
Rail track	846,646.08	94,071.79
Single track	530,376.83	58,930.76
Double track	1,291,805.09	143,533.90
Bridge	7,559,784.43	839,976.05
Tunnel	12,513,442.51	1,390,382.50
Electrification, single track	362,689.84	40,298.87
Electrification, double track	725,379.69	80,597.74

A.6.4 Material

For emissions modelling with data on material use, emissions factors as published by Ecoinvent v3.3 has been included into the tool. Here, the method 'ReCiPe Midpoint w/o Lt GWP100' has been used. Emission factors for a selection of relevant materials used in infrastructure projects are summarised in Table 36.

Table 36 Emission factors for types of materials (Ecoinvent v3.3)

Material	[kg CO_2e/kg]
Sand	0.01206852
Gravel, crushed	0.01838795
Gravel, round	0.01208828
Limestone	0.00220569
Clay brick	0.31809655
Cement	0.82532166
Concrete	0.09461327
Mastic asphalt	0.28249516
Steel, low-alloyed	1.87545263
Reinforced steel	2.40380191

Aluminium	8.51923239
Copper	7.87448991
HDPE polyethylene, high density	2.00787824
PVC, polyvinylchloride	2.14409967
Glass fibre reinforced plastic	9.01181376
Synthetic rubber	2.82793597
Wood	0.08949028
Wood preservative	2.29950215
Lubricating oil	1.13005188

A.7 Electricity

Table 37 Emission factors for electricity (EBRD internal information)

Geographical region	[g CO_2/kWh]
Afghanistan	
Albania	
Algeria	447.994
Angola	475.852
Argentina	512.072
Armenia	428.000
Australia	690.060
Austria	154.061
Azerbaijan	426.803
Bahamas	723.000
Bahrain	561.912
Bangladesh	641.232
Barbados	
Belarus	385.761
Belgium	205.128
Belize	152.100
Benin	666.347
Bolivia	428.106
Bosnia and Herzegovina	972.983
Botswana	964.450
Brazil	440.000
Brunei Darussalam	509.724
Bhutan	778.500
Bulgaria	678.480
Burundi	
Cambodia	745.661
Cameroon	342.099
Canada	209.774
Cape Verde	622.111
Central African Republic	
Chad	
Chile	512.787
China	768.969
Hong Kong	682.510
Colombia	228.457
Congo, Democratic Republic of (DRC)	964.450
Congo, Republic of	348.228
Comoros	
Cook Islands	
Costa Rica	175.123

Geographical region	[g CO_2/kWh]
Côte d'Ivoire	452.118
Croatia	279.195
Cuba	698.269
Curacao	659.092
Cyprus	657.875
Czech Republic	713.444
Denmark	400.677
Djibouti	
Dominica	
Dominican Republic	488.700
Ecuador	473.303
Egypt	417.399
El Salvador	401.605
Eritrea	747.310
Estonia	918.127
Ethiopia	0.339
EU 28	391.980
Fiji	509.500
Finland	229.519
FYR of Macedonia	812.633
France	94.209
Gabon	503.518
Gambia	682.000
Georgia	190.145
Germany	562.649
Ghana	393.919
Gibraltar	689.778
Greece	604.903
Guatemala	459.116
Guinea	
Guinea-Bissau	
Guyana	
Haiti	667.386
Honduras	530.888
Hungary	281.213
Iceland	
India	761.031
Indonesia	626.810
Iran, Islamic Republic of	509.743
Iraq	927.654

Geographical region	[g CO_2/kWh]
Ireland	381.418
Israel	592.133
Italy	361.481
Jamaica	649.177
Japan	491.162
Jordan	612.074
Kazakhstan	604.285
Kenya	407.383

Geographical region	[g CO_2/kWh]
New Zealand	204.951
Nicaragua	525.556
Niger	711.054
Nigeria	399.238
Niue	
Norway	29.036
Oman	468.440
Pakistan	497.315

Geographical region	[g CO_2/kWh]
Kiribati	
Korea (North), Democratic Republic of	572.985
Korea (South), Republic of	488.623
Kosovo	927.815
Kuwait	631.161
Kyrgyzstan	172.855
Laos	560.000
Latvia	191.144
Lebanon	695.310
Lesotho	964.450
Liberia	
Libya	567.634
Lithuania	296.764
Luxembourg	319.969
Madagascar	556.000
Malaysia	533.197
Maldives	
Malta	703.790
Marshall Islands	
Mauritania	
Mauritius	915.000
Mexico	451.699
Moldova	430.003
Mongolia	1,212.436
Montenegro	684.742
Morocco	572.148
Mozambique	964.450
Myanmar	348.152
Namibia	964.450
Nauru	
Nepal	19.429
Netherlands	360.175

Geographical region	[g CO_2/kWh]
Palau	
Panama	474.866
Papua New Guinea	703.750
Paraguay	
Peru	472.667
Philippines	607.007
Poland	778.864
Portugal	339.551
Qatar	425.990
Romania	450.668
Russian Federation	417.836
Rwanda	584.000
Saint Kitts and Nevis	
Saint Lucia	
Samoa	
San Marino	
Sao Tomé & Principe	674.000
Saudi Arabia	494.500
Senegal	620.248
Serbia	820.146
Seychelles	
Sierra Leone	
Singapore	442.921
Slovak Republic	234.848
Slovenia	457.298
Solomon Islands	
Somalia	
South Africa	964.450
South Sudan	744.678
Spain	312.793
Sri Lanka	736.753
Sudan	177.500

Geographical region	[g CO_2/kWh]
Suriname	562.551
Swaziland	964.450
Sweden	27.672
Switzerland	24.461
Syrian, Arab Republic	517.518
Taipei (Chinese)	533.308
Tajikistan	15.420
Tanzania	481.765
Thailand	434.743
Timor-Leste	
Togo	375.927
Tonga	
Trinidad and Tobago	506.075
Tunisia	415.034
Turkey	380.816

Geographical region	[g CO_2/kWh]
Turkmenistan	656.901
Tuvalu	
Uganda	513.500
Ukraine	599.693
United Arab Emirates	500.130
United Kingdom	428.224
United States	459.023
Uruguay	270.732
Uzbekistan	532.500
Vanatu	
Venezuela	376.171
Vietnam	449.186
Yemen	653.001
Zambia	964.450
Zimbabwe	964.450