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A Study of Economic Impacts of Freight Speed Increase and Travel Time Reliability Improvements by Rail

Appraisal Report March 2016



## Appraisal Report

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## 1. Introduction

The aim of this report is to provide guidelines (methodologies, default unit values) on a number of selected topics in the appraisal of rail projects in freight transport in JASPERS countries. It was written to assist JASPERS staff and administrations in JASPERS countries on assessing rail freight projects. The focus is on calculating the benefits of the project in the freight markets.

## 1.1 Aims and context of the project

This study is about the economic impacts of infrastructural developments in freight transport by rail in JASPERS countries (especially Eastern Europe). To this end, this study covers the following four topics for rail freight transport:

- Value of time (VOT), also known as value of travel time (VTT) and value of travel time savings (VTTS);
- Value of (delivery time) reliability (VOR), also known as value of travel time variability (VTTV);
- **Transport cost savings** that accrue as a result of technological innovations in the train system (such as a higher loading gauge, longer trains, electric instead of diesel trains);
- **Approaches** and **outcomes** (e.g. elasticities) for estimating changes in modal split at the aggregate level for the purpose of project appraisal.

## 1.2 Aims of phase 4 of the project and relation with other tasks

This report contains the outcomes of phase 4. The aim of this phase is to produce recommendations for the appraisal of rail projects in freight transport in JASPERS countries, in terms of methodologies and unit values to be used as default values. In phase 2 of this project we reviewed the results from the existing literature and in phase 3 we carried out a number of interviews with firms involved in (rail) freight transport in JASPERS countries (market analysis). In this way, phases 2 and 3 feed into the appraisal phase (4) and the final reporting phase (5).

In this phase 4 of the project, guidelines are provided, based on both the literature review and the market analysis, on how to appraise rail freight projects. These guidelines can be used by JASPERS staff to evaluate projects submitted to JASPERS, but potentially also by professionals preparing project proposals to be submitted to JASPERS.

This report does not intend to cover the whole appraisal framework. It does for instance not include guidelines on the calculation and treatment on investment costs and track maintenance costs. Nor does it include advice on unit values that could be used for including external effects of projects (such as harmful emissions and accidents or positive effects on employment or a region's productivity) in cost-benefit analysis (CBA). What this report does is discuss how to appraise a number of selected project effects in rail freight in JASPERS countries:

- Transport time benefits;
- Transport time reliability benefits;
- Transport cost savings other than through time;
- Modal shift from road to rail, which affects the above internal benefits, but also has an important external benefit through a reduction in harmful emissions (possibly also a reduction in casualties).



#### 1.3 Stepwise overview of the general approach

Figures 1-1 and 1-2 provide an overview of the general approach that we recommend for appraisal of rail freight projects in JASPERS countries. Before starting with these four steps it is recommended to do a qualitative market consultation to understand the context.

**Step 1:** Collect data on transport flows, transport distances, transport time, transport time reliability and transport cost for the reference situation and the project situation.



Figure 1-1: Stepwise approach to appraisal of rail freight projects

Actually the data in Step 1 are all predictions since both situations refer to the future. Transport distance and transport time without the project (reference) and with the project are usually obtained from the transport networks that are included as the supply side in transport models. Within each freight transport model, there are transport cost functions, that usually read in time and distance and then calculate the time-dependent and distance-dependent transport costs, using functions that include unit cost assumptions for costs per hour and per km (either per tonne or per transport). In a number of transport models there is a feedback effect (the broken lines in Figure 1-2): if a route is used above capacity, this route is made less attractive (e.g. longer travel times) until a feasible equilibrium is reached. This first step is discussed in chapter 2 that also includes guidelines on how to calculate transport costs (on the basis of distance and time) for projects where this information is not available.

Step 2: Apply the transport models for reference and project situation to produce the transport flows

The transport models preferably are specific models estimated on data for the country or corridor of the project under investigation (or even a model developed specifically for the project in case of some large projects). If proper transport models are not available, and it is not possible to improve existing models or build new ones, then as a last resort one might use more generic approaches, such as the simplified transport models HIGHTOOL and an elasticity-based model such as EXPEDITE, for a quick scan analysis. An important role of the transport model is that it provides how many



existing rail users there will be (transported tonnes that use rail in reference and in the project case) and how many will switch to rail with the project (new rail users). For the latter group we assume that the rule of half from welfare analysis will be used (if required we can expand on this issue). The transport models are discussed in chapter 3.

**Step 3:** Calculate the transport distance, time and reliability benefits as part of the cost-benefit analysis for one or more specific future years

Step 1 and 2 refer to the Q-side (Q of quantity) of the CBA. Now in step 3 we also involve the P-side (P of price), consisting of unit values of time and reliability for conversion into money units.

The general approach recommended within CBA is discussed in chapter 4 and the calculation of the benefits is in chapter 5. The distance cost savings are by definition already in money units. The time benefits consist of cargo time saved and transport staff and vehicle time saved. These need to be converted into money using values of time. The zone to zone differences in time and distance between the reference and the project situation are the same as those used in the transport model. The CBA also uses the transport flows from the transport model to determine for how many goods flows there are time and distance savings.

Reliability changes should ideally come from a specific reliability forecasting model, but usually this is not available (also in the EU-15), so the best source will probably be manual adjustment of existing data on the transport time distribution. One might test several scenarios in this respect to reflect the high degree of uncertainty in the inputs.

Quantifying the changes between the reference and the project case in the probability of damage/loss is guesswork most of the times. Also it's just a small part in the CBA. Therefore, it is best not to recommend a default value of damage/loss reduction. The market analysis (IR3) also showed that costs, time and reliability are more important. Countries that want to make a case for damage/loss reduction benefits can try so, using their own methods. They should first establish through market consultation whether the risk of loss or damage is a relevant factor for decision-making and whether it impacts insurance.

For all benefits mentioned here, except the transport distance costs savings, unit conversion values are needed. These are listed in Figure 1-2 on the right-hand side, which we called the P-side. Preferably the source for these consists of country, corridor or project specific valuation studies, notably stated preference investigations. However, this will often not be available/ possible and default values are provided in chapter 5 of this report.

In chapter 6 we discuss how various rail projects affect the components of transport models and the CBA.

**Step 4:** Use time escalation factors to calculate year by year benefits and perform the CBA over the complete project horizon

In chapter 7 escalation factors are discussed to calculate the benefits for all the required future years. Once these have been calculated, they can be used in the CBA (with proper discounting) and the CBA itself can be performed to yield its typical outputs such as the net present value and the benefit to cost ratio of the project investigated.





*Figure 1-2: Overview of the general approach to appraisal of rail freight projects in our recommendations* 



## 2. Data collection

## 2.1 Required data for appraising rail freight projects

In order to calculate expected changes in modal split as a result of a rail freight project and to estimate time, reliability and other cost benefits, the following data items are required.

## Data on the **reference** situation:

The reference situation is a situation in the future that includes all expected developments but without the implementation of the project that is being investigated. For this situation we need the following information:

- A. A matrix of transport flows (in tonnes) between origin zones and destination zones that covers the area that will potentially be affected by the project under investigation (the study area) for rail freight. A distinction between types of goods is also required, notably in (solid and liquid) bulk, non-containerised general cargo and containerised cargo.
- B. A similar matrix for each of the competing modes (which in any case includes road transport, but in some cases also inland waterway transport and/or short sea shipping will be available as competitors to rail, depending on the local topography).
- C. The distances between each of these zones (taking centres of gravity in each zone as start and endpoint) by rail.
- D. The distances between the zones by each competing mode. Distances for competing modes in the reference and project situation are not needed to calculate transport distance cost benefits of the project (since in CBA we use the rule-of-half), but are required to include all transport costs for each available mode in a transport model that can properly predict modal shift.
- E. The travel time distribution for all rail freight transports between the zones. For calculating the time benefits, the expected transport time would suffice (the expected travel time may differ from the scheduled time and include an average expected delay). But to include reliability benefits in the evaluation, one needs data on the travel time distribution. The travel time distribution does not only include the expected transport time, but records how long the trains in a sufficiently long period of time (e.g. a year) actually took between departure and arrival (also taking into account access and egress transport to and from the rail terminals).
- F. The travel time distribution between the zones for each competing mode. Travel times for competing modes in the reference and project situation are not needed to calculate time and reliability benefits of the project, but are required to include all determinants for each available mode in a transport model that can properly predict modal shift.
- G. Preferably there would also be study-area specific information on transport costs by rail in the form of transport cost between the zones, distinguishing between time-dependent and distance-dependent costs, between container, wagonload and block trains and between diesel and electric traction. If no local, regional or national transport cost data would be available, one can use calculations based on transport time and distance between the zones and unit cost rates (by country) that will be provided in section 2.2 of this report.
- H. Preferably transport cost between the zones for each competing mode (otherwise we can provide default unit cost rates for these modes, that need to be multiplied with their time and distance, see section 2.2). Transport costs for competing modes in the reference and project situation are not needed to calculate benefits of the project in the CBA, but are required to include all determinants for each available mode in a transport model that can properly predict modal shift.



#### Data on the **project** situation:

The project situation is a situation in the future that includes the same expected developments as the reference but also includes the implementation of the project that is being investigated. For this situation we need the following information:

- A. A matrix of transport flows (in tonnes) between origin zones and destination zones for rail freight.
- B. A similar matrix for each of the competing modes.
- C. The distances between each of these zones (taking centres of gravity in reach zone as start and endpoint) by rail.
- D. The distances between the zones by each competing mode
- E. The travel time distribution for all rail freight transports between the zones.
- F. The travel time distribution between the zones for each competing mode.
- G. The transport cost between each of these zones by rail.
- H. The transport cost between the zones by each competing mode.

#### 2.2 How to get these data?

#### **Rail OD matrices**

Information on the rail freight OD matrix for a base year (usually a few years before now) will usually be available (from national authorities, statistical offices, rail operators and rail network managers). But in order to obtain a rail freight OD matrix for a the reference situation (which will be in the future, e.g. in 2025), some form of a transport model is needed. This transport model is then applied twice<sup>1</sup>: once for the reference situation and once for the project situation. Transport models (how to judge and improve/recalibrate existing models, how to construct new transport models and how to use an elasticity-based transport model as a last resort) will be discussed in chapter 3 of this report.

#### OD matrices for competing modes

In some cases (especially where a multimodal national or regional freight model is available) there will also be OD matrices for the competing modes. If this would not be the case, matrices for 2010 by mode (at the NUTS3 level and by NSTR 2 digits) can be derived from the ETIS+ project (<u>www.etisplus.eu</u>), if needed also for rail freight. As for rail, for the competing modes we need matrices for the reference and the project situation, not for the situation in 2010. Preferably we thus need a transport model to produce this information. In the absence of a transport model, when no other major infrastructure or policy changes are expected, it might be possible to expand the 2010 matrices manually (using growth factors based on the expected economic growth of the zones) for the reference situation and use an elasticity approach to get the changes in the flows between the project and the reference situation. This will also be discussed in chapter 3.

#### Distances

Distances between zones (by mode) can be derived from maps (including Google maps) for the base situation (provided this does not change significantly between the base and the reference situation). If network-based transport models are available, the networks can be used to read off the distances for the reference situation. The distances with the project can be derived from maps drawn especially for the project case.

<sup>&</sup>lt;sup>1</sup> It is also possible to run the transport model (both for the reference and the project situation) for several years in the future, e.g. for 2025 and 2035. This is especially worthwhile when the evaluation horizon is long and the environment dynamic.



## Travel time distribution for rail

The current travel time distribution can be measured by recording the actual departure time and arrival time of each rail transport (often rail operators and infrastructure managers do this already). To get a reliable picture, data from at least 50 transports in a representative period are needed (e.g. in the winter, transports may be less reliable than in summer). If there will be no other infrastructure or operational changes than the one investigated as the "project", this can also be used as the reference travel time distribution. For the project situation, specific assumptions need to be made how the project influences the reference transport time distribution (no models are available for this) and a case needs to build up to show that these assumptions are plausible.

## Travel time distribution for competing modes

When we are investigating a rail project, we can assume that the travel times by road will not differ between the reference and the project situation (there might be an impact through a reduction of congestion on the roads, but it is more than likely that this effect will be small). So, information on transport time for road, inland waterways and short sea shipping can usually be the same for the reference and the project situation. For competing modes (certainly including road transport), it might be hard to obtain data on the variation of transport times. In EU-15 countries, information from loop detectors in the highways may be used, as well as camera data along all kinds of roads, but in JASPERS countries this data will probably not cover enough of the networks. Alternatively, one could use GPS data (e.g. from the navigation systems), mobile phone data, tracking and tracing data from logistics service providers or provide trucks (and trains) with one's own tags. Should it not be possible to obtain a road freight travel time distribution, then the reliability or road transport cannot be used in the modal split model (assuming that we do have information on the average or expected transport time by road). It might be possible to use modal split models that focus on changes between the reference and the project situation (incremental (logit) models) to avoid having to collect travel time distribution data for road (since the projects investigated do not change the road transport attributes). In this case, one does not need road travel time information, not even for the reference situation.

## Transport cost for rail

Data on the transport cost in the base situation can be provided by the rail operators. The shippers will know the freight rates paid, but may not be aware of the split between time-dependent and distance-dependent transport costs. For obtaining the transport cost for a reference situation and a project situation (both in the future), assumptions on price changes over time need to be made. If study-area-specific or national freight transport models would be available, these may already contain transport cost assumptions relating to future years (as inputs to transport demand forecasting). The difference between the transport cost in the project and reference situation depends on the nature of the project. In the EU-15, this information is usually contained in the formulation of the project (as provided by its proponents, which may be a regional authority, railway operator or infrastructure manager). Should there not be (sufficiently reliable) information on transport costs for the reference and project situation, we recommend using default calculations based on time and distance and unit rates, as described in section 2.3.

## Transport cost for competing modes

For the competing modes, we will assume that the transport costs are the same in the reference and the project situation. If a proper transport model would be available, this would also comprise input data on transport costs between zones for the competing modes for the future. It this would not be the case, the default rates and equations in section 2.4 can be used.



## 2.3 Defaults for the calculation of transport cost by rail

Preferably one would use good local cost data for rail from the study area of the project that is investigated. These can come from railway operators and infrastructure managers in the specific corridor. If these are not available, default calculation rules as provided in this section could be used. It might be attractive to use transport cost functions that are part of existing European transport forecasting models. However, the European transport models (Transtools 1, 2 and 3, NEAC, Worldnet) do not have country-specific unit transport costs for rail; they use the same unit cost all across Europe.

As we learned from the market analysis (IR3), current rail markets in JASPERS countries are mainly nationally organised (rather unlike road transport), and so unit rail transport cost may differ between:

- Countries;
- Between domestic and international trips.

Rail transport cost can also vary depending on train length, block/wagonload/container train (see IR2 and IR3) and whether electric or diesel traction is used.

In Table A2-1 (See Annex 2) are default values for the costs of these train types, by country, for the JASPERS countries. More default cost figures are provided in an excel sheet provided with this report.

These values are based on costs data for various EU-15 countries (Austria, Belgium, France, Germany, Italy, The Netherlands) and Switzerland. To calculate the figures for JASPERS countries, we assumed that the crew cost would be lower (based on Eurostat labour statistics) and for the taxes on diesel (from Eurostat energy statistics) and for the rail infrastructure access charges we used country-specific data (from van Essen et al. 2010). All other costs are assumed to be the same as the average for the EU-15 countries used. We calculated train costs with and without taxes (distinguishing taxes for the crew costs and for diesel). VAT is not included in either set of figures, because firms can get this refunded.

For economic analysis (impacts on society), transfers between groups in society, such as taxes are usually not included (as also recommended in the EU Guide to CBA of Investment Projects). The rail infrastructure access charges may also be excluded from the economic analysis as transfer costs, and infrastructure operation cost (including maintenance and traffic management) savings will be considered instead. In a financial analysis and in a modal split model on the other hand, all cost paid (with taxes, with rail access charges) are taken into account.

2.4 Defaults for the calculation of transport cost by competing modes

In the CBA itself, the cost of competing modes are not required (since these are not used in the rule-of-half calculations of rail projects, which only depend on attributes of the train and on the growth in train use). For the modal shift model however, cost of competing modes are an important piece of input information. Preferably these should be based on local data, but in the absence of these we also provide some averages that could be used as defaults: see Table A2-2 (Annex 2). These costs for road, inland waterway and sea transport are based on costs for The Netherlands, modified for the lower crew costs in JASPERS countries (based on Eurostat labour statistics).





## 2.5 Conclusions on data collection

In order to calculate the benefits of a rail freight project a number of inputs is needed, either to be used directly in the CBA and/or in the application of a transport model that feeds into the CBA:

- A. A matrix of transport flows (in tonnes) between origin zones and destination zones for rail freight and a similar matrix for each of the competing modes.
- B. The distances between each of these zones (taking centres of gravity in reach zone as start and endpoint) by rail and by each competing mode
- C. The travel time distribution for all rail freight transports between the zones and for each competing mode.
- D. The transport cost between each of these zones by rail and by each competing mode.

These inputs are required for the reference situation (without the project) and the project situation. Common sources of data are national and regional transport models and the rail operators and rail infrastructure managers. If no transport costs data are available, defaults are provided in a spreadsheet that was submitted with this report, for various train types and for competing modes.

Rail projects such as increasing train length, electrification, new or better rail infrastructure and more priority to freight trains will have an impact on society through changes in the time-dependent transport costs, the distance costs, reliability and by changing the modal split in favour of rail transport (this is further worked out in chapter 6). This leads to differences in these variables between the reference and the project situation.









## 3. Transport models

## 3.1 Recommendations on model types

Given that many of the project benefits in rail projects evaluated by JASPERS come from modal shift, **multimodality** is important. A unimodal model is not sufficient here, what is required is a multimodal model that includes the competition between rail and other modes (certainly including road transport; in some situations also inland waterway transport and short sea shipping).

For rail freight projects, the submodel within transport models that is most relevant is the modal split (or mode choice) model. This is the submodel that is sensitive to changes in transport time and cost by mode, which can be changed for the rail mode by the projects investigated. Production, attraction and distribution of freight transport are usually not sensitive to changes in rail time and cost and therefore not discussed here. Route choice models (network assignment) are needed to determine the rail routes used and therefore also the distance and time by rail in the reference and project situation. So, route choice in the rail network is important for CBA, but for rail freight the networks are not very dense and the optimal routes can usually be determined quite easily.

Within the models for modal split, the three types that are used most in Europe are the following.

- Disaggregate models for freight transport are used in Scandinavia and Germany.
- Aggregate logit models for freight transport are used in The Netherlands, Flanders, France and in the European models, NEAC and Transtools 1 and 2.
- Multimodal assignment models for freight were used in Scandinavia and The Netherlands, but have been replaced by other types of models. The model for the Walloon Region in Belgium uses multimodal assignment and so does the Great Britain Freight Model.

In principle we recommend disaggregate choice models (models at the level of the individual decisionmaker: the firm, or the shipment) if disaggregate data are available. The advantages of these models are (also see Table 3-1):

- These models include the behaviour of the actual decision-makers: the firms (shippers and/or carriers).
- They are based on a behavioural theory (usually being utility maximisation or cost minimisation) and the results can be interpreted in this framework (which for instance yields restrictions on the sign of the estimated coefficients).
- These models can include many causal and policy-related variables that explain modal split.
- They can be estimated using formal statistical methods that also provide measures of fit of the model and significance of estimated parameters.
- If disaggregate data are available, aggregating these could lead to aggregation bias.

However disaggregate models require data on individual firms, preferably on individual shipments of these firms (e.g. from a shipper survey such as the CFS in Sweden or ECHO in France). In JASPERS countries under the current circumstances these will probably never be available. It is possible to collect project-specific disaggregate data, especially Stated Preference (SP) data (which is a form of disaggregate data), but a forecasting model for modal split should not be based on SP data alone (monetary values on the other hand, such as VOT and VOR, can be based on SP data).

Multimodal assignment models do not require disaggregate data. But an important disadvantage is that these models are usually not estimated on the data using statistical estimation methods, so the degree of fit to the data and the significance of the estimates is unknown Another disadvantage is that the elasticities

Type of model	Advantages	Disadvantages
Elasticity-based	-Very limited data	-Elasticities may not be
	requirements	transferable over space and time
	-Fast in application	-Only impact of single measures,
		no synergies
Aggregate mode	-Limited data requirements	-Weak theoretical basis
split	-Can be statistically estimated	-Little insight into causality
	on data	
Disaggregate mode	-Theoretical basis	-Need disaggregate data (shipper
split	-Potential to include many	or commodity survey and/or
	causal variables and policy	SP)
	measures	
	Can be statistically estimated	
	on data	
	-Can handle choice between	
	transport chains (and shipment	
	sizes)	
Multi-modal	-Limited data requirements	-Little insight into causality
network	-Some theoretical basis	-usually not estimated statistically
	-Can handle multimodal	on data
	transport chain	-Danger of under- and
		overshooting when predicting
		impact of price and time changes
		if all-or-nothing assignment

Table 3-1 Advantages and disadvantages of the modal split models that are used most often	in Europe
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from these models may suffer from the use of an all-or-nothing methodology often used in the assignment. This means that only one cheapest path is selected for each transport flow between two zones. Alternatives do not come into the picture until the complete flow shifts to some alternative path. However, stochastic multimodal assignment is a way to cope with this and obtain flows for several alternatives per flow in the multimodal network.

In practice for JASPERS countries as things stand now, **our recommendation boils down to using aggregate logit models** (multinomial or nested) for mode choice in freight transport. The aggregate data (flows by commodity type in tonnes by mode between zones) that are required here are more often available than disaggregate data. Also aggregate logit models can be estimated statistically on the data for the shares of each mode per OD relation by commodity type. A good example is the Transtools modal split model (for Europe), described in Annex 3 of IR2. In our discussion on the required data in chapter 2, we listed the data as are required by aggregate logit models.

## 3.2. How to judge/compare transport models

The following criteria can be used to judge transport models, focusing on aggregate logit models for modal split:

• Does the model include all the relevant modes (certainly road and rail, also inland waterways and short sea shipping if these compete with rail in the study area)?

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- Does the model distinguish between different types of train in terms of the calculation of transport costs (preferably distinguishing at least block train, wagonload train and container train; also diesel versus electric traction)?
- Does the model include the required policy variables (transport cost, time and preferably also reliability)?
- Does the model use different segments for different commodity groups (at least bulk versus general cargo) in terms of different behaviour between segments (different model coefficients per segment) and in terms of outputs that the model can provide?
- What type of data was used? SP data is suited for deriving monetary valuations, not for forecasting models; this requires data that are fully or partly revealed preference (RP). Other types of data are time series and panel data (both of which are best suited for short to medium term forecasting)
- Was the model estimated on the data using statistical methods, so that measures of model fit and significance of estimated coefficients are available and statistical test can be performed?
- For models that are statistically estimated, especially on the same data:
  - What is the model fit in terms of R<sup>2</sup> or Loglikelihood value relative to benchmark models?
  - What are the standard deviations or t-ratios of the estimated coefficients (t-ratios should be below -1.96 or above 1.96)?
- Do the estimated coefficients have the right sign?
- Are the relative sizes of the effects of costs and time (etc.), expressed as elasticities, plausible within their segment, given the literature (see section 3.6)?

## 3.3 How to improve/re-calibrate transport models

The preferred option when a transport model is available, is to use a transport model that was developed for (part of) the country where the project is (or for the international corridor of the project). That first of all requires checking whether this model is appropriate. The criteria to judge transport models, are in section 3.2 above, but most important is that the model includes competition between the available modes, includes at least transport cost by mode as influencing factor for modal choice and shows acceptable elasticities for the influence of transport cost. A model that lacks relevant modes or transport costs or that has implausible elasticities is difficult to repair. In such cases it's better to build a new one.

It is hard to imagine a modal split model without transport cost by mode. These transport costs will include the time-dependent costs (especially crew, overhead and vehicle costs) and the distance dependent costs (for rail this refers mainly to cost of diesel or electricity for traction and infrastructure access charges). The influence of transport time on modal split can largely be covered by the time-dependent component of transport cost.

Some models will additionally include the influence of time on modal split through the cargo itself (e.g. interest cost on the cargo in transit). But if these would not be part of the model, the transport model can be improved/extended by adding an extra influencing variable to the modal split model, whose influence relative to transport cost depends on the cargo component value of time. In Annex 1, we describe how this can be done in a way that is consistent with the recommended values of time for appraisal (see Chapter 5).

In a similar way, the modal split model can be improved/extended by adding a reliability variable to it, with a coefficient that is derived from the value of reliability. We measure reliability as the standard deviation of transport time. This is discussed in Annex 1.

After these extensions, the model needs to be re-calibrated, so that for the base year it will predict the observed shares of the available modes. This re-calibration is not only needed when new variables have been added to the model, but also when the study area of the model and the project are different. An



example of this would be a national model that has to be applied for a specific corridor within a country. This requires that in the corridor zones at a fine geographic level are kept, but outside the corridor zones will be aggregated. The market shares of the modes at the national level and the corridor-level will differ and the model first needs to be recalibrated so that for the base situation it predicts the observed mode shares for the project corridor.

This re-calibration is done by adjusting the mode-specific constants of the modal split model. All other coefficients of the model remain unchanged. In Annex 1 is an example of how to do this.

## **3.4 How to construct new transport models**

Should there not be an transport model available that is appropriate or can be improved to become appropriate, the next best option is to construct a new model, specifically for the study area (this may not be the most efficient option, because the cost of constructing a model are substantial (even for a standard aggregate logit model, the model building is likely to cost half a year), but for larger projects this might still be an attractive option).

The key activity in the model construction then is to estimate an aggregate logit model for modal split that best explains the available data. First one needs to decide which modes will be used in the model (rail, road, inland waterways and/or short sea shipping). The availability of modes can differ by origin-destination pair. Within rail transport, a further distinction between container, wagonload and block trains is highly recommended and if possible also between diesel and electric trains. The data needed for estimation should all refer to the same base year. This should include:

- As variable to be explained, the observed shares of the modes in the transport flows (in tonnes) between the zones, with some distinction by commodity class (at least between bulk and general cargo).
- As explanatory variables, the transport cost by mode (and vehicle type such as train type, if these distinctions can be made) between the zones, the transport time between the zones and if possible also the transport time reliability (standard deviation).

The number of observations then is the number of origin-destination combinations. Each alternative (minus one for normalisation) should also include an alternative-specific constant (=mode-specific constant) as explanatory factor, to account for other differences between the modes (on average) than in cost, time and reliability (or other factors that are explicitly included in the model).

Specific software exists to estimate logit models. After the model has been estimated, it needs to be implemented (programmed) into a computer programme that can be used to predict the mode shares for a reference and a and a project situation. This can be done in a scientific programming language (e.g. C# or Delphi), a spreadsheet (if the model remains relatively simple) or specific transport modeling software (such as CUBE, VISUM, OMNITRANS, EMME). These transport modelling software packages can also handle the choice of route and the calculation of transport distance and time on a network. The data used in the model predictions refers to the same explanatory variables as used in estimation, but now the values that these variables take should reflect the reference and the project situation in the future. How to derive transport cost, time and reliability for these situations was discussed in chapter 2.

## 3.5 Last resort: use of elasticities from the literature

If no transport models are available or can be constructed for use in a specific project case, one could do a quick scan using a simplified model. An example of such a model at the European level is the HIGHTOOL model, but this will only be completed in 2016. Also it will probably not have any further distinctions (e.g. by country) in terms of unit cost for rail than Transtools or NEAC (see IR2).

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Alternatively, for a quick scan of a project, one might use elasticities from the literature. Transferring a single elasticity (e.g. for the impact of rail cost on rail demand in tkm) from one country to another, that is then supposed to cover all freight transport, is not recommended. To make the elasticity approach work as a reasonable approximation of a full local transport model, it is required to distinguish elasticities by segment (e.g. commodity and distance class). One might for instance re-use the EXPEDITE elasticities (dating back to 2002 but we have no indications for structural changes in elasticities since). The EXPEDITE elasticities were submitted as excel files together with this report. These are elasticities by mode, segmented by commodity type and distance class for the impact of time and cost changes, by mode, on tonnes and tonne-km by mode, derived from runs with various national and European transport models (taking averages over models for the same segment). When one uses elasticities from the literature, the transport cost function to use can be chosen freely (since there is no transport model with its own transport cost functions). So it would be possible to use detailed cost functions (with distinctions in unit values between countries), then calculate percentage changes on costs that would result from the project and evaluate the impact of these on transport demand using a set of elasticities.

## 3.6. Recommendations on elasticity values

Elasticities can be used as one of the criteria ('reality check') to assess transport models (see section 3.2) and also when no transport models are or can be made available, for a first quick scan of the effects of a transport time or cost change on the modal split (also see in section 3.6). A quick scan is a an analysis that focuses on the getting approximations for the main effects to find out whether a project has enough potential net benefits for society to be investigated in more detail in a next phase (using a proper network-based transport model (so to distinguish the promising from the unpromising projects).

Since the elasticities that are available in the literature constitute a considerable range (this is partly due to the difference in the starting mode shares between the studies), and there is additional uncertainty that results from transferring the elasticities (that practically all were derived for OECD countries) to JASPERS countries<sup>2</sup>, we recommend not to use a single elasticity value (not even per segment), but if possible perform a sensitivity test by using the 'triangle': test the top, the lower bound and the upper bound for elasticity (sensitivity analysis).



For the modal split effect of a change in rail transport costs per tonne or per tonne-km on the number of tonnes transported by rail we have on average -0.7, -1.1 and -1.5 for lower bound, top and upper bound (based on the literature, using the 80-20 rule for the bounds). For its impact on tkm we have -0.8, -1.2 and - 1.6. The impact of a change in transport time depends on the share of the time-dependent costs in the total rail freight costs (often 70-80%) and on whether there also is an impact through the cargo value of time, but on average can be taken to be very similar to the transport cost elasticities or just below (in absolute values).

<sup>&</sup>lt;sup>2</sup> In the literature we studied were no elasticities from specific models estimated on data in JASPERS countries.



Finally, we also analysed the literature on rail price elasticities for different commodity types, distance classes and train types, in as far as available in the literature. We find:

- Several studies where rail transport price sensitivities are larger for general cargo compared to bulk products (e.g. solid fuel, petroleum, iron ore, fertilisers, stones, wood), but some studies find the reverse.
- The price elasticities for short distance rail transport are smaller than for long distance rail transport.
- At small and high market shares elasticities are smaller than in between.

Given these differences we recommend distinguishing between elasticities: by mode, commodity type (especially bulk versus general cargo) and by distance class, and also by input variable (e.g. time or cost) and output variable (e.g. tonnes or tkm). Distinguishing also by the current market share (e.g. segments defined as different mode share bands) is rather problematic because market share is something that we should explain in an analysis/model (therefore an 'endogenous' variable, not something that we should take as a given and use as a segmentation ('exogenous' variable and segmentation). If the market share is high we should try to explain why it is high (based on the size of the transport flow, the distance, the prices, the quality offered, etc.) and not take this high share as a given.

However, there can be specific situations where the market share of rail is so close to either 0 or 100% that the existing elasticities from the literature, that are probably based on more competitive situations closer to the middle, steeper part of the logit curve) are not so representative. Coal movements for instance with a 100% market share for rail should have an elasticity of 0 or very close to 0. When using elasticities as a substitute for a transport model, conservative values should be taken from the literature and plausibility check should be made on market share. We also recommend that when using an elasticity-approach, only the own price and time elasticities are based on the literature. The cross elasticities then can be derived by splitting the amount that is transferred proportional to the available market shares of the available competing modes. This gives cross elasticities that are in line with one of the basic assumptions of the standard logit model (uniform elasticities) but that match with the observed market shares in the study area.

Application of the elasticities then should take place on the basis of a full OD matrix of transport flows, not only on a relative change in transport costs on a small section of the network.

## **3.7 Conclusions on transport models**

In practice, given the data situation in JASPERS countries, we recommend using aggregate logit models for modal split. These models can provide predictions of modal shift as a result of a rail project, which are needed to calculate the new users for the internal benefits in CBA, but also for the external benefits of the project.

When national or regional freight transport models are available as inputs to project appraisal, these models should be judged first, to see whether they include the right modes, explanatory variables and segments and whether their sensitivity to changes in cost is in line with what we know about elasticities in the literature.

Existing freight transport models can be extended to include the cargo component of the value of time and to include reliability. National and regional models can be customized for application to a specific corridor by aggregating zones outside the study area and by re-calibrating the mode-specific constants.

If transport models are not available and cannot be constructed as part of the project, elasticity-based models can be used as a last resort, but these will only be very approximate. We recommend only to use elasticity-based models for a first analysis ('quick scan') of a project, to see whether it deserves further investigation. This further investigation then should use a proper network-based transport model, so that funding decisions will not be directly be based on elasticity calculations.



## 4. General recommendations on the appraisal method

After having completed the collection of data on transport cost, time and reliability and having applied the transport models to predict the flows of goods between zones in the reference and the project situation, the actual project appraisal can be carried out.

In this report we take as given that there is the requirement to evaluate proposed projects and that this evaluation includes financial and economic analysis of the impacts of the project, as described in the European Commission's 'Guide to Cost-Benefit Analysis of Investment Projects, Economic appraisal tool for Cohesion Policy 2014-2020' of 2014. This implies that a choice for cost-benefit analysis (CBA) as general economic appraisal method has already been made. This report will therefore not discuss the position, advantages and disadvantages of CBA versus other evaluation methods (such as cost-effectiveness analysis, multi-criteria analysis, combination of cost-benefit and multi-criteria analysis). What this report for JASPERS is about is how to calculate the societal values of the impacts of rail freight projects to the freight transport market (the internal or user benefits). These impacts on the rail freight market potentially consist of:

- Transport time benefits
- Transport time reliability benefits
- Other transport quality benefits (such as reductions in loss and damage of the goods)
- Other transport costs saving.

Furthermore, an important benefit in case of a substantial modal shift from road to rail will be:

• reduction of the external costs (e.g. harmful emissions, possibly also in accidents).

In a CBA, these internal and external effects are compared to the other costs and benefits of the project (say a new railway line, electrification, improve railway access, make longer trains possible). This is depicted in Figure 4-1. In the top part are the cost, including those of construction of the line and maintaining it. In the bottom part are the benefits, containing the above-mentioned internal and external effects.

Costs
Construction costs
Change in maintenance costs
Benefits
Time benefits: VTT * hours gained
Reliability benefits: VTTV *hours of standard deviation gained
Other transport cost savings from freight measures
Reduction in external costs as a result of modal shift or due to more efficient rail operations
Figure 4-1: Overview of the CBA for rail freight projects

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In a CBA all costs and benefits are expressed in money units, so that they can be directly compared. The time benefits are originally expressed in number of hours or minutes that are saved as a result of the project. This is usually the output of running a transport model twice: for a reference situation (=without the project) and a project situation. In CBA of rail transport projects these benefits are usually calculated for the existing users of rail and for the new users (with the help of the rule of a half) separately. These time benefits in hours or minutes are multiplied by a unit (per hour or minute) value of time (the VTT) to give the monetary time benefits. The VTT preferably comes from a specific study carried out in the project area, but many countries also have standard values of time that are used for appraising national projects. In chapter 5, we will provide unit VTT for JASPERS countries that can be used in the absence of project specific VTT. These are values for the year 2010 in euros of 2010. In chapter 6, we will discuss how unit values for future years can be calculated.

For reliability benefits the story in some ways is similar. Here too, there is a quantity component and a price component. The price component is the unit value of travel time variability (VTTR). Again, this preferably would come from a specific study in the project corridor, but standard unit values will be provided in chapter 5. Unlike for the VTT, many countries do not have an official VTTR that is used for project evaluation. This topic has only recently gained attention of policy makers, and in several countries researchers are working on the VTTR now. The reliability benefits before monetisation (measured for instance as a reduction in the standard deviation of transport time) are usually not included in transport models and therefore need to be calculated from a project-specific reliability forecasting model or in an ad hoc fashion (e.g. using scenario assumptions). A simpler alternative would be to assume that the reliability benefits are a fixed percentage surcharge on the time benefits. However in that case one cannot cope with projects that have a different impact on time and reliability. In chapter 5 we will provide defaults for the VTTR, measured as the standard deviation of transport time.

The final component of the potential user benefits are the other transport costs savings: reductions in the transport costs brought about by the project under investigation that are not already comprised in the benefits discussed earlier. These are by nature already in money units, so a conversion factor is not needed. Just as the time savings, the transport cost savings are provided by running the transport model for the reference and the project situation.

The reduction in external costs (e.g. in harmful emissions) can be a result of modal shift from road to rail when the project makes rail more attractive (lower transport costs, shorter transport time, more reliable) and can provide more capacity (given that there was a suppressed demand for rail). But it can also be the results of increased efficiency in the rail operations (the same amount of tonnes between zones is transported with fewer train km). This report will not discuss unit values for external effects, but modelling and predicting modal shift was discussed in chapter 3.

An important decision that needs to be taken is to define the time benefits and the transport costs savings in such a way that:

- they do not overlap;
- no potentially important components are left out.

Travel time savings, certainly in the long run, lead to reductions in the costs of transport staff and transport vehicles, as well as savings that are related to the goods themselves (reduction of the interest on the capital that is invested in the goods during the time of the transport, but also being out of stock). We therefore see two options for defining the scope of time benefits in CBA:

A. Narrow definition of VTT; Exclude transport cost savings from VTT (only include the benefits of cargo time saved)



B. Broad definition of VTT; Include cargo time saved, staff (crew, but in the medium to long run also company overheads, such as administration and office costs) time saved and vehicle time saved in VTT (only include distance cost saved in cost savings).

This is also depicted in Figure 4-2 (approach A on the left and B on the right).

Approach A	Approach B
Time savings:	Time savings:
Cargo time saved	Cargo time saved
	Staff time saved (crew and overheads)
	Vehicle time saved
VTT	VTT

Transport cost savings:	Transport cost savings:
Distance cost saved (energy and access charges)	Distance cost saved (energy and access charges)
Staff cost saved (crew and overheads)	
Vehicle cost saved	

Figure 4-2: Approaches to time/cost benefits in CBA

Both approaches are internally consistent and comply with the two requirements given above. Different countries use different systems (e.g. Sweden uses A and The Netherlands uses B). However, in some project evaluations transport cost savings have been interpreted in a broad fashion and time savings as well, including staff and vehicle time savings in both and thus doing double-counting. Previous guidance on unit values, e.g. the HEATCO report of 2006 and the report of RAND Europe and CE Delft for the EIB of 2004 may not have been entirely clear on these distinctions and have been misinterpreted.

For the evaluation of rail freight transport projects in JASPERS **we recommend option B**, since in these projects there is some focus on time (and reliability) benefits and these then are at once fully captured in the VTT. The JASPERS team agreed on this. In the remainder of this report, approach B will be followed.

In line with almost all national guidance and the current academic position on this issue, we recommend using the same unit values for small and large savings (e.g. time reductions) instead of using a zero or smaller unit value for small savings. This was discussed in IR2 of this project.









## 5. Calculating the transport time benefits, the reliability benefits and the distance cost benefits

## **5.1 Transport time benefits**

If no project-specific values of time are available or can be established as part of the project (due to time and costs constraints or missing expertise on VOT studies), standard unit values or rules can be used. Another reason to work with standard values can be that is it seen as desirable that all projects (in a given area) should be evaluated using the same unit values. Such rules and unit values are presented below in this section.

The transport time benefits consist of savings in crew time, vehicle time and company overheads (the transport cost component of the VTT) and savings in the time that the goods are in transit (the cargo component of the VTT). The overhead costs also largely consist of labour costs and are sometimes also expressed per hour of transport. Together with the crew cost we call these overhead cost the 'staff' cost, and in terms of time, the 'staff time'.

The market research (see IR3) that we carried out found that unit transport cost, and consequently also the **transport cost component** of the VTT, differ not so much between commodity types defined in terms of NSTR, but between combinations of mode of appearance and train type:

- (solid and liquid) bulk in block trains
- non-containerised general cargo in wagonload trains
- containerised cargo in container trains.

The **cargo component** of the VTT depends clearly on the type of goods, especially in relation to the value of the goods, so here we expect a differentiation between commodity types.

The staff and vehicle time saved, together with the transport distance cost saved, in the long run (minimally 5 years since the opening of new infrastructure) make up the full costs of providing the transport services (the transport costs). In the short to medium run, only a part of the staff and vehicle time costs may be saved if transport time is reduced.

The time benefits should be based on expected transport times and therefore will include expected delays (relative to the timetable) if these exist. The unexpected delays are covered in the reliability benefits. In the rail sector, there is also a reliability-related gain associated with tightening timetables (reduction of slack/buffer time) on the basis of improved reliability. This is related to the standard deviation but will be evaluated according to the standard VTT. If slack that is built into timetables is removed (smaller buffer) there will be time gains, to be valued using the unit VTT. If reliability is not an issue, there is no reason for slack in the timetable and the expected or average travel time will be equal to the time in the timetable.

If **buffer time** is reduced, this should be evaluated using the **VTT**. Buffer time changes cannot always be taken from changes in the schedule: in practice trains may just stop and wait instead of reducing the buffer time and arriving earlier. So for information on buffer times one has to do a market consultation (especially discussions with the operator).

## Recommended approach for staff and vehicle time component (based on methods used in The Netherlands)

A key feature of our recommended approach for time benefits in CBA of freight projects is the distinction between the short-medium term and the long run. In the long run (here defined as minimally 5 years after the start of the operation), time saved will translate fully into savings of transport crew and of overheads (together the 'staff' cost) and transport vehicle (depreciation, insurance, maintenance) costs (these are regarded as the time-dependent transport costs). So for the long run VTT in a country one can simply take

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the full staff and vehicle cost per hour for rail freight transport of the country or project under investigation (see IR2). These costs are likely to vary between countries and between domestic and international corridors (see IR3).

For the staff and vehicle time benefits of a rail freight project after minimally 5 years, we take the full staff and vehicle transport cost (but not the distance-dependent transport cost, notably the energy costs and the rail access charges).

For year 1, we use a fraction of this full 100%, taken from Stated Preference surveys carried out in the Netherlands (the responses of the firms in these surveys are regarded as inherently short-term in nature). In Table 5-1 are the ratios for year 1 recommended as defaults for the CBA of rail freight projects in JASPERS countries.

Table 5-1: Ratio of year 1 value to year 5 and later value for VTT

	Ratio short-long run
All goods	0.44
Containers	0.50
Bulk	0.44
Wagonload	0.42

These ratios are the maximum values for year 1 for the JASPERS countries. For these countries we recommend that for the first year the ratio between short and long run is taken from Table 5-1 and then multiplied by the full staff and vehicle cost (as used for year 5 and later). Lower year 1 values for JASPERS countries than in Table 5-1 can be argued for in specific project case studies.

We then get, for existing rail users the following staff and vehicle time benefits

For existing rail users:

Year 5 and later: time cost per tonne per hour \* tonnes per year \* (time in reference – time with project) =

Year 1: 0.44 \* time cost per tonne per hour \* tonnes per year \* (time in reference – time with project)

Where time cost is the sum of crew, vehicle and overhead cost, per tonne per hour (all transport cost minus energy and rail access charges).

For example for bulk products transported by electric block train in Bulgaria assume that we have for a specific origin-destination (OD) flow 100,000 tonnes per year and that the travel time is reduced by the project from 10 to 8 hours.

(339.37/1143) \* 100,000 \* (10-8) = 59,382 euro in year 5

0.44 \* (339.37/1143) \* 100,000 \* (10-8) = 26,128 euro in year 1

The value of 339.37 comes from the transport cost Excel sheet (cell S13 of the JASPERS countries tab page: for electric block train without taxes, for Bulgaria) and 1143 is the assumed load in tonnes of the block train (see cell F22 of the tab page tonnage per train). We take the values from the Excel spreadsheet when there are no national or project-specific cost figures available.

For new rail users (modal shift to rail, but could also be induced demand = new transport):

Year 5 and later: 0.5 \* time cost per tonne per hour \* (tonnes per year with project – tonnes per year in reference) \* (time in reference – time with project)



Year 1: 0.5 \* 0.44 \* time cost per tonne per hour \* (tonnes per year with project – tonnes per year in reference) \* (time in reference – time with project)

For the years in between year 1 and 5, we recommend linear interpolation to get the VTT (for the moment abstracting from the time escalation of values, to correct for costs increases over time and that depends on the calendar year for a value; this is discussed in chapter 6).

More extensive worked out examples for different types of goods can be found in Annex 3 and a spreadsheet, entitled 'numerical example', that was supplied together with this report.

### Recommended approach for the cargo component (based on methods used in France)

The French approach for value of time benefits only refers to the cargo component. For the staff and vehicle time saving our recommendation is using a variant of the Dutch approach as described above.

We recommend a unit value for the cargo component in euro per tonne of cargo per hour, that differs between three types of commodities.

Table 5-2: Recommended unit values for the cargo component in the value of time (in 2010 euro/tonne/hour)

commodity	Value in euro per tonne per hour
freight with low added value: < 6000 euro/tonne, e.g.	0.01
bulk/aggregates	
ordinary freight: 6000-35000 euro/tonne, e.g. other rail, sea and	0.2
river transport	
freight with high added value: > 35000 euro/tonne, e.g. combined,	0.6
parcels, refrigerated, roro	

Instead of using the absolute Euro value from France, we think it is better to correct for the ratio of staff and vehicle time cost (in one of the JASPERS countries; below we take this to be Bulgaria) and the EU-15 (for Bulgaria we now get 339.37/416.56<sup>3</sup>). This leads to the following calculation for the cargo cost component for a bulk transport (as an example):

Existing rail users:

(339.37/416.56) \* 0.01 \* tonnes per year \* (time in reference – time with project)

For the earlier example this gives:

(339.37/416.56) \* 0.01 \* 100,000\* (10 - 8) = 1629 euro

New rail users:

(339.37/416.56) \* 0.01 \* (tonnes per year with project – tonnes per year in reference) \* (time in reference – time with project)

<sup>&</sup>lt;sup>3</sup> The values 339.37 and 416.56 are the time cost in euro (without taxes) of an electric block train per hour for Bulgaria and the EU-15 respectively (see the transport cost excel sheet submitted with this report: JASPERS countries cell S13 and EU15 cell E14). For other countries and other train types, the sheet also contains the required figures.

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Unlike the Dutch method, the French method does not use a different ratio in the first year or first 5 years, but starts with the full value in year 1. This can be justified by the fact that the cargo component to a large extent consist of interest costs, which will already accrue in year 1.

In order to link to one of the three commodity types in Table 5-2 one needs to know the average value of the goods transported (in 2010 euros), or a distribution of the transported tonnes over the three categories can be used to apply all three values. The threshold values then are 6000 and 35000 euro per tonne. If this information is not available, one can use 0.01 for bulk and 0.2 for all other goods transported by rail. JASPERS countries that want to use the high value (0.6, for goods above 35000 euro/tonne), have to make a specific case for it. In fairly representative surveys in freight transport in Germany, France and Sweden no single commodity category had an average value per tonne above 35000 euro.

## **5.2 Reliability benefits**

For the VOR we do not explicitly distinguish a transport cost and a cargo component because there is no empirical literature that gives these two components. The evidence that we have (especially from the Netherlands) is that the total reliability benefits below can be taken to be the same as the cargo component of reliability, with zero value for the transport cost component of reliability.

Similarly to what was said for the cargo component of the VOT, for the VOR the preferred method is to carry out a specific SP study, which could be combined with the VOT. Should this not be possible, several default values are provide below.

## Recommended approach for reliability benefits (based on a mix of methods used in The Netherlands, France and Germany)

As in the Dutch CBA, the reliability for all modes is defined as the standard deviation of transport time. The importance of the standard deviation relative to transport time itself is given by the reliability ratio. The reliability ratio refers to intrinsic remaining reliability and not to savings in expected transport time gained from improving reliability (the latter are evaluated using the VTT).

We calculated reliability ratios for the same commodity categories as used for the cargo component (as used in project appraisal in France) on the basis on the reliability values from the German Federal Infrastructure appraisal (since the Dutch reliability ratio for rail freight of 0.2 was deemed to be rather low). For products with a low added value ('bulk') a reliability ratio of 0.4 was found, which implies that a change in the standard deviation by 1 hour is equivalent to a change in transport time by 24 minutes. For the remainder of products, we recommend a reliability ratio of 0.65. We decided not to recommend a higher value for goods with high added value (>35000 euro/tonne), because for these products the value of time is already very high and through the reliability ratio the value of reliability is proportional to the value of time.

commodity	Reliability ratio (=VTTV/VTT)
freight with low added value: < 6000 euro/tonne, e.g.	0.40
bulk/aggregates	
ordinary freight: 6000-35000 euro/tonne, e.g. other rail, sea and	0.65
river transport	
freight with high added value: > 35000 euro/tonne, e.g. combined,	0.65
parcels, refrigerated, roro	

Table 5-3: Recommended unit values for the reliability ratio

For example for bulk transport (<6000 euro/tonne), for existing rail users, the reliability benefits are therefore calculated as:

Existing rail users:



Year 5 and later: 0.40 \* (time cost per tonne + cargo time component per tonne) \* tonnes per year \* (standard deviation in reference – standard deviation with project)

This gives for the earlier example of a 100,000 tonnes bulk flow in Bulgaria:

Year 5 and later: 0.40 \* ((339.37/1143) + (339.37/416.56) \* 0.01) \* 100,000 \* (10-8) = 24405 euro

The other equations for reliability are:

Year 1: 0.40 \* (0.44 \* time cost per tonne + cargo time component per tonne) \* tonnes per year \* (standard deviation in reference – standard deviation with project).

New rail users:

Year 5 and later: 0.5 \* 0.40 \* (time cost per tonne + cargo time component per tonne) \* (tonnes per year with project – tonnes per year in reference) \* (standard deviation in reference – standard deviation with project)

Year 1: 0.5 \* 0.40 \* (0.44 \* time cost per tonne + cargo time component per tonne) \* (tonnes per year with project – tonnes per year in reference) \* (standard deviation in reference – standard deviation with project).

The factor 0.44 comes from Table 5-1, and represents the share of the long term benefits that is realised already in the first year, in this case for bulk products. The value of time that is used in the year 1 equation is that for the long run, not for year 1 (by multiplying it with 0.44 we get the year 1 value of time). Through the reliability ratio (either 0.4 or 0.65) the value of reliability will be based on the value of time (transport component plus cargo component).

## **5.3 Distance cost benefits in CBA**

We have kept the distance costs saved out of the time savings in our definition of the VTT. These distance costs will include energy costs of the traction (either electric or diesel) and infrastructure access charges. These costs are regarded as purely distance-specific, not time-dependent. If a project reduces the transport distance, there will also be transport distance cost savings, on top of the benefits discussed in chapter 4. These can be calculated as:

Existing rail users:

Distance cost savings = distance costs per tonne per km \* number of tonnes per year \*(distance in reference - distance with project)

For the 100,000 tonnes bulk transport in Bulgaria, we assume that the distance is reduced because of the project from 200 km to 175 km. The distance cost per tonne per km can be taken from the Excel transport cost sheet (if no national of project cost data are available). For Bulgaria we find 5.48 euro per train (with a load of 600 tonnes) for energy and track access cost (without taxes, cell S17 for JASPERS countries). So we get:

(5.48/1143) \* 100,000 \* (200-175) = 11986 euro

For new rail users, the calculation rule is:

Distance cost savings = 0.5 \* distance costs per tonne per km \* (tonnes per year with project – tonnes per year in reference) \* (distance in reference - distance with project)

It seems appropriate to assume that these gains already fully materialise in year 1; a distinction between year 1 and year 5 and later, as for time benefits, is then not necessary.



For the distance cost per tonne per km one can use the sum of energy (diesel or electricity) costs and rail infrastructure access charges. But for economic analysis it is also possible to exclude the rail access charges from the distance costs (on the grounds that these are a transfer between groups in society) and include infrastructure operational cost savings (maintenance and traffic management) in the CBA instead.

## 5.4 Conclusions on calculating the user benefits for CBA

The time benefits of a rail freight project consist of the staff and vehicle time savings and the cargo component. The former is calculated by taking all savings in transport costs except those for energy and rail access. For the first years after the start of a project we take a part (ratios that depend on the commodity type) of the full staff and vehicle time savings, from year 5 on we take the full staff and vehicle time benefits. For the cargo component we recommend specific euro per tonne per hour values that need to be corrected for the transport cost difference between the country studied and the EU-15.

Reliability is measured as the standard deviation of time. The benefits are calculated with the help of reliability ratios that give the value of the standard deviation relative to the value of time (both per hour).

The distance costs (either the energy costs or the sum of energy cost and rail access charges) need to be included in the CBA separately.





# 6. Impacts of transport projects on components of the transport models and the CBA

Below we list how various types of rail projects impact components of the CBA. Projects that influence the transport costs or time also have an impact on the modal split through the impact of transport cost or time in the transport costs model.

Impact of projects:

a. Train length  $\uparrow$   $\rightarrow$  transport cost per tonne  $\downarrow$   $\rightarrow$  staff and traction vehicle time  $\downarrow$ 

If the train length is increased by 10%, the cost of hiring wagons will go up more or less proportionally. For non-container trains, the default for these costs is 1.47 euro per hour per wagon (see the excel sheet on transport costs). For these trains we assume 18 wagons per train as default, giving a base cost of wagons of 26.47 euro per hour per train. A 10% longer train will therefore lead to 2.65 euro per hour extra wagon cost. For container trains, the average default cost is 1.12 euro per hour per wagon. For the default train length for container trains of 20 wagons this gives 22.35 euro per train per hour and a 10% increase then is 2.24 euro per hour per train.

Furthermore we assume that in this case the energy cost also go up proportionately (this is a conservative assumption). There might also be an increase in the rail infrastructure access charges, depending on whether the current category of trains in the charging system leaves room for an increase in train weight or not. Here we assume that all distance-based cost go up by 10%. The defaults vary between 5.39 and 7.85 euro per kilometre per train, so the costs per km would increase by 0.54 to 0.79 euro per train per km.

There will be no other cost increases than for wagon cost and distance cost.

Because of the longer trains, the shippers need fewer trains for the same amount of transport. We assume proportionality, so this reduces the total transport costs in the above example by 10%. This therefore applies to all cost components.

So all in all there will be a reduction in transport cost per tonne, which consists of a proportional reduction of the crew costs, the costs of hiring locomotives and overhead costs (assuming the longer trains do not require extra staff and locomotives).

In the transport model, one can simulate this by reducing these transport costs components for rail, which will lead to substitution towards rail.

The reduction in staff time costs and for hiring locomotives in the CBA is handled by reducing these costs and thus calculating time benefits.

b. Electrification  $\rightarrow$  traction cost (part of distance cost) and transport time  $\downarrow$  (maybe also impact on reliability)

Electrification leads to a shift from a diesel train column to an electric train column in the Excel sheet on transport costs. This will bring a slight reduction in the costs of hiring locomotives (e.g. from 169.28 euro per hour to 165.70 for non-container trains or from 191.63 to 188.06 for container trains, when using the defaults). More important is the reduction in energy costs (e.g. from 5.59 to 3.12 euro per km, when taxes are included).



Moreover, there will be an decrease in transport time, as the electric trains will be faster and probably also more reliable. We have however no data on the size of this speed and reliability change, so this information should come from local train operators and network managers.

The speed increase will lead to shorter travel times, which together with the above cost reductions can be inserted in the modal split model as transport costs changes, leading to substitution towards rail. The amount of substitution will be larger when reliability benefits can be included.

In the CBA, there will be distance costs savings as well as staff and vehicle time savings (potentially also reliability benefits).

- c. Maximum axle loads ↑ → transport cost per tonne ↓
  This will affect transport cost components in the same way as increasing the train length (see above). However this is only relevant for bulk products in block trains since for other trains the maximum axle load is not a critical factor.
- d. Train speed  $\uparrow \rightarrow$  transport time  $\downarrow$

See the comments on speed increase under electrification.

e. Better rail infra and maintenance  $\overrightarrow{}$  transport cost per tonne, transport time and unreliability  $\downarrow$  (maybe also damage  $\downarrow$ )

This will probably not change the unit costs per hour nor the overhead or rail access cost, but can reduce the traction cost per km. However it's difficult to give general guidelines to determine by how much, and this also goes for the reduction in transport time and unreliability as a result of a higher quality of rail infrastructure and maintenance. The best thing to do is to take these impacts from similar projects that have been carried out elsewhere.

f. More prioritisation freight  $\overrightarrow{}$  transport time and unreliability  $\downarrow$ 

The time gains can be derived from the old and the new timetable. Reductions in buffer times should also be counted here and valued using the same VTT. For the change in reliability (standard deviation), the basis can be observations on actual travel time over a longer period (e.g. a year). For the impact of policy measures/projects on reliability, specific assumptions then need to be made how these might influence the base distribution of transport time.

- g. Better train and loading equipment, packaging, monitoring ightarrow damage  $\downarrow$
- h. New and improved intermodal terminals  $\rightarrow$  access and waiting time  $\downarrow$  (maybe also an impact on reliability and damage)

This will reduce the terminal costs, which are incorporated in the rail access charges in the Excel sheet on transport costs. But they can also lead to time gains, which are as relevant to the transport models and the CBA as the time gains between terminals, since what matters are the door-to-door transport times (therefore see speed changes above). It can also lead to reductions in unreliability and damage.

i. Improve railway access (e.g. new railheads in ports)  $\rightarrow$  access and waiting time  $\downarrow$ 

Here we have the same chain of effects as under h. starting with access charges and door-to-door time.

j. Improve signalling -> higher capacity and speed -> transport cost per tonne  $\downarrow$ , transport time  $\downarrow$ 



The capacity changes are described under a and the speed increases under b.

k. Other institutional issues: reduction of the time blocks during which railway lines or line sections are closed (e.g. to allow for maintenance) and reduction in customs time -> waiting time  $\downarrow$  (maybe also an impact on reliability).

See the chain of effects for speed changes under b.

I. Reducing the gradient of the railway line

If the railway line in the reference situation has a steep gradient (in a mountainous area) and this gradient is reduced as part of the project (e.g. by more curves or by more tunnels) this will reduce the need for a more than standard number of locomotives. For the reference situation one could for instance calculate the transport coasts using two locomotives (in the standard costs sheet in Excel one locomotive is assumed, but this can be changed by doubling the variable traction cost). And then one could use a single locomotive for the project situation, so that the project will reduce the traction cost. There will also be an impact on travel time (and reliability), which could be quite large in the case of tunnel projects.









## 7. Recommendations on changes of unit values over time

In a CBA, costs and benefits usually refer to different years (most commonly investment costs refer to years before the project starts operation and once the new facility is opened, the benefits accrue year by year). In CBA, the comparison of these items in different years is made possible by discounting: cost and benefits in later years receive a lower weight, depending on the discount factor, which often is related to the interest rates on capital.

This implies, that costs and benefits need to be calculated for every year within a period that may last until 20-50 years after the opening of the facility. The transport models used are often static models based on cross-sectional data. These models are used to predict transport volumes (and changes in transport times, costs and distances for a single forecast year (e.g. 2030) or just a few future years (e.g. 2020, 2030 and 2040). For all other years, the relevant volumes are assumed to be the same as in one of these forecasting years (or a weighted combination of these).

This will get costs and benefits for all relevant years in the CBA. However, after conversion into money units, the values need to be corrected for price change (and possibly also for real growth in productivity; but usually there are not sufficient data on productivity in transport). All unit values, such as the VOT, presented in this report are in euros of 2010. For later years, these need to be corrected for changes in the wages and prices that are relevant for the production of transport services over time.

Some countries use a correction based on real GDP per capita growth here (on top of the general price increase). For instance in the values of time and safety that RAND Europe and CE Delft recommended for EIB (in 2004), a GDP per capita elasticity of the VOT of 1 was used. HEATCO in 2006 recommended an elasticity of 0.7 here.

We think it is better to base the time escalation factor on the changes over time in the transport costs (instead of GDP/capita), since the transport cost are the key driver of the changes of the values over time. This method for escalation is also used for freight transport value of time and reliability in The Netherlands.

The amount of change in the transport costs depends on the changes in the various components of transport costs (notably the rail transport cost here):

- Crew cost
- Cost of wagons and locomotives
- Energy costs (electric, diesel)
- Infrastructure access cost
- Overhead costs.

The preferred method for escalation is to make bottom-up assumptions on the evaluation over time of these costs items (if these are highly uncertain one might do this for say three different scenarios on future cost development, which could be connected to existing scenarios on the development of other input variables). This then needs to be combined with the shares on total transport costs of these cost items. Together this will yield the growth in nominal terms of transport costs, but also of value of time and value of reliability for the cases that were given in absolute euros of 2010. For ratios of benefits to the transport costs or the time benefits (or short to long run benefits), no specific escalation of the ratios is required: once the transport costs or time benefits are escalated, these benefits will increase proportionately, as they should.

The above nominal growth in the transport costs can be compared to the general price increase to reflect how the transport costs increase more (or less) than the general price level (inflation). Given that many inputs to the CBA will be in real prices (euros of a fixed year: constant prices), it will be good to subtract the



general price increase from the transport cost increase to get the real transport cost increase per year. This can then be applied to the benefits in the CBA for each of the relevant years.

If it would not be possible to provide proper assumptions on the future increase of specific cost items, one could use the expected general price increase (so that there will be no real costs increase for this component). In various European projects, scenarios have been constructed for the expected increase in transports cost by mode and the general price level, which if needed could be used as a default.

When no forecasts for the different cost components can be obtained/made, we suggest to increase the crew cost with the wage increase (should be close to the GDP growth) and the other components only with the general price increase. This in spite of the fact the overhead has a large labour component (because overheads in JASPERS countries can be expected to decrease in general).





## 8. Conclusions

In this report we have presented a general methodology for calculating the benefits to the transport sector (user benefits) of investment projects in rail freight in JASPERS countries, as well as specific unit values for value of time and value of reliability that can be used if values specific to the study area are not available and cannot be determined.

One of the conclusions is that good information on transport costs is not only important for calculation of distance costs benefits, but also for time and reliability benefits. Transport cost functions are available in several countries, either for monitoring/guideline purposes or as input for transport modelling, but there is no consistent source that can provide country-specific information for each JASPERS country. These costs should preferably come from rail operators and infrastructure managers working in rail transport in the study area. If no cost information would be available, default unit values for different types of train and for competing modes have been provided in this report and an accompanying transport cost spreadsheet.

In this appraisal report we also discussed which transport models are best suited for JASPERS projects and how they can be judged. There is a clear distinction between the disaggregate approach (using data at the level of individual decision-makers and shipments) and the aggregate data (using data at the zonal level) in modelling modal split in freight transport. The model type used most in freight transport analysis is the aggregate logit model. Given the data availability situation in most JASPERS countries this seems a plausible choice as one of the components of a more comprehensive freight transport model. For an initial quick scan analysis, relatively simple models, such as elasticity-based models (but distinguishing a large number of segments), can be sufficient.

For the escalation of the monetary unit values over time, we propose using assumptions on how transport costs (components) are likely to develop (relative to the general price increase).









## Annex 1. How to improve and extend a modal split model

## A1.1 How to add a cargo time component to the modal split model

Suppose a modal split model is available that includes transport cost as one of the explanatory factors of the modal split. This includes time-based (vehicle and crew, but also overhead costs) and distance based costs.

So it can also be taken to equal the freight rates that shippers pay for transport services (taking the excess profit margin to be zero). The cargo component of time however is not included (e.g. interest on goods in transit), nor is reliability.

We assume that the existing transport model can be written in the form of the following utility functions per available mode:

$$U_{rail} = ... + \beta (C_{rail}) ....$$

 $U_{road} = ... + \beta (C_{road}) ....$ 

Where:

U denotes the utility of the mode (for road or rail)

C denotes cost of the mode (for road and rail) per tonne

 $\beta$  denotes a coefficient that has been estimated (e.g. as hypothetical example  $\beta$ =-0.06).

The cost inputs for all commodity types are calculated as (also hypothetical example):

 $C_{rail} = 0.7*hours_{rail} + 0.05*km_{rail}$ 

 $C_{road} = 1.8*hours_{road} + 0.02*km_{road}$ 

Where:

Hours: number of hours for a transport between two zones, by mode

Km: number of kilometres for a transport between two zones, by mode.

The cargo time component can be added by changing the cost input specification to:

 $C_{rail} = (0.7 + 0.01)*hours_{rail} + 0.05*km_{rail} \text{ for bulk transport}$   $C_{road} = (1.8 + 0.01)*hours_{road} + 0.02*km_{road} \text{ for bulk transport}$   $C_{rail} = (0.7 + 0.2)*hours_{rail} + 0.05*km_{rail} \text{ for other transport}$   $C_{road} = (1.8 + 0.2)*hours_{road} + 0.02*km_{road} \text{ for other transport}$ 

The values 0.01 and 0.2 euro can be corrected for the time cost difference between JASPERS countries and the EU-15 (see chapter 5). The utility function can remain the same.

## A1.2 How to add reliability

After having done A1.1, reliability can also be added to the modal split model, as follows:  $C_{rail} = (0.7 + 0.01)$ \*hours<sub>rail</sub> + 0.40\*(0.7 + 0.01) \* standarddeviation<sub>rail</sub> + 0.05\*km<sub>rail</sub> for bulk transport  $C_{road} = (1.8 + 0.01)$ \*hours<sub>road</sub> + 0.40\*(1.8 + 0.01) \* standarddeviation<sub>road</sub> + 0.02\* km<sub>road</sub> for bulk transport  $C_{rail} = (0.7 + 0.2)$ \*hours<sub>rail</sub> + 0.65\*(0.7 + 0.2) \* standarddeviation<sub>rail</sub> 0.05\*km<sub>rail</sub> for other transport A study of Economic Impacts of Freight Speed Increase and Travel Time Reliability Improvements by Rail



 $C_{road} = (1.8 + 0.2)*hours_{road} + 0.65*(1.8 + 0.2)*standarddeviation_{road} + 0.02*km_{road} for other transport transport the transport of the transport transport to the transport transport to the transp$ 

Where:

Standarddeviation is the standard deviation of the travel time distribution for the transport between the zones, by mode (if this cannot be calculated, reliability cannot be added to the modal split model).

## A1.3 How to do a re-calibration of a modal split model to observed market shares

Suppose we have three modes in a study area for a rail project: rail, road and inland waterways (IWW). The aggregate logit modal split model uses three utility functions U, one for each mode (this is a hypothetical example, just for explanation):

 $U_{rail} = -0.06*transportcostpertonne_{rail} - 1.50$ 

 $U_{road}$  = -0.06\*transportcostpertonne<sub>road</sub>

 $U_{iww} = -0.06*$ transportcostpertonne<sub>iww</sub> - 2.00

The market shares (in probabilities) predicted by this model are defined as (for example for rail):

 $P(rail) = \exp(U_{rail}) / ((\exp(U_{rail}) + \exp(U_{road}) + \exp(U_{iww}))$ 

Further suppose that using this formulation for the study area this model predicts for the base year:

Rail: 15%

Road: 75%

IWW: 10%.

The observed shares for the study area in the base year (say 2010) are:

Rail: 25%

Road: 60%

IWW: 15%.

We want the re-calibrated model to reproduce these observed shares. In a first step we change the modespecific constants by adding the natural logarithm of the ratio of the observed to the predicted share. So we get:

Rail: new constant =  $-1.50 + \ln(25/15) = -1.50 + 0.51 = -0.99$ 

Road: new constant =  $0 + \ln(60/75) = 0 - 0.22 = -0.22$ 

IWW: new constant is -2.00 + ln(15/10) = -2.00 + 0.41 = -1.59.

This will make rail and IWW more attractive and road less attractive (as required). The new constants then replace the values -1.50, 0 and -2.00 in the model and the model is applied with the new constants. The new predicted shares of the modes will be closer to the observed shares, but not necessarily close enough. In that case the above procedure needs to be repeated a number of times (iterative process) until we are as close as we want to be (e.g. no more than 1% off).



## Annex 2. Default transport costs for JASPERS countries

Time dependent cost (including overhead cost) per train per hour												
Train type		wagonload train				container train						
Traction	elec	tric	die	sel	eleo	ctric	die	sel	eleo	ctric	di	esel
Taxes	with	without	with	without	with	without	with	without	with	without	with	without
country												
Bulgaria	340.57	339.37	385.56	367.36	377.68	380.88	439.88	417.80	317.54	316.35	356.07	342.06
Croatia	360.57	356.34	405.26	374.93	397.97	394.37	459.73	422.67	337.39	329.46	375.78	350.87
Czech Republic	362.97	361.61	407.63	384.56	400.41	399.72	462.11	434.69	339.77	334.66	378.14	359.51
Estonia	356.05	354.31	400.82	378.47	393.39	392.32	455.25	429.07	332.91	327.46	371.33	353.17
Greece	397.08	379.10	441.25	399.58	435.01	417.46	495.98	448.80	373.64	351.89	411.76	375.02
Hungary	356.59	355.87	401.35	372.26	393.94	393.90	455.78	418.83	333.44	329.00	371.86	348.69
Latvia	349.97	348.76	394.82	371.89	387.22	386.69	449.20	421.84	326.87	321.99	365.33	346.84
Lithuania	355.27	355.02	400.04	378.06	392.59	393.04	454.47	428.10	332.13	328.16	370.55	353.01
Poland	355.47	354.39	400.25	375.22	392.80	392.39	454.67	424.09	332.34	327.53	370.76	350.66
Romania	344.59	345.72	389.51	369.99	381.76	383.60	443.86	420.48	321.53	318.99	360.03	344.70
Slovakia	359.45	363.26	404.16	387.29	396.84	401.39	458.62	438.02	336.28	336.28	374.68	361.99
Slovenia	382.67	364.33	427.05	386.12	420.40	402.47	481.67	436.46	359.34	337.33	397.56	361.70
FYR Macedonia	341.56	343.94	386.54	366.52	378.69	381.80	440.86	416.08	318.53	317.24	357.05	341.61
Montenegro	341.11	342.90	386.09	365.50	378.23	380.74	440.41	415.04	318.07	316.21	356.60	340.58
Serbia	345.70	347.69	390.62	370.22	382.89	385.60	444.97	419.83	322.64	320.94	361.13	345.31
Variable traction	n cost per kn	n										
Train type		Block t	rain			wagonlo	ad train		container train			
Traction	elec	tric	die	sel	eleo	ctric	die	diesel electric d		diese	9	
Taxes	with	without	with	without	with	without	with	without	with	without	with	without
country												
Bulgaria	3.12					-						
Croatia		3.12	5.59	4.47	3.12	3.12	5.59	4.47	3.12	3.12	5.59	4.47
	3.12	3.12 3.12	5.59 5.59	4.47 4.19	3.12 3.12	3.12 3.12	5.59 5.59	4.47 4.19	3.12 3.12	3.12 3.12	5.59 5.59	4.47 4.19
Czech Republic	3.12 3.12	3.12 3.12 3.12	5.59 5.59 5.59	4.47 4.19 4.42	3.12 3.12 3.12	3.12 3.12 3.12	5.59 5.59 5.59	4.47 4.19 4.42	3.12 3.12 3.12	3.12 3.12 3.12	5.59 5.59 5.59	4.47 4.19 4.42
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Czech Republic Estonia Greece Hungary	3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08	3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08	3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08
Czech Republic Estonia Greece Hungary Latvia	3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42
Czech Republic Estonia Greece Hungary Latvia Lithuania	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42
Czech Republic Estonia Greece Hungary Latvia Lithuania Poland	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.08 4.42 4.42 4.30	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30
Czech Republic Estonia Greece Hungary Latvia Lithuania Poland Romania	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47
Czech Republic Estonia Greece Hungary Latvia Lithuania Poland Romania Slovakia	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.08 4.42 4.42 4.42 4.30 4.47 4.47	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47
Czech Republic Estonia Greece Hungary Latvia Lithuania Poland Romania Slovakia Slovenia	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.36	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.39	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.39
Czech Republic Estonia Greece Hungary Latvia Lithuania Poland Romania Slovakia Slovenia FYR Macedonia	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.36 4.39	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.30 4.47 4.39 4.39	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.47 4.39 4.39
Czech Republic Estonia Greece Hungary Latvia Lithuania Poland Romania Slovakia Slovenia FYR Macedonia Montenegro	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.36 4.39 4.39	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.39 4.39 4.39	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.39 4.39 4.39
Czech Republic Estonia Greece Hungary Latvia Lithuania Poland Romania Slovakia Slovakia Slovenia FYR Macedonia Montenegro Serbia	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.36 4.39 4.39 4.39	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.39 4.39 4.39 4.39	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	3.12 3.12 3.12 3.12 3.12 3.12 3.12 3.12	5.59 5.59 5.59 5.59 5.59 5.59 5.59 5.59	4.47 4.19 4.42 4.47 4.30 4.08 4.42 4.42 4.42 4.30 4.47 4.47 4.47 4.39 4.39 4.39 4.39

Table A2-1: Summary of default transport cost by train type and JASPERS country, in euro per train per year, with and without taxes (more details are in a spreadsheet delivered together with this report)



Rail infrastructure access charge per km														
Train type	block train				wagonload train				Container train					
Traction	elec	tric	die	esel	electric diesel		diesel		diesel		electric		diesel	
Taxes	with	without	with	without	with	without	with	without	with	without	with	without		
country														
Bulgaria	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36		
Croatia	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86		
Czech Republic	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39	3.39		
Estonia	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63		
Greece	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11		
Hungary	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12		
Latvia	9.97	9.97	9.97	9.97	9.97	9.97	9.97	9.97	9.97	9.97	9.97	9.97		
Lithuania	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14		
Poland	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00		
Romania	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32		
Slovakia	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75		
Slovenia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
FYR Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Montenegro	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00		
Serbia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

The train lengths and tonnages we are assuming as default here are (but in chapter 6 we discussed how train length can be varied):

- Block trains, electric: 18 wagons, gross tonnage 1705 tonnes, net tonnage (=cargo weight) 1143 tonnes;
- Block trains, diesel: 18 wagons, gross tonnage 1733 tonnes, net tonnage 1143 tonnes;
- Wagonload trains, electric: 18 wagons; gross tonnage 1705 tonnes, net tonnage 1143 tonnes;
- Wagonload trains, diesel: 18 wagons; gross tonnage 1733 tonnes, net tonnage 1143 tonnes;
- Container trains, electric: 20 wagons, gross tonnage 1385 tonnes, net tonnage 750 tonnes;
- Container trains, diesel: 20 wagons, gross tonnage 1413 tonnes, net tonnage 750 tonnes.

Table 2-2: Default costs for competing modes in JASPERS countries, in euro per vehicle/vessel per year, with taxes

			Inland	Short sea
Variable	Calculations	Truck	waterways	shipping
Capacity (tonnes)		27	2500	30000
crew cost per hour	G	20	60	90
crew cost in total	g*hours	52000	122220	589680
fuel cost per km	Н	0.4	6	10
fuel cost in total	h*kms	52000	190662	2950000
other cost	1	49000	288000	2390000
total cost	g*hours+h*kms+i	153000	600882	5929680



# Annex 3. Hypothetical example of the calculation of time, reliability and distance cost benefits (Example 1)

### Inputs

In this annex, the proposed methods for calculating the various user benefits of rail transport projects will be explained for the case of a specific (hypothetical) example of an investment project in rail transport. For didactical reasons we keep the example relatively simple; in practical applications there are for instance likely to be more transport zones. We call this Example 1.

The detailed calculations are given in a spreadsheet ('numerical example following cost spreadsheet) that was also submitted with this report (the spreadsheet also contains an Example 2, for different commodities, solid bulk instead of containerised goods).

The example concerns a study area in a JASPERS country Europe with 4 zones, w, x, y and z (also see Figure A2-1 below). In the reference case (the future situation without the project), the railway line that needs to be used (the old route A) passes through the main city of zone x where there also is some waiting time and time. The project is a bypass (the new route using B) of this city, which reduces the rail transport distance, increases the speed and reliability of the transport and takes away the need for waiting in zone x. Some further exogenous data for Example 1 are given below.

- Example 1 only considers containerised goods
- We use the numbers in the spreadsheet for Bulgaria
- Distance cost for rail: 5.48 euro/km for an electric block train. After division by the net (cargo) tonnage per train of 750 tonnes this gives 0.007307 euro/tonne/km
- Time (staff and vehicles) cost for rail: 316.35/750 = 0.4218 euro/tonne/hour.



Figure A3-1: Configuration of the zone and network structure in Example 1 (the same in Example 2)



rail distanc	ce in km pe	r transp	ort; refe	erence		rail distance in km per transport; project					
	w	х	у	z			w	х	у	Z	
w	180	200	200	240		w	180	190	175	215	
x	200	100	150	200		х	190	95	145	190	
у	200	150	100	150		у	175	145	100	150	
Z	240	200	150	180		Z	215	190	150	180	
rail time in	hours per	transpo	rt; refer	ence	r	rail time in	hours per	transport	; projec	t	r
	w	х	у	z			w	х	у	Z	
w	6	8	10	12		w	6	7	7	9	
х	8	4	6	8		х	7	3	5	7	
у	10	6	3	5		у	7	5	3	5	
Z	12	8	5	6		Z	9	7	5	6	
rail reliabil	ity in stand	lard dev	iation p	er trans	port;	rail reliabil	ity in stand	ard devia	tion per	transpo	ort;
reference				1		project		[			1
	w	х	У	Z			W	х	Y	Z	
w	1	1.5	2	2.5		W	1	1	1	1.5	
x	1.5	1	1.5	1		Х	1	0.7	1.1	0.8	
У	2	1.5	1	1		У	1	1.1	1	1	
Z	2.5	1.5	1	1		Z	1.5	0.8	1	1	
rail volume	e in tonnes	(*1000)	per yea	ar; refere	ence	rail volume	e in tonnes	(*1000) p	er year;	project	1
	w	х	У	Z	total		W	Х	у	Z	total
w	500	300	150	200	1150	W	500	340	220	300	1360
x	200	200	100	100	600	х	230	250	120	110	710
У	100	100	100	150	450	У	200	120	100	150	570
Z	150	100	150	400	800	Z	220	110	150	400	880
total	950	700	500	850	3000	total	1150	820	590	960	3520

*Table A3-1: Distance, time reliability and rail volume (demand) in Example 1 for reference and project situation* 

## Intermediate results

From these data that are given for Example 1, we first calculate a number of intermediate results. These results include:

- Time cost per year: the product of the number tonnes per year, the number of hours and the timedependent cost per tonne per hour;
- Distance cost per year: the product of the number tonnes per year, the number of kilometres and the distance-dependent cost per tonne per km;

In the spreadsheet submitted together with this report is also an Example 2. This assumed flows and the calculation rules are the same for this example as for Example 1 and will not be discussed in this report. However, since Example 2 refers to solid bulk products, the outcomes are sometimes quite different from those in Example 1 (container goods).

time cost in euro (*1000) per year; reference				time cost	in euro (*100	0) per yea	ar; proje	ct			
	w	х	у	Z	tot		w	x	y	z	tot
w	1265	1012	633	1012	3923	w	1265	1004	650	1139	4058
х	675	337	253	337	1603	х	679	316	253	325	1573
У	422	253	127	316	1118	У	591	253	127	316	1286
Z	759	337	316	1012	2425	Z	835	325	316	1012	2489
tot	3121	1940	1329	2678	9069	tot	3370	1898	1346	2792	9406
distance c	ost in euro	(*1000)	per yeai	r; refere	nce	distance cost in euro (*1000) per year; project					
	w	х	у	z	tot		w	x	у	z	tot
w	658	438	219	351	1666	w	658	472	281	471	1882
х	292	146	110	146	694	х	319	174	127	153	773
у	146	110	73	164	493	У	256	127	73	164	620
Z	263	146	164	526	1100	Z	346	153	164	526	1189
tot	1359	840	566	1187	3953	tot	1578	925	646	1314	4464

TableA3-2: Various intermediate calculations for Example 1 for reference and project situation

## Staff and vehicle time savings (part of the time benefits)

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These savings are based on the transport costs for staff and vehicle time (except that for a societal CBA, taxes can be omitted as these are simply transfer payments). The outcomes of these calculations are in Table A3-3, A3-4, A3-5 and A3-6. Please note that there are different tables for the existing train users that do not switch a and for new train users (e.g. modal shift from road to rail), that use the rule of half.

Table A3-3: Staff and vehicle time savings for existing traffic, year 1, in euro (\*1000) per year, for Example 1

Zones	w	Х	у	Z	total
w	0	63	95	127	285
x	42	42	21	21	127
у	63	21	0	0	84
Z	95	21	0	0	116
total	200	148	116	148	612

Table A3-4: Staff and vehicle time	savings for new traffi	c, year 1, in euro	(*1000) per year,	for Example 1
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zones	w	Х	у	Z	total
w	0	4	22	32	58
x	3	5	2	1	12
У	32	2	0	0	34
Z	22	1	0	0	23
total	57	13	24	33	127



Table A3-5: Staff and vehicle time savings for existing traffic, year 5 and later, in euro (\*1000) per year, for Example 1

Zones	w	Х	у	Z	total
w	0	127	190	253	569
x	84	84	42	42	253
у	127	42	0	0	169
Z	190	42	0	0	232
total	401	295	232	295	1223

Table A3-6: Staff and vehicle time savings for new traffic, year 5 and later, in euro (\*1000) per year, for Example 1

zones	w	Х	у	Z	total
w	0	8	44	63	116
x	6	11	4	2	23
у	63	4	0	0	67
z	44	2	0	0	46
total	114	25	49	65	253

## Cargo component of time benefits

The cargo component of the time benefit is calculated using the French method. The outcomes for existing and new train users are in Table A3-7 and A3-8, together with the earlier results on the staff and vehicle time component.

Table A3-7: Cargo component and staff and vehicle time component of the time benefits in euro per year(\*1000) for year  $1^1$  for Example 1

Method	Existing train users	New train users	Total benefits
Cargo component	468	97	565
Staff and vehicle time	612	127	738
component			

1 For the cargo component in this table there is no methodological distinction between year 1 benefits and those for year 5 and later.

Table A3-8: Cargo component and staff and vehicle time component of the time benefits in euro per year(\*1000) for year 5 and later<sup>1</sup> for Example 1

Method	Existing train users	New train users	Total benefits
Cargo component	468	97	565
Staff and vehicle time	1223	253	1476
component			

2 For the cargo component in this table there is no methodological distinction between year 1 benefits and those for year 5 and later.

#### **Reliability benefits**

The reliability benefits are based on formulating reliability as the standard deviation of travel time and using monetary values that are based on the values used for the Evaluation of the Federal Infrastructure plan in Germany. The outcomes are in Tables A3-9 to A3-12.



Table A3-9: Reliability benefits for existing traffic, in euro (\*1000) per year in year 1, for Example 1

	W	Х	у	Z	total
w	0	36	36	48	121
х	24	15	10	5	53
У	24	10	0	0	34
Z	36	17	0	0	53
total	85	77	46	53	261

Table A3-10: Reliability benefits for new traffic, in euro (\*1000) per year in year 1, for Example 1

	W	x	у	z	Total
w	0	2	8	12	23
x	2	2	1	0	5
У	12	1	0	0	13
Z	8	1	0	0	9
total	22	6	9	12	50

Table A3-11: Reliability benefits for existing traffic, in euro (\*1000) per year in year 5 and later, for Example 1

	w	х	Υ	Z	total
w	0	57	57	76	190
х	38	23	15	8	83
У	38	15	0	0	53
Z	57	27	0	0	83
total	133	121	72	83	409

Table A3-12: Reliability benefits for	r new traffic, in euro (*1000,	) per year in year 5 and	later, for Example 1
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	w	Х	Y	Z	Total
w	0	4	13	19	36
х	3	3	2	0	8
У	19	2	0	0	20
Z	13	1	0	0	15
total	35	9	15	19	79

## **Distance cost savings**

Finally the distance cost savings are in Table A3-13 and Table A3-14. These do not differ between year 1 and year 5 and later.

Table A3-13: Distance cost savings for existing traffic, in euro (\*1000) per year, for Example 1

	w	x	у	Z	total
w	0	22	27	37	86
х	15	7	4	7	33
У	18	4	0	0	22
Z	27	7	0	0	35
total	60	40	31	44	175



	w	х	у	Z	total
w	0	1	6	9	17
х	1	1	0	0	3
У	9	0	0	0	9
Z	6	0	0	0	7
total	17	3	7	9	36

Table A3-14: Distance cost savings for new traffic, in euro (\*1000) per year, for Example 1







