# Estimation of a mode choice model for long distance travel in Portugal

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## Abstract

This paper describes the calibration of the mode choice model in the Portuguese National Transport Model (PoNTraM). PoNTraM represents the supply and demand of medium and long distance travel within Portugal. The mode choice model for conventional modes is estimated on a large scale long distance travel survey. The model was extended with High Speed rail parameters calibrated to exogenous elasticity targets. HSR is a significant planning alternative in Portugal and a typical project that fits into the scope of a national model long distance travel.

The results provide detailed elasticities and cross elasticities for long distance travel in Portugal for car, train and bus travel. This contributes to the empirical literature in long distance travel survey. The demand elasticities from the calibrated model is validated with elasticities from empirical studies in the literature. We show that the elasticities and cross elasticities for the conventional modes (car, rail and bus) are comparable to the elasticities found in literature.

KEYWORDS: Demand models, long distance travel, high speed rail, elasticities, Portugal

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# 1 Introduction

The scope of the Portuguese National Transport Model (PoNTraM) is to evaluate transport measures that have a regional or national impact, such as the construction of a new national airport or a high speed rail link (FEUP, 2007a; Abrantes and Pimentel, 2007). It considers five modes relevant to long distance travel: car, coach, rail, taxi and high-speed rail. An important aspect in the projections of PoNTraM is the competition between conventional transport modes (car, train and bus) and high-speed rail (HSR) since the construction of a new HSR line is a major current planning issue in Portugal. Scenarios exist for a line between Lisbon and Porto, and additional plans for extensions between Lisbon - Madrid or Porto – Vigo.

The validation of a modelling system such as PoNTraM is critical to guarantee the reliability of the modelled policy effects. Application of the model gives insight into the expected effects of planning alternatives, and these alternatives can be very distinct across different design dimensions, e.g. new road or rail infrastructures, increase in road capacity, pricing strategies for public transport or car, time tables for rail and bus services. This requires the model to provide valid responses to distinctive transport measures. Currently, the Instituto da Mobilidade e dos Transportes Terrestres (IMTT) has initiated the 2nd development phase of PoNTraM, with the purpose to improve the current model. These improvements are focused on updating the supply data in the model (highway and public transport networks) and a thorough revision of the demand model, including the calibration of time and cost parameters.

In a recent analysis the behavioural responses of the current model were evaluated by comparing the implicit elasticities from PoNTraM with international literature (De Bok et al., 2009). This analysis identified some areas for improvement. First of all the unobserved differences between modes need to be better represented. This improvement will be made by calibrating mode choice utilities functions that include mode specific constants (MSC) for the transport modes. The coefficients for conventional modes can be estimated on revealed preference (RP) data from the IMMLD.

Secondly, the difference in preference between different types of travelers need to be made explicit by segmenting the demand model to main travel purposes. For each travel purpose, separate mode choice parameters will be estimated. Travellers will be segmented by trip purpose: commuters, business and other.

Third, the high speed rail alternative need to be modeled with distinctive parameters. The calibration of these parameters is not straightforward in absence of a survey from which high speed rail parameters can be estimated. Instead a more rudimentary calibration approach has been applied in which we identified the MSC for HSR reflecting a target elasticity best. HSR has been implemented successfully in many EU countries, such as Thalys (F), ICE (D) and AVE (S), leading to considerable market shares for HSR on the respective corridors (Vickerman, 1997; Román et al., 2007). The experiences in these existing high-speed rail corridors have been used to calibrate the demand responses within PoNTraM.

The paper first discusses the literature on empirical studies for long distance travel, that are used in the calibration and validation of the mode choice model. Next the calibration of the model is discussed. In a first step, we estimate the utility parameters for the mode choice model based on an extensive survey for long distance travel in Portugal. The optimal model specification of the mode choice model was identified in an iterative process, testing different model specifications for the utility funtions by travel purpose. This model specification was implemented in PoNTraM to derive elasticities and calibrate the mode specific constant for high speed rail. These are calibrated by optimizing the implicit demand elasticities to a fixed target, based on the review of the empirical literature.

# 2 Empirical studies for long distance travel models

In this section we will discuss a number of empirical studies on long distance travel, to collect representative elasticity and cross elasticity values for long distance travel. These values will be compared to the behavioural responses in the current version of PoNTraM. The review include studies that report elasticities and cross elasticities for long distance travel, and in many different European countries. Table 1 gives an overview of the elasticity values that were found in the empirical studies, and specifies briefly the context from which these elasticities were derived. The last four sources report elasticities for high speed rail in particular (RAVE, 2003; Román et al., 2007; Cabanne, 2003 and Atkins, 2002). The values from these sources will be used for benchmarking the elasticities in PoNTraM.

The implicit elasticities that are reported in the literature are context dependent: they are influenced by regional differences in socio-economic context (value of time, level of fuel prices, GDP per capita), quality of different transport modes, or market segmentation (travel purpose, distance classes, transport modes). The research context of different studies varies so the reported elasticities cannot always be compared against each other. Important dimensions that affect elasticity values are the distance range to which they apply, and the level of competition between modes. In the interpretation of elasticities it is important to realise that elasticities are usually estimated (and therefore only valid) for small changes of a system. If the system changes more significantly over time, the elasticity value is likely to change too. For instance, car fuel elasticities can increase under influence of increased fuel prices or decrease under increased fuel efficiency of cars (for detailed discussions of different types of elasticity and their variation with respect to different explanatory variables see Dargay and Hanly (2002), Balcombe et al. (2004) or Wardman (2004)).

The elasticity to time or costs can also be influenced by changes in values of time. If the value of time increases, time is transferred into more cost units in the generalised cost, decreasing the relative importance of costs in this function, and this leads to a decrease of cost elasticity. If studies are analysing effects for a planning horizon that lies further in time (e.g. twenty years ahead) it is likely the value of times and elasticities will have changed with economic growth: DfT (2005) reports different elasticity values in the UK National Model under high or low economic growth scenarios (for an up to date analysis of the change in values of time over time and as a function of income please see Abrantes et al. (2009)).

The DATELINE project provides relevant information that reveals structural differences in contexts for the transport market in different European countries (Gomes and Santos, 2004). This study shows significance structural differences in modal shares for long distance travel in different EU countries. In the UK, 61% of surveyed individuals use car for long distance travel compared to 77 % in Portugal

**Table 1: Overview of reported elasticity values for long distance travel**

| Study | Description | Reported (cross) elasticity values | | | | |
|---|---|---|---|---|---|---|
| DfT (2005) | UK National Model, year 2001 (elasticities are presented for high and low demand scenario for 2010 and for distance travelled or number of trips) | | For UK: | | | |
| | | | Car | Rail | Bus | |
| | | Fuel cost | -0.22 to -0.17 (kms) | +0.12 (trips) | | |
| | | Rail fare | +0.02 (trips) | -0.62 to -0.48 (kms) | | |
| | | Bus fare | | | -0.68 to -0.57 (kms) | |
| | | | For London and the South-East: | | | |
| | | | Rail short d | Rail med. d | Rail long d | |
| | | Rail fare | -0.28 (kms) | -0.59 (kms) | -0.88 (kms) | |
| Rohr *et al.* (2008) | UK National Travel Survey, year 2004, d>80.5 km. We report the tour elasticities from the combined frequency/mode choice model (FM) | | Car | Rail | Bus | Air |
| | | *Commuting* | | | | |
| | | Car time | -1.06 | 0.015 | 0.010 | 0.002 |
| | | Car cost | -1.207 | 0.014 | 0.010 | 0.002 |
| | | *Business* | | | | |
| | | Car time | -0.426 | 0.023 | 0.023 | 0.029 |
| | | Car cost | -1.085 | 0.076 | 0.073 | 0.054 |
| | | *Other* | | | | |
| | | Car time | -0.358 | 0.198 | 0.182 | 0.310 |
| | | Car cost | -1.402 | 0.731 | 0.687 | 0.657 |
| MVA (1985) | Long Distance Travel Study, The Netherlands, year: ´82-´83, d>40km. Trip elasticities are presented. | | Rail | Car | | |
| | | *Commuting* | | | | |
| | | Rail fare: | -0.26 | +0.14 | | |
| | | IVT train: | -0.29 | +0.16 | | |
| | | *Family visit* | | | | |
| | | Rail fare: | -0.52 or -0.62 | Range +0.06 to +0.16 | | |
| | | IVT train: | -0.69 or -0.79 | | | |
| | | *Business travel* | | | | |
| | | IVT train: | -1.74 | +0.31 | | |
| De Jong and Gunn (2001) | Italian National model for long distance travel (d>30 km). Elasticities are presented in an article for a cross European comparison of elasticities (long term trip elasticities are presented) | | Car | Public transport | | |
| | | *Commuting* | | | | |
| | | Car fuel price | -0.55 | 0.22 | | |
| | | Car time | -0.56 | 0.23 | | |
| | | *Other* | | | | |
| | | Car fuel price | -0.16 | 0.50 | | |
| | | Car time | -0.09 | 0.30 | | |
| Mandel *et al.* (1997) | Survey of German long distance passenger traffic (d>50 km) observed for the year 1979/1980. Trip elasticities from the linear model are presented. | | Demand elasticity | | | |
| | | Car cost | -0.04 | | | |
| | | Car time | -0.08 | | | |
| | | Rail cost | -0.13 | | | |
| | | Rail time | -0.63 | | | |
| | | Rail frequency | 0.19 | | | |
| | | Air cost | -0.99 | | | |
| | | Air time | -0.75 | | | |
| | | Air frequency | 0.12 | | | |
| RAVE (2003) | Survey among rail travellers in Portugal | | High Speed Rail demand | | | |
| | | HSR Price | -0.31 to -0.61 | | | |
| | | HSR Time | -0.12 to -0.44 | | | |
| Roman *et al.* (2007) | RP data (Madrid-Zaragoza) and RP/SP data (Madrid-Barcelona) for high speed train. Trip elasticities are presented. | | High Speed Rail demand Madrid-Zaragoza corridor | | | |
| | | HSR cost | -0.55 | | | |
| | | HSR time | -0.59 | | | |
| | | HSR access time | -0.36 | | | |
| | | HSR headway | -0.05 | | | |
| | | Car cost | +0.12 | | | |
| | | Car time | +0.04 | | | |

**Table 1 (continued): Overview of reported elasticity values for long distance travel**

<table>
<tr><td>Study</td><td>Description</td><td colspan="4">Reported (cross) elasticity values</td></tr>
<tr><td rowspan="6">Cabanne (2003)</td><td rowspan="6">Demand data from period ´80 to ´00 in France, d>40 km. Trip elasticities are presented.</td><td></td><td>Car</td><td>Rail</td><td>Air</td></tr>
<tr><td>Car price</td><td>-0.60</td><td></td><td></td></tr>
<tr><td>Car accessibility</td><td>+0.74</td><td></td><td></td></tr>
<tr><td>Rail fare</td><td></td><td>-2.00</td><td>+0.99</td></tr>
<tr><td>Rail accessibility</td><td></td><td>+0.45</td><td>-0.16</td></tr>
<tr><td>Air fare</td><td></td><td></td><td>-0.77</td></tr>
<tr><td rowspan="9">Atkins (2002)</td><td rowspan="9">RP and SP survey among rail travellers on two corridors in UK, year: ´01-´02, d>48km). Trip elasticities are presented.</td><td rowspan="2"></td><td colspan="3">(cross) Elasticities Rail demand</td></tr>
<tr><td colspan="2">Business</td><td>Leisure</td></tr>
<tr><td>Rail cost</td><td colspan="2">-0.48 or -0.62</td><td>-0.86 or -0.72</td></tr>
<tr><td>Rail IVT</td><td colspan="2">-0.92 or -1.31</td><td>-0.78 or -0.88</td></tr>
<tr><td>Car cost</td><td colspan="2">0.20 or 0.28</td><td>0.33 or 0.40</td></tr>
<tr><td>Car time</td><td colspan="2">0.73 or 0.95</td><td>0.56 or 0.62</td></tr>
<tr><td>Air cost</td><td colspan="2">0.26 or 0.22</td><td>0.76 or 0.64</td></tr>
<tr><td>Air time</td><td colspan="2">0.12 or 0.12</td><td>0.13 or 0.11</td></tr>
<tr><td>Rail Headway</td><td colspan="2">-0.15 or -0.06</td><td>-0.18 or -0.25</td></tr>
</table>

(Gomes and Santos, 2004). This is important to realise, because the induced elasticities from logit models are sensitive to mode share. The cross elasticities of dominant modes are lower compared to inferior modes. For example the cross elasticities in the National Model in the UK are influenced heavily by differences in market shares: the cross elasticity of car trips to rail fares is +0.02, while the cross elasticity of rail trips to car costs is +0.12 (DfT, 2005). So, in our comparison we need to consider the relative high share of car use in Portugal, leading to relative higher cross elasticity between car prices and rail travel. Thus, for example, this cross elasticity in PoNTraM should be higher than the value of 0.12 found in the UK (DfT, 2005).

Elasticities are also sensitive to distance classes. This is shown for instance in the implicit passenger miles elasticities with respect to rail fares that were derived from the UK National model. These elasticities vary with distance: from -0.28 for short distances to -0.88 for long distances (DfT, 2005). In Atkins (2003) also more competition was found (higher cross elasticities) between car and rail on longer distances. This is a reflection of the fact that rail’s market share increase with distance as does the value of time for car travel reflecting the increased discomfort of long car journeys (Abrantes et al., 2009). In the Portuguese National Model, long distance travel is defined as all trips greater than 50 km. The elasticities reported in the studies in this overview apply different definitions. The UK national model defines long distance travel for trip of at least 100 km as does the EU project DATELINE (DATELINE Consortium, 2003; Gomes and Santos, 2004). The former long distance travel model for The Netherlands uses a 40 km threshold (MVA, 1985) as does Cabanne (2003) in a study for France. This highlights the fact that the elasticities cannot be compared one on one but are merely indicative, used to evaluate the size of an impact roughly.

High speed trains compete with all modes available on long distance travel and take market shares from each mode. But considering the current small market share of rail use in Portugal (4%; compared to 10 % in The Netherlands and 11 % in the United Kingdom) a decrease in such a small market will lead to a change in elasticity values for this relatively small mode. We test, for the current model, if the implicit cross elasticities for train travellers decrease after introduction of the high speed trains.

The empirical studies that segmented traveller confirmed distinctive price- and time elasticities across different purposes. Atkins (2003) and MVA (1985) found relatively higher time elasticities and lower cost elasticities for rail amongst business travellers compared to leisure travellers. Rohr et al. (2008) found different cost and time elasticities by travel purpose: compared to commuters, business and other travellers have low cost elasticities and high time elasticities (not mode specific). Most sources confirm relative high time elasticities compared to cost elasticities for commuters (De Jong and Gunn, 2001; Rohr et al. (2008)) although this was not found in MVA (1985) for rail time and costs.

# 3 Portuguese national model for long distance travel

## 3.1 Scope and application of the model

The Portuguese National Transport Model (PoNTraM) represents the supply and demand of medium and long distance travel within the country. After initial development between 2006 and 2007 (FEUP, 2007a, Abrantes and Pimentel, 2007) this paper discussed part of the follow up research work that has got under way to significantly upgrade the model. The purpose of PoNTraM is to evaluate transport measures that have a regional or national impact. The model can be used as a decision support tool, for instance to prioritise network development investments, which is increasingly important with the current pressure on available funds. The results can be used to forecast revenues, support vehicle planning, or to analyse effects on competing modes (for instance reduction of congestion on highways). In recent case studies the model was first used to generate passenger forecasts for different planning alternatives for a new High Speed Rail between Lisbon and Porto (Costa et al., 2009). In the second case study the model was used to optimise coach timetables, and show its secondary effects on the competing modes. The results showed how optimisation scenarios can help to increase the market share of the coach, and even reduce highway traffic on some parts of the road network. This can help in improving the revenue for coach companies, optimising their operational costs and as a side effect reducing congestion on the car network (Costa et al., 2009).

## 3.2 Structure of the model

PoNTraM represents the supply and demand of medium and long distance travel within the country. In this context, medium and long distance travel include all trips of a distance greater than 50 kilometer. The model represents the four modes relevant to long distance travel: car, coach, rail and high-speed rail. In addition to these main modes, taxi, metro and suburban rail services are included to represent the access modes for bus and rail. In particular for long distance travel these auxiliary modes of transport are necessary to represent well the accessibility to infrastructure networks from any location in the country.

The demand side of the national transport model consists of the choices that long distance travellers make in travelling from their origin to a specific destination. These choices include a destination choice, a mode choice, a route choice and a time of day choice. The model follows the conventional sequential four-step model: trip generation, trip distribution, mode choice and route assignment. The trip generation and trip distribution steps are carried out simultaneously on the basis of the trip matrix obtained from the household survey (FEUP, 2007b). Mode choice is the third step and is the crucial element that calculates the market shares of transport modes accounting for the preferences of travellers.

The model is implemented using the transport analysis package EMME. The mode choice model is run iteratively with the network assignment until convergence to reflect variations in road travel time (affecting coach and car travel) following from changes in mode choice. By doing so, travelers base their choices on the representative travel times taking into account congestion levels.

## 3.3 Mode choice model

The mode choice model includes four main modes for long distance travel: car, coach, rail, and high-speed rail. Taxi, metro and suburban rail services are included to represent the access modes for bus and rail. The mode choice model follows a multinomial logit (MNL) formulation, in which the choice between transport modes is organized at a single level.

The MNL mode choice model determines the choice probability by OD pair between bus, conventional rail, high speed rail (new mode) and car (for non-captive users). The model that was initially developed (FEUP, 2007a) distinguished two types of travel segments: captive and non-captive travelers. The updated mode choice model however, will be further segmented by the main travel purposes: commuting business travel and other travel. Section 4 will discuss this issue further. In the MNL model the probability of choosing a mode, e.g. car, between a specific origin *i* and destination *j* is given by:

$$P_{car;ij} = \frac{\exp(V_{car;ij})}{\exp(V_{car;ij}) + \exp(V_{bus;ij}) + \exp(V_{train;ij}) + \exp(V_{HSR;ij})} \tag{1}$$

where:

$V_{car;ij}$ represents the utility or generalized cost for the car mode, on the connection from *i* to *j*.

The PoNTraM model has a dedicated setup that includes the transport infrastructure for a planned high speed rail network between Lisbon and Porto and other metropolitan areas on this corridor. The base set-up that includes the current infrastructure networks in which no HSR alternative is available.

The access mode for coach travel is assumed to be taxi to the nearest coach, metro or suburban railway station and then rail to the nearest coach station if necessary. For rail and high speed rail travel (HSR) the access mode is assumed to be taxi to the nearest metro, suburban or inter-city rail station and then suburban rail or metro to the nearest inter-city rail station if necessary.

# 4 Estimation conventional modes

## 4.1 Data

The main source for the calibration of PoNTraM is the household long distance travel survey (IMMLD), carried out in Portugal in 1999 (Ine, 2001). This large scale survey contains observed long distance travel behaviour in Portugal. It is used to estimate the mode choice model. The level of service derived from an historic road an public transport network implemented in PoNTraM are linked to the IMMLD. For each observation we linked the time and costs attributes for all modes on the observed origin destination pair. Table 2 gives an overview of the observed choices in the estimation set that was constructed from the IMMLD.

**Table 2: Observed mode choices by travel purpose in the IMMLD.**
**Source: INE, 2001 and computations by authors**

| | Observed mode choices: | | | |
|---|---|---|---|---|
| | Car | Rail | Bus | All |
| *Commuting:* | | | | |
| captives | 0 | 51 | 99 | 150 |
| non-captives | 4084 | 709 | 233 | 5026 |
| total | 4084 | 760 | 332 | 5176 |
| *Business:* | | | | |
| captives | 0 | 42 | 50 | 92 |
| non-captives | 3041 | 45 | 68 | 3154 |
| total | 3041 | 87 | 118 | 3246 |
| *Other:* | | | | |
| captives | 0 | 490 | 1314 | 1804 |
| non-captives | 9810 | 590 | 1195 | 11595 |
| total | 9810 | 1080 | 2509 | 13399 |

## 4.2 Tested utility specifications

The original PoNTraM model only included a time and cost parameter for captive and non-captive travelers that were calibrated to an aggregate mode share and exogenous value of time (Abrantes and Pimentel, 2007a). It did not include mode specific constants. The utility functions for the updated mode choice models are estimated on the IMMLD using BIOGEME (Bierlaire, 2009). The initial specification was based on the previous mode choice mdel in PoNTraM with only a parameter for time and costs. To identify the optimal utility specification a series of model were estimated to test the influence of each modification in the specification gradually. In successive series of model estimations we tested the added value of mode specific constants (MSC’s), application of generalized time with exogenous value-of-time, segmentation by travel purpose, time and cost parameters for captives and non-captives. This paper discusses the most relevant model specification where we tested additional time and cost parameters for captive travelers and compare linear and logarithmic cost models.

Model 7 uses separate coefficients for time and costs (as in the original specifications) and is segmented to travel purpose. It has MSC´s for car and bus and a coefficient for access time. The utility functions for each mode are:

$$V_{car;ij} = MSC_{car} + \beta_{\cos t} \cdot (c_{fuel;ij} + c_{toll;ij}) \\ + \beta_{time} \cdot t_{car;ij} \tag{2}$$

$$V_{train;ij} = \beta_{\cos t} \cdot (c_{train;ij} + c_{accesstrain;ij}) \\ + \beta_{time} \cdot (t_{IVTtrain;ij} + t_{waittrain;ij}) + \beta_{acctime} \cdot t_{accesstrain;ij} \tag{3}$$

$$V_{bus;ij} = MSC_{bus} + \beta_{\cos t} \cdot (c_{bus;ij} + c_{busaccess;ij}) \\ + \beta_{time} \cdot (t_{IVTbus;ij} + t_{waitbus;ij}) + \beta_{acctime} \cdot t_{busaccess;ij} \tag{4}$$

The value of time for captive is very likely to be different compared to non-captives. This is tested by inclusion of additive cost- and time parameters for captive travellers in model 10. The train utility function for captives becomes:

$$V_{train;ij} = (\beta_{\cos t} + \beta_{c;\cos t} \cdot X_c) \cdot (c_{train;ij} + c_{accesstrain;ij}) \\ + (\beta_{time} + \beta_{c;\cos t} \cdot X_c) \cdot (t_{IVTtrain;ij} + t_{waittrain;ij}) \\ + \beta_{acctime} \cdot t_{accesstrain;ij} \tag{5}$$

with:

$X_c$ as a dummy that has value 1.0 for captive travelers and 0 for non-captives.

Model 8 and 14 apply logarithmic costs, instead of linear costs as in model 7 and 10. This model specification represents better the increasing value-of-times with long distance travel (Fox et al., 2009). The utility function for car in the logarithmic cost model becomes:

$$V_{car;ij} = ASC_{car} + \beta_{\cos t} \cdot \log(1 + c_{fuel;ij} + c_{toll;ij}) + \beta_{time} \cdot t_{car;ij} \tag{6}$$

### 4.3 Results

The estimation results are presented in Table 3. The estimated coefficients and t-statistic is presented for each model as well as the general descriptives of the model. The values of time (VoT) in the table, are computed from the estimated time and cost parameters. Based on the plausibility of values of time and elasticities, and optimal segmentation of demand, the models that were implemented in PoNTraM are 7a for commuting, 10b for business travelers and 10c for other travel purposes. The selection of these models is elaborated in the discussion of the results.

All models have time and cost coefficients that are plausible (negative sign) and significant. An exception is the composite cost parameter for captives in the commuters model 10a in which has a positive and thus unrealistic value (-0.120 + 0.336 = +0.216).

**Table 3: Estimation results for linear cost models (series 7 and 10) and logarithmic cost models (series 8 and 14)**

| | | Commuting | | | | Business travel | | | | Other travel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7a | 10a | 8a | 14a | 7b | 10b | 8b | 14b | 7c | 10c | 8c | 14c |
| | | commuters | ommuters | comuters | ommuters | business | business | business | business | other | other | other | other |
| No of param | | 5 | 7 | 5 | 7 | 5 | 7 | 5 | 6 | 5 | 7 | 5 | 7 |
| No of obs | | 5176 | 5176 | 5176 | 5176 | 3246 | 3246 | 3246 | 3246 | 13370 | 13370 | 13370 | 13370 |
| Null LLH | | -4303.8 | -4303.8 | -4303.8 | -4303.8 | -3016.8 | -3016.8 | -3016.8 | -3016.8 | -11506.8 | -11506.8 | -11506.8 | -11506.8 |
| Final LLL | | -2206.7 | -2185.5 | -2136.3 | -2109.7 | -532.2 | -530.1 | -535.3 | -534.9 | -6041.5 | -6033.5 | -5959.6 | -5968.1 |
| Adj Rho2 | | 0.486 | 0.491 | 0.502 | 0.508 | 0.822 | 0.822 | 0.821 | 0.821 | 0.475 | 0.475 | 0.482 | 0.481 |
| | | | | | | | | | | | | | |
| MSC car | | 0.41 | 0.392 | 0.212 | 0.16 | 3.49 | 3.6 | 3.3 | 3.38 | 1.91 | 1.84 | 1.55 | 1.44 |
| | | 4.85 | 4.62 | 2.36 | 1.77 | 17.1 | 15.51 | 15.08 | 13.82 | 33.35 | 30.23 | 27.12 | 23.46 |
| MSC coach | | -0.751 | -0.826 | -0.706 | -0.808 | 0.387 | 0.519 | 0.455 | 0.555 | 0.638 | 0.593 | 0.665 | 0.593 |
| | | -10.08 | -11.07 | -9.38 | -10.65 | 2.38 | 2.84 | 2.73 | 3.01 | 13.35 | 11.7 | 14.17 | 11.79 |
| MSC rail | (ref) | - | - | - | - | - | - | - | - | - | - | - | - |
| COST | | -0.118 | -0.12 | | | -0.0746 | -0.0746 | | | -0.0814 | -0.0841 | | |
| | | -19.88 | -19.91 | | | -10.47 | -9.61 | | | -23.71 | -23.71 | | |
| LOGCOST | | | | -1.74 | -1.58 | | | -1.47 | -1.31 | | | -1.37 | -1.22 |
| | | | | -25.78 | -25.63 | | | -9.02 | -8.35 | | | -27.54 | -25.96 |
| TIME | | -0.0146 | -0.0147 | -0.012 | -0.0118 | -0.0157 | -0.016 | -0.0125 | -0.0112 | -0.00554 | -0.00665 | -0.00628 | -0.00738 |
| | | -8.63 | -8.61 | -7.6 | -7.45 | -5.11 | -4.4 | -4.61 | -4.04 | -7.93 | -8.24 | -9.2 | -9.48 |
| ACESS_TIME | | -0.0636 | -0.0628 | -0.0609 | -0.0599 | -0.0323 | -0.0286 | -0.0311 | -0.0289 | -0.0121 | -0.0122 | -0.0143 | -0.0152 |
| | | -9.26 | -9.29 | -8.74 | -8.7 | -2.63 | -2.39 | -2.58 | -2.34 | -6.26 | -6.28 | -7.88 | -8.27 |
| COST CAPTIVES | | | 0.336 | | | | -0.0981 | | | | 0.0293 | | |
| | | | 5.19 | | | | -1.9 | | | | 2.69 | | |
| LOGCOSTCAPTIVES | | | | | 5.01 | | | | -1.04 | | | | 0.363 |
| | | | | | 5.71 | | | | -1.69 | | | | 2.13 |
| TIMECAP | | | -0.0364 | | -0.0484 | | 0.00865 | | 0 | | 0.00449 | | 0.00481 |
| | | | -1.83 | | -2.59 | | 1.1 | | 0 | | 2.85 | | 3.04 |
| | | | | | | | | | | | | | |
| VoT | euro/h | 7.423729 | 7.35 | | | 12.62735 | 12.86863 | | | 4.083538 | 4.744352 | | |
| VoT captives | euro/h | | -14.19444 | | | | 2.553561 | | | | 2.364964 | | |

The mode specific constants for car and bus are all significant and plausible. Compared to the train (reference mode), car alternatives have an intrinsic higher utility which is the result of the higher privacy, comfort and flexibility of private transport. Bus alternatives are valued a but less over train by commuters, but for other travelers bus has a higher utility over rail. The same goes for business travelers but this travelers segment has few captive travelers: less than 3 % of business travelers are captives (see Table 2). Thus, the coefficient is only just significant.

The values of time in the linear models seem to have plausible values and consistent across purposes. For commuting a value of time of 7 €/hour was found, 12 €/hour for business travelers and 4 €/hour for other travelers. The value of time of captive travelers for business and other travel purposes is lower compared to the non-captives, which is a plausible result. The value of time for captives in the commuting model is not plausible, which follows from the unrealistic cost parameter for these captives that was discussed before. There for model 10a was rejected for the commuting model. Model 8 and 14 have logarithmic costs, so the value-of-time increases with travel distance (travel costs). These value of times are not presented in the table but graphically in Figure 1. The figure illustrates the difference between the constant value-of-time in model 7 and the cost dependent value-of-time calculated from the estimated time and logcost parameters in model 8.

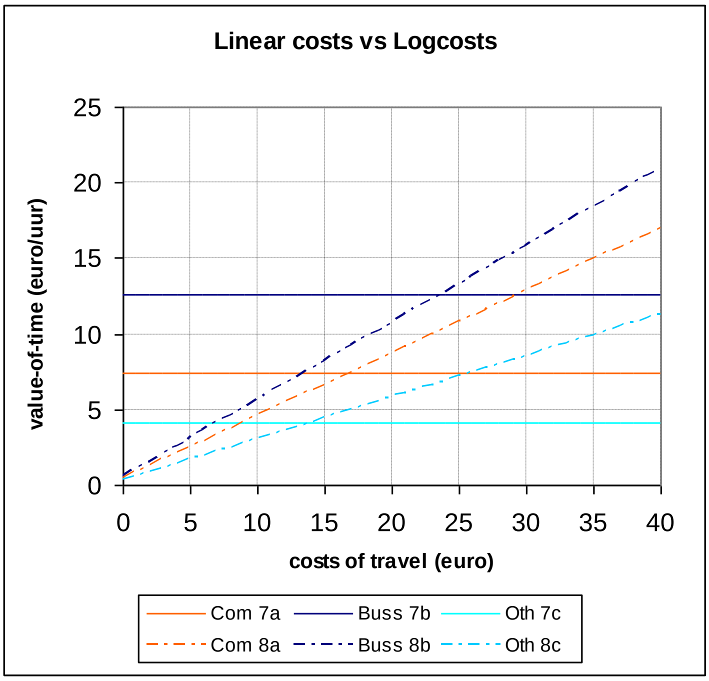

**Figure 1: value of time in linear model 7 and logarithmic model 8**

The models with logarithmic costs prove to have significant and plausible coefficients, and plausible value of time. In terms of model fit, the log cost model seems to explain the observations in the estimation set a little bit better compared to the linear cost model, judging the adjusted r squared of the models.

However, in the implementation the logarithmic models proved to be less elastic compared to the linear model. Considering the elasticities from the literature, the linear model has more representative elasticities and was therefore selected for the model implementation.

## 4.4 Elasticities

The chosen model specifications that are implemented are 7a for commuting, 10b for business travelers and 10c for other travel purposes (see section 4.3). The behaviour of the estimated model is validated to the elasticities and cross elasticities between the different modes. These demand elasticities describe the aggregate change in demand for a given mode subject to a certain change in its cost or travel attributes. Cross elasticities measure the change in demand for a given mode subject to changes in the attributes of competing modes. The elasticities are calculated from scenarios in which one of the utility attributes (time or costs) of a specific transport mode is increased by 10%, with constant networks, tour generation, and no changes to the utility functions for the other modes. The elasticity $e_m$ of demand $T_m$ for mode *m* subject to changes in attribute $x_n$ for mode *n*, is calculated as:

$$e_m = \frac{\Delta T_m^1}{T_m^0} \Big/ \frac{\Delta x_n^1}{x_n^0} \tag{7}$$

where $x_n^0$ is the variable value in the reference scenario, and $x_n^1$ the value in the elasticity scenario. In our scenario's the ratio $\Delta x_n^1 / x_n^0$ is always equal to 10 %. For elasticities m = n and for cross elasticities m ≠ n.

In the analysis we focus on the impact of changes in travel time or costs on the number of trips by transport mode, since we are mostly interested in the effects on mode choice. This gives us the demand elasticity for the specific transport mode, and cross elasticities with the competing modes. The elasticities are calculated for the time and cost attributes for each of the estimated transport modes (car, bus, train). Table 4 presents the elasticities and cross elasticities from the elasticity scenarios.

The elasticity for car cost (-0.135 for total demand) is rather low compared to the elasticities reported on the survey in the UK (-1.21;-1.09 and -1.40), see Table 1, although the order of most elastic modes is similar: other is most cost elastic, followed by commuting and business. The Italian National model reports elasticities in a comparable range to the estimations for Portugal (-0.55 for commuting and -0.16 for other) while Mandel et al. found much lower cost elasticities for Germany. In general the car cost elasticities are valued as plausible. The cross elasticities with bus travel are relatively high in Portugal (0.48), resulting from the large market share for bus compared to the countries where the other empirical elasticities were derived

Car demand is less elastic to car time than to car costs (time elasticity total demand is -0.083), also found in most sources in literature (De Jong and Gunn, 2001; Rohr et al, 2009). As far as a comparison can be made, the mode specific elasticities correspond to literature differently. Some time elasticities match well, such as the time elasticity for other reported in De Jong and Gunn (2001), while they are generally low compared to those found by Rohr et al. (2009).

The elasticities for rail travel time (-0.456 for commuting; -0.567 for business and -0.356 for other) correspond well to the results reported in the UK and Netherlands. The Long Distance travel study in The Netherlands reported elasticities of -0.29 for commuters and -1.74 for business travel (MVA, 1985). In the UK, rail travel time elasticities are reported varying between -0.78, for leisure, and -1.31, for business travel (DfT, 2005;). Differences between the studies can be attributed to different segmentations by travel purpose, or other definitions of long distance travel. The cross elasticities of car use to rail travel time are low (0.031) and comparable to cross elasticities found in the literature: 0.02 in the UK National Model, although MVA (1985) reports cross elasticities varying between 0.06 to 0.31.

**Table 4: Elasticities from estimated mode choice model**

| | Car | Bus | Rail |
|---|---|---|---|
| CAR COST (fuel+toll) | | | |
| commuting | **-0.120** | 0.455 | 0.269 |
| business | **-0.068** | 0.304 | 0.310 |
| other | **-0.278** | 0.647 | 0.452 |
| total demand | **-0.135** | 0.483 | 0.297 |
| CAR TRAVEL TIME | | | |
| commuting | **-0.084** | 0.285 | 0.228 |
| business | **-0.062** | 0.269 | 0.303 |
| other | **-0.110** | 0.256 | 0.182 |
| total demand | **-0.083** | 0.273 | 0.229 |
| Bus TRAVEL TIME | | | |
| commuting | 0.052 | **-0.514** | 0.251 |
| business | 0.042 | **-0.363** | 0.387 |
| other | 0.114 | **-0.363** | 0.205 |
| total demand | 0.060 | **-0.441** | 0.258 |
| Bus COST | | | |
| commuting | 0.022 | **-0.158** | 0.039 |
| business | 0.009 | **-0.140** | 0.297 |
| other | 0.060 | **-0.202** | 0.144 |
| total demand | 0.025 | **-0.168** | 0.078 |
| RAIL TRAVEL TIME | | | |
| commuting | 0.040 | 0.163 | **-0.456** |
| business | 0.015 | 0.087 | **-0.567** |
| other | 0.020 | 0.037 | **-0.356** |
| total demand | 0.031 | 0.111 | **-0.454** |
| RAIL COST | | | |
| commuting | 0.028 | 0.117 | **-0.325** |
| business | 0.008 | 0.172 | **-0.726** |
| other | 0.027 | 0.065 | **-0.544** |
| total demand | 0.024 | 0.112 | **-0.393** |

The elasticities for rail costs (-0.325 for commuting; -0.726 for business and -0.544 for other) are in a similar range compared to the elasticities in the UK and Netherlands. in the UK the magnitude of elasticities is the same but the order of rail cost elasticities varies between purposes: -0.48, for business travel, and -0.86, for leisure (DfT, 2005). The Long Distance Travel Study in The Netherlands reports elasticities between -0.26, for commuters, and -0.62, for leisure (MVA, 1985). The cross elasticity of car use to rail costs are minimal (0.028 for commuters) and low compared to the results found in The Netherlands but no further sources exist. The low cross elasticity from rail costs to car use in Portugal follows from the relative small share of rail in Portugal (4% compared to 10 and 11 % in the Netherlands – Gomes and Santos, 2004).

# 5 Calibration HSR

The utility function for high speed rail has a similar structure to the utility functions of the other modes, and includes a mode specific constant. The utility function for high speed rail in model 7 is written as:

$$\begin{aligned} V_{HSR;ij} = {} & MSC_{HSR} + \beta_{\cos t} \cdot (c_{HSR;ij} + c_{HSRaccess;ij}) \\ & + \beta_{time} \cdot (t_{IVTHSR;ij} + t_{waitHSR;ij}) + \beta_{acctime} \cdot t_{HSRaccess;ij} \end{aligned} \tag{6}$$

The $MSC_{HSR}$ is calibrated for each travel purpose. It is calibrated by implementing different values for $MSC_{HSR}$ and calculating the demand elasticities for high speed rail price and cost. These time and cost elasticities are compared to elasticities for high speed rail from literature. The values from international literature were quite diverse but based on the sources in the literature review in section 2 the following plausible range for time and cost elasticities for high speed rail is assumed:

| | |
|---|---|
| Cost elasticity: | -0.5 to -0.9 |
| Time elasticity: | -0.8 to -1.3 |

The empirical literature did not specify elasticities by travel purpose, which will make the comparison between the purpose specific elasticities derived from PoNTraM less straightforward.

The initial MSC's for high speed rail were for each travel purpose chosen taken into account the absolute value of the MSC for car. Since it is assumed that HSR will be valued more comfortable to the conventional public transport modes, the MSC of high speed rail will be more comparable to car. From the initial MSC value other values were tested increasing or decreasing the MSC with a fixed amount.

For each MSC value three model runs are performed to calculate the time and cost elasticities following associated to that MSC: a reference scenario, HSR cost +10% scenario, and a HSR time +10% scenario. Running these three scenario's for each MSC value and deriving the elasticities is labour intensive, so the MSC's are calibrated with a limited precision.

Figure 2 visualises the time and cost elasticities in the different calibration scenarios. The HSR model in PoNTraM is less elastic compared to the elasticities from literature. Therefor the MSC's were chosen from the calibration scenarios that gave the most elastic model. Table 5 shows the MSC that are used for implementation.

**Table 5: calibrated MSC's for high speed rail**

| | MSC HSR | time elast | cost elast |
|---|---|---|---|
| Commuting | 0.2 | -0.384 | -0.139 |
| Business | 3.2 | -0.441 | -0.535 |
| Other | 1.4 | -0.153 | -0.231 |

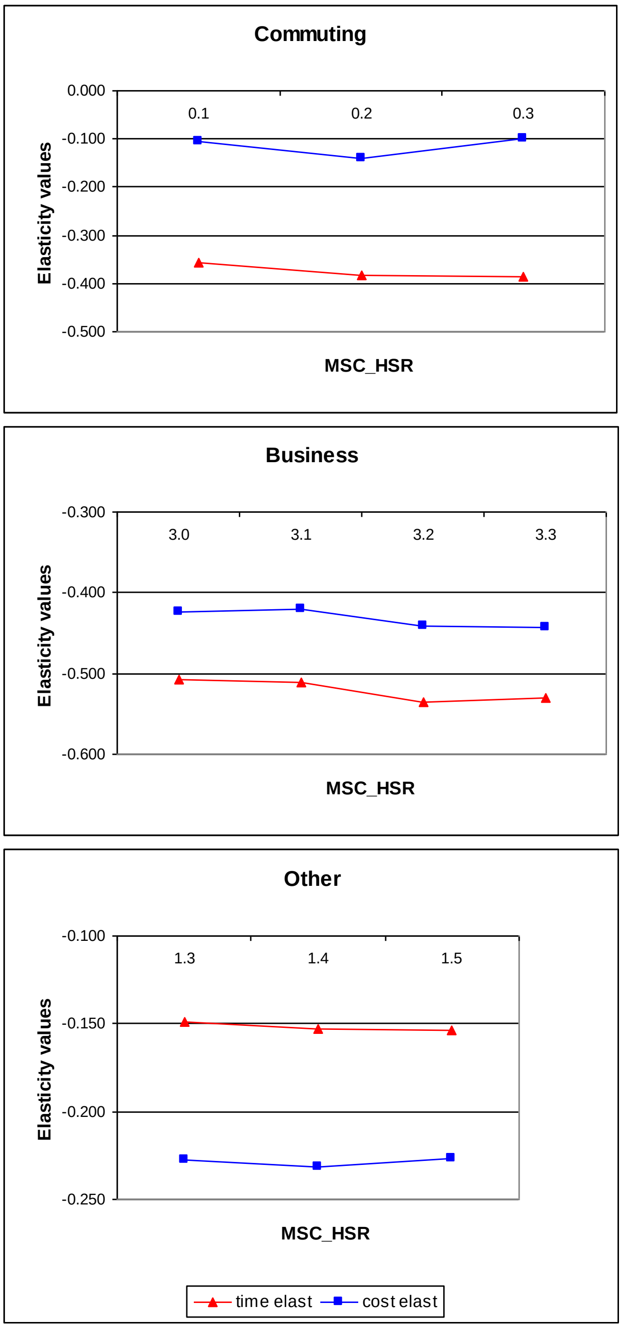

**Figure 2: Time- and cost elasticities for in the calibration scenario's**

# 6 Conclusions

This paper has discussed the calibration of the mode choice model in the Portuguese National Transport Model (PoNTraM). After initial development between 2006 and 2007 (FEUP, 2007a, Abrantes and Pimentel, 2007) the calibration of the mode choice model is part of a follow up research work that has got under way to significantly upgrade the model.

The mode choice model for conventional modes is estimated on a large scale long distance travel survey, taken in 2001. The estimation strategy has led to model specifications that provide plausible and significant MSC's and time and cost parameters. Thus the IMMLD (INE, 2001) proves to be a valuable source for deriving traveler preference for long distance travel in Portugal. The models that were estimated for commuting, business and other travel lead to value's of time that are representative and plausible for the purposes considered. This confirms that the segmentation of demand to main trip purposes indeed lead to a more representative demand model.

The empirical results include elasticities and cross elasticities for long distance travel in Portugal for car, train and bus travel, contributing to the empirical literature in long distance travel. The demand elasticities from the calibrated model are compared to elasticities from the other empirical studies in the literature, which are scarce for long distance travel. As far as elasticities between different contexts can be compared the elasticities and cross elasticities calculated for the conventional modes (car, rail and bus) in PoNTraM are in a plausible range and have a plausible pattern between purposes, looking at the values reported in the empirical literature.

The model was extended with separate utility parameters for high speed rail because this is a significant planning alternative in Portugal and a typical project that must be included in the scope of a national model long distance travel. In the absence of a survey from which high speed rail parameters can be estimated, a more rudimentary calibration approach has been applied in which the MSC for HSR was indentified that reflects best a target time and cost elasticities for high speed rail.

Given the pragmatic nature of this calibration approach, it can be a usefull effort to invest in the collection of a stated preference (SP) dataset with observed preferences for high speed rail in Portugal. A combined RP/SP estimation of traveller preferences will improve the validity of the competition between conventional and high speed rail in PoNTraM.

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