DETERMINING PRICE ELASTICITIES OF RAIL TRANSPORT DEMAND FOR MARKET-CAN-BEAR TESTS

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1. INTRODUCTION

On the basis of EU-Directive 2012/34/EU and corresponding national legislation, rail infrastructure companies in Europe levy a charge on the rail operators for the use of the infrastructure. In this way, the rail operators pay for the direct costs. On top of this, member states also have the possibility to levy a markup, which should be based on „what the market can bear“. A method which can be applied to determine what the market can bear is the Ramsey-Boiteux-Principle (Ramsey, 1927; Boiteux, 1956). This principle implies that the markup for a market segment should be inversely proportional to the own price elasticity for this market segment: segments with a large sensitivity to a price change pay a smaller markup and segments that are more insensitive pay a higher markup.

Several member states in Europe are applying the market-can-bear principle for levying markups on rail transport providers, or are planning to do so in the near future. In order to calculate the Ramsey-Boiteux markup, it is important for rail infrastructure companies to determine price elasticities of demand for rail transport by market segment. Demand here refers to the demand by final consumers of rail transport services: travellers in passenger transport and shippers and logistics service providers in freight transport. The rail operator is the link between the rail infrastructure company and the final consumer, and often the assumption is made that the extra charges will be passed on by the rail operator to the final consumer.

Price elasticities of demand for rail transport by these agents can be determined using three different methods:

1. Identify the price elasticities using existing transport models for the study area in question.
2. Develop new transport models on available or new data. The data might involve stated preference (SP) experiments, where respondents are asked to choose between hypothetical alternatives.
3. Base the elasticities for a certain study area on a review of the literature on elasticities in freight and/or passenger transport. Here it is important to select those studies that are most transferable to the study area and the market segments studied.

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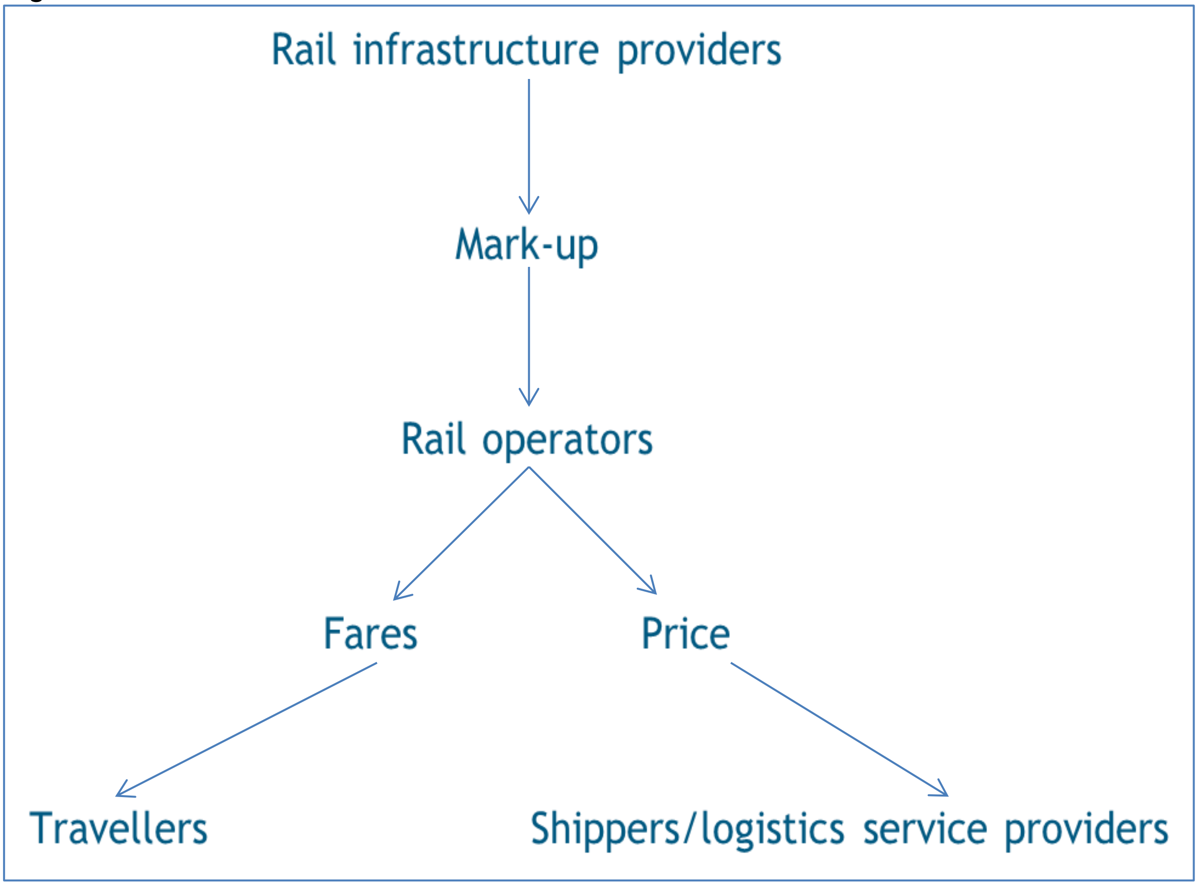
This paper will discuss all three methods giving some examples (sections 3, 4 and 5). But first, the context of Ramsey-Boiteux pricing is further discussed in section 2.

2. THE CONTEXT

The situation that is covered in this paper is that of a rail infrastructure provider or manager that is carrying out market-can-bear tests to determine mark-ups on the charge for the direct cost following EU-Directive 2012/34/EU. These charges and the markup are paid by a number of rail transport operators that use the infrastructure provided (see Figure 1). These operators are delivering rail transport services to travellers and to shippers/logistic service providers and ask a fare or price for these services.

Figure 1. The context of market-can-bear tests



The Ramsey-Boiteux method is very suitable here because the capacity to bear the charge is determined such that social welfare if maximised, by looking at the optimal competitive position of the different market segments.

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This method has been used for market-can-bear tests in the railway sector in Germany (BVU, 2015; TNS Infratest, 2015; Produkt + Markt Marketing Research, 2016), Austria (see ÖBB-Infrastruktur, 2017) and The Netherlands (see Significance, 2018). There also is consensus between regulators in Europe on the economic method for determining the markup that best fits the legal frameworks of the relevant EU directives, with a strong preference for Ramsey-Boiteux pricing (IRG Rail, 2016).

The market-can-bear principle was originally formulated by Frank Ramsey (Ramsey, 1927) in the context of taxation. Marcel Boiteux (1956) extended it to the context of a natural monopoly (as we have here in case of railway infrastructure). The basic equation for a Ramsey-Boiteux charge, where the price of the monopolist is set such that societal welfare is maximised (given the profit function of the monopolist), is:

$$\frac{P_i - MC_i}{P_i} = \frac{\gamma}{\varepsilon_i} \qquad (1)$$

Where:
P_i: price that the monopolist sets for market segment i;
MC_i: marginal costs for the production of the goods or services for market i;
γ : a constant that will be smaller than or equal to 1 (this constant originates from the Lagrange multiplier of the formula that equates the revenues of the monopolist to his costs);
ε_i: the price elasticity of demand for market segment i.

Equation (1) says that the markup (which is relative to the price set by the monopolist) that comes on top of the payment for the marginal costs of a segment is proportional to the inverse price elasticity of that segment. In other words, market segments that have a high elasticity will get a low markup, and segments that are not so price-sensitive will get a high markup, so that there will not be a large shift to competing products/services. In the case of railways, such a competing alternative may be road transport.

For a rail infrastructure provider such as ProRail in The Netherlands, DB Netze in Germany or ÖBB-Infrastruktur AG in Austria, the situation is somewhat more complicated than sketched above. The rail infrastructure provider will levy a markup that is paid by the rail transport operators (like NS, Arriva or DB Cargo in The Netherlands, or ÖBB, Westbahn and Rail Cargo in Austria) in passenger and freight transport, that then decide whether to pass this on or not to their customers. These customers are the "final consumers": travellers and shippers/logistics service providers, LSPs. These final consumers then react to the price change of the operators and their reaction is summarised in the form of the price elasticity of demand (per segment). The difference to the situation described in equation (1) is that the degree of price transfer to the final consumer also matters in the

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determination of the Ramsey-Boiteux markup. The optimal charge (the markup) now depends on:

- The price elasticity of final consumer demand of the respective market segment;
- The share of the markup in the total costs for travellers and shippers/logistic service providers;
- The degree to which the charge is passed on by the rail operators to the final consumers.

For the implementation of the market-can-bear principle in rail transport, each of these three components needs to be quantified for every market segment. This paper however only deals with the first issue: how to determine the price elasticities by market segment that can be used in a market can bear test. In the following sections 3, 4 and 5, we will discuss three methods, one by one:

I. Use existing transport models for the study area in question (e.g. national models);
II. Develop new transport models on available or new data;
III. Base the elasticities for a certain study area on a review of the literature on elasticities in freight and/or passenger transport.

A key aspect of a market-can-bear test is that several market segments are distinguished that have clearly different elasticities (in principle it would also be possible that the segments differ on one or both of the other two components). There is a large degree of interdependence between the determination of elasticities and the identification of proper market segments:

- The market segmentation depends to a considerable extent on which groups have different elasticities;
- Once a researcher has determined the elasticities for different groups of the population and different circumstance (e.g. trip purposes), using either one of the above methods I, II or III, the market segmentation may need to be reviewed to reflect these elasticities (feedback).

3. METHOD 1: USE EXISTING TRANSPORT MODELS

Some countries have (up-to-date) national transport models, for passenger transport, freight transport or both (e.g. Sweden, Denmark, Norway, Germany, The Netherlands), which can be used to derive rail price elasticities by market segment for market-can–bear tests.

These models have various submodels. For determining price elasticities, they should include the right transport choices:

- At least mode choice between rail and its competitors;

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- Or transport chain choice;
    - e.g. road-rail-road versus direct road or road-waterways-road;
- Possibly also distribution;
    - This refers to destination choice (passenger transport) or choice of supplier region (goods transport).

Depending on the model form, the elasticities can be read out from the estimated coefficient values (when the model uses the constant elasticity of substitution function) or calculated from the outcomes of runs with the model for a base situation and a situation with a change in the rail transport prices. This also goes for any new model (see section 4).

Significance carried out a market-can-bear test study for ProRail (Significance, 2018):

- Review of the national and international literature (for validation);
- New runs with the existing national passenger transport model LMS (see Figure 2);
- New runs with the existing national freight model BasGoed (see Figure 3).

Both these national transport models are owned by Rijkswaterstaat, Ministry of Infrastructure and Water Management, that granted permission for use for this market-can-bear test for ProRail.

Figure 2. Structure of the Dutch national passenger transport model (LMS)

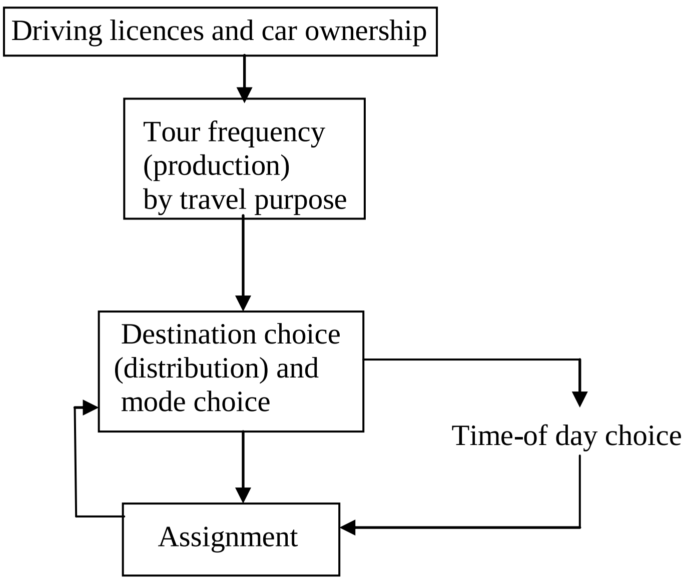

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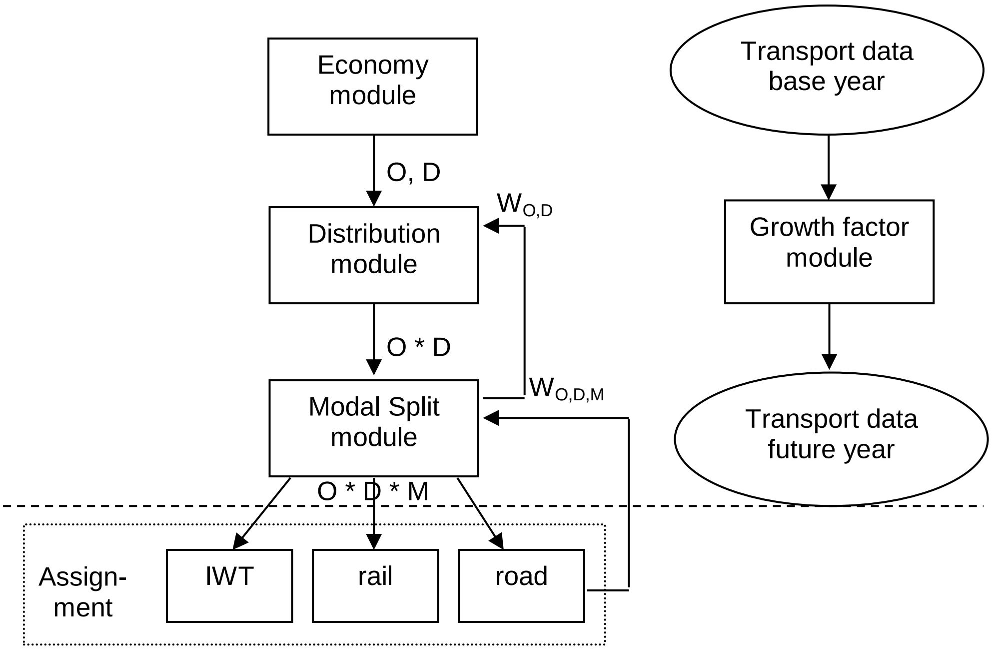
Figure 3. Structure of the Dutch national freight transport model (BasGoed)



Legend: O = origin, D = destination, M =mode, W = transport times and –costs, IWT = inland waterway transport.

For passenger transport the change in the rail fares in the LMS affects mode and destination choice. In BasGoed the relevant modules are modal split and distribution.

The runs with LMS and BasGoed were carried out for the years 2020 and 2024 respectively. For both these future years, two different scenarios (”low” and “high”) were used for the exogenous developments (e.g. economic growth, growth and composition of the population, changes in fuel prices), based on the so-called “WLO2” scenarios (CPB and PBL, 2015) for The Netherlands in the long run. Furthermore, we tested for the sensitivity of the elasticity to the size of the price change.

The main outcomes from the LMS runs for passenger transport are in Table 1 (for 2020) and 2 (for 2024). These outcomes refer to all trip purposes combined.

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Table 1. Elasticities for a change in the price of train trips for travellers on the number of passenger kilometres by train per year in 2020, for different scenarios and different price changes

Scenario and price change	2020_low			2020_high		
	0.5%	1.5%	2.5%	0.5%	1.5%	2.5%
Elasticity	-0.51	-0.50	-0.50	-0.49	-0.49	-0.50

Table 2. Elasticities for a change in the price of train trips for travellers on the number of passenger kilometres by train per year in 2024, for different scenarios and different price changes

Scenario and price change	2024_low			2024_high		
	0.5%	1.5%	2.5%	0.5%	1.5%	2.5%
Elasticity	-0.51	-0.50	-0.50	-0.52	-0.51	-0.50

We concluded from these outcomes that the rail price elasticity of passenger kilometres by rail only varies in a very limited way between the two years, the two scenarios and the different price changes, and that a single most likely value of -0.50 could be used for the elasticity of passenger demand for rail, transport (all trip purposes together) for the period 2020-2024.

The main results for freight transport (from runs with BasGoed) are in Table 3.

Table 3. Rail transport price elasticities of tonne-kilometres by rail per year, for different scenarios and different price changes

Scenario, year/ price change	Low scenario		High scenario	
	2020	2024	2020	2024
0.3%	-1.015	-1.015	-1.094	-1.102
1.5%	-1.036	-1.003	-1.067	-1.111
2.5%	-1.001	-1.014	-1.070	-1.101

The results in Table 3 refer to the impact on the number of tonne-kilometres by rail for all freight transport together. Again the differences between the two years, the two scenarios and the different price changes turn out to be very limited. On the basis of this, our recommendation was to use an overall price elasticity value for freight of -1.05 for the market-can-bear test for 2020-2024.

EU-Directive 2012/34/EU calls for the determination of the markup for at least three market segments:

- Freight transport services;
- Passenger transport services in the context of public service contracts;

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- Other (private) passenger transport services.

This is the minimally required market segmentation. In the determination of the segmentation of the market in the study for ProRail, the approach was to only distinguish finer segments than these three when:

- The price elasticities found between different parts of the rail freight or passenger transport market are substantially different, and
- ProRail has available reliable information on these parts of the markets to determine and levy the markup, and
- Additional market segments should not become too small.

The first condition has been studied on the basis of distinctions that the existing transport models LMS and BasGoed could provide, as well as the national and international literature for validation. The main result was that there are parts with substantially different elasticities, but that for these distinctions the other conditions for market segmentation were not met. Other distinctions that could be made on the basis of the information that is available to ProRail did not lead to substantially different elasticities. So we reached the conclusion that the minimum segmentation of the market in three segments was sufficient.

The segment of other (non-public) passenger transport is very small in The Netherlands (about. 0.05% of all train-kilometres in 2017 on the railway infrastructure managed by ProRail) and the LMS does not provide separate elasticities for this segment. These trains are mainly ski-trains and car sleeper trains. For this segment we recommended using the elasticity from the LMS for the travel purpose “social, recreation and other”, which on average is -0.90.

The elasticities that were used in the market-can–bear test 2020-2024 for Prorail thus are:

- Passenger transport services in the context of public service contracts: -0.50;
- Other (private) passenger transport services: -0.90;
- Freight transport services: -1.05.

4. METHOD 2: DEVELOP NEW TRANSPORT MODELS

If no transport model is available for the study area under consideration (or no permission to use it can be obtained from the model owners), then elasticities could be determined by developing a new model first and then using this for similar runs as described in section 3.

The first step in the development of a new transport model then is to acquire or collect data. Transport models can be estimated on aggregate data (usually the

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observational unit then is a zone-to-zone transport flow) or disaggregate data on individual decisions by travellers or decision-makers in freight transport. Disaggregate data is defined as data at the level of the decision-maker, which in our context coincides with the final consumer. One also needs data on transport time and cost by mode between the zones (e.g. from networks).

Disaggregate data might refer to data on decisions that have been made in practice (such as trip diaries with information on trips actually carried out during one or more days; or a commodity flow survey in freight), which is called “revealed preference” (RP) data or to “stated preference” (SP) data (also called “experimental” data). In the latter case respondents are shown hypothetical choice alternatives and asked to choose between these (or rank or rate these). In recent work on the determination of rail price elasticities for market-can-bear tests, SP data has often been used (e.g. BVU, 2015; TNS Infratest, 2015; Produkt + Markt Marketing Research, 2016).

In Figure 3 below is an example of the choice alternatives that are presented in SP to travellers, from a study that was recently carried out for ÖBB-Infrastruktur AG (Significance et al., 2018). Here the traveller is asked to choose between three modes, each described by scores on four attributes. The levels of the cost and time are based on responses earlier in the interview on a trip that was actually made by the respondent (base time and cost of a reference trip) and changes in these levels are based on an efficient statistical SP design.

The new model is then estimated on the data acquired/collected.

However, a model that is solely based on SP data is not very suitable for providing elasticities; joint models on SP and data on observed choices (revealed preference) are preferred. To explain why this is the case, we need to look at the equations that are used in standard disaggregate models.

Suppose that we are estimating a modal split model on disaggregate data, with train as one of the modes. For each available model we then estimate a utility function on the data. A typical utility function for the train alternative would be (there would be similar functions for each of the other modes):

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Figure 4. Example of a choice screen in the SP survey for ÖBB-Infrastruktur AG (Signicance et al., 2018)

	BUS	AIRPLANE	TRAIN	CAR
Ticket price	€ 40,00	€ 300,00	€ 140,00	€ 80,00
Travel time	6 hours	3 hours	4 hours	5 hours
Frequency	1 bus every 3 hours	1 plane every 3 hours	1 train every hour	
Reliability	1 out of 20 buses has a delay of more than 20 minutes	1 out of 20 planes has a delay of more than 20 minutes	1 out of 20 trains has a delay of more than 20 minutes	
	o prefer bus	o prefer airplane	o prefer train	o prefer car

$$U_{train} = \beta_c \,.\, Cost_{train} + \beta_t \,.\, Time_{train} + \beta_r \,.\, Relia_{train} + cons_{train} + e_{train} \quad (2)$$

Where:
U_{train} : utility when the decision-maker chooses train as the mode for a certain trip
$Cost_{train}$: transport costs by train
$Time_{train}$: transport time by train
$Relia_{train}$: transport time reliability for train
$Cons_{train}$: train-specific constant
E_{train}: error term or random (or unobserved) component for this utility function.

For the error term e_{train} we use some statistical distribution with a mean 0 and some variance (usually this is the extreme value distribution that gives rise to the standard logit model). Now the larger the variance of e_{train}, the smaller the contribution of the attributes like cost and time.

The value of transport time (VTT) is defined as β_t / β_c. Because we take the ratio here, the error term cancels out; the VTT does not depend on variance of e_{train}. The implication of this is that VTTs can be estimated on SP-only models.

But model forecasts and elasticities (which could be regarded as a type of forecasting) depend on all the components of (2) including e_{train}. Therefore, unlike the VTT, elasticities are dependent on the variance of e_{train}. This follows from the definition of an elasticity in such a model, see eq. (3) below.

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In a standard or Multinomial Logit (MNL) model the own rail price elasticity of rail transport is:

$$e^{train}_{train} = \beta_c \,.\, Cost_{train}\,(1 - P_{train}) \qquad (3)$$

where:
e^{train}_{train} : elasticity of rail price on rail transport
P_{train}: probability (market share) of rail transport.

Since the elasticity depends on the probability of rail transport, all components of the utility function (2) influence the elasticity, including the variance of the random term.

Now models on SP data have a different variance of the random component e_{train} than models on RP data (because in SP many attributes not included which are relevant in the real world). As a result of the dependence of the model on this variance, RP-models and SP-models are likely to produce different elasticities. What we need for forecasts and elasticities is to represent the real world and therefore we would like to have the RP-based variance.

The conclusion is that it is better not to base elasticities on models estimated on SP data only. A viable alternative is to use RP models. Another is to use models estimated jointly on SP/RP data, that are scaled to the RP-based variance of the random component. In the market-can-bear project for ÖBB–Infrastruktur AG, the latter approach was adopted (e.g. by estimating the models not only on new SP data, but also on the trip diary data (RP) from Österreich Unterwegs).

New SP data were collected in Austria for travellers as well as shippers/logistics service providers (Significance et al., 2018).

In this project we not only estimated Multinomial Logit models (MNL), as discussed above, but also:

- MNL-models with interaction coefficients (e.g. for person and household attributes);
- MNL-models with non-linear specification of the dependence on time and cost;
- Nested-Logit models;
- Mixed-Logit models (ML) with a lognormal distribution for cost coefficients.

The final models (that performed best) for passenger transport, were ML models with interactions and non-linear specifications (for freight transport there were not enough observations to estimate ML models). The mode-specific constants in these models

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were re-calibrated to represent the observed mode shares (the estimation sample itself is not representative for the modal split, but focuses on rail transport, for reasons of efficiency in the data collection). These models were then run for a base case and a case with a 1% change in the rail price to obtain the following elasticities (Table 4).

Table 4. Price elasticities of rail transport passenger kilometres and tonne kilometres for the market-can-bear test for ÖBB-Infrastruktur AG (Significance et al., 2018).

	Marktet segment	Elasticity
Passenger transport	Commercial passenger traffic	-0.35
	Public service long-distance passenger traffic	-0.35
	Short-distance traffic high	-0.23
	Short-distance traffic low	-0.27
Freight transport	Combined transport (containerised)	-0.55
	Wagonload transport	-0.75
	Direct flows (not containerised)	-0.32

5. METHOD 3: ELASTICITIES FROM THE LITERATURE

The final method is transferring elasticities from the literature to the study area. This method is relatively fast and cheap, but has the disadvantage that one does not use a model that is estimated on data for the study area. There always is the question whether the elasticities from other times and places will be transferable. To minimise such problems, it is important to select those studies that are most transferable to the study area and the market segments studied (e.g. transfer from countries with a similar GDP per capita, modal split, trip lengths and price levels for the use of the modes).

Only a brief look at the literature on price elasticities in transport will reveal that the elasticity values can be very different – it may seem as if anything goes. However, there are a number of good reasons why elasticities can be different and this needs to be borne in mind when contemplating a transfer of elasticities from the literature.

Elasticities can be different because of (Significance and CE Delft, 2010):

- Different stimulus variables; this refers to the variable in the denominator of the elasticity (e.g. infra cost, energy cost or all transport cost);

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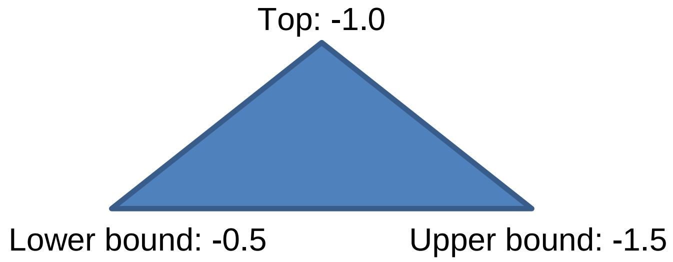
- Different response variables; this refers to the variable in the numerator (e.g. trips, tonnes, passenger-km, tonne-km, train-km);
- Different market segments (bulk vs general cargo, short vs long distance);
- Price increase vs decrease, magnitude of price change;
- Different response mechanisms are included (related to long vs short run).

These possible response mechanisms (for a change in the rail transport prices) are:
- Change fuel efficiency (buy other trains, drive slower);
- Change transport efficiency (depot locations, shipment size, consolidation, empty driving);
- Change mode choice (road, inland waterways, short sea);
- Change transport demand (different suppliers or customers, production per location);
- Change commodity demand.

The first two responses are mainly in the domain of the operator, the next two are often decided by the final consumer of transport services (travellers, shippers) whereas the last one (only relevant for freight) refers to the final consumer of the goods that are transported.

Some practical advice on transferring elasticities is the following:
- Do not transfer cross-elasticities (e.g. impact of rail price or demand for road transport) because these are very dependent on the market shares of the area they were estimated for.
- Be very careful in transferring own elasticities (e.g. impact of rail price on rail demand):
  - For determining price elasticities, they should include the right transport choices (as state above, for market-can-bear test one would like to include mode choice and maybe distribution as well;
  - Do a sensitivity analysis using the triangle: top, lower bound and upper bound for the elasticity value.

Following the outcomes of a literature review we carried out for The Netherlands for rail price elasticity of rail freight tkm (Significance, 2018), this triangle would be:



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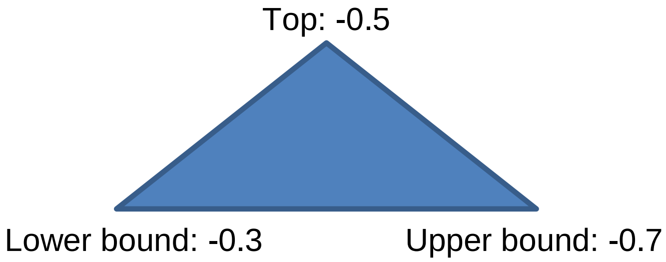
And for the rail price elasticity of rail passenger-km from the same Dutch study this would be:



6. CONCLUSIONS

In the past, price elasticities have been used in transport analysis to check the plausibility of the responses to price changes in a model (as a check on model quality) and also to develop simple elasticity-based models for situations where no model was available (to do initial quick scan analysis). Now another reason for determining elasticities has arisen: price elasticities are needed to determine Ramsey-Boiteux prices for market-can-bear tests for the markup that rail infrastructure providers levy on rail operators for the use of their infrastructure.

In this context, elasticities can be determined in three different ways:

- Existing transport models – cost efficient, but not always available;
- Develop new transport models – can be tailored to the research question, but can be expensive;
- Transfer elasticities based on a review of the literature – here one has to be very careful.

Results from market-can-bear studies in The Netherlands and Austria were presented, as well as some key results from a literature review. The Dutch elasticities come from the application of existing transport models and are close to the relevant mid-points from the literature. The Austrian elasticities come from new models estimated on new SP data and RP data. They generally show smaller price sensitivities than the Dutch values, but unlike the Dutch outcomes, the Austrian elasticities do not include the effects of changes in distribution. Moreover, in The Netherlands there are often more alternatives (bicycles for passenger trips and inland waterways for freight transport) competing with rail than in Austria.

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