Valuation of Travel Time for International Long-Distance Travel

- Results from the Fehmarn Belt Stated Choice Experiment

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Abstract

The geographical scope of travel varies from short distances in urban areas to long distances across cities and countries. While urban travel has been widely analysed in the literature, travel over longer distances and particularly across countries, has received much less attention. While this may be justified due to the number of travellers it cannot be justified when looking at the mileage consumption and its resulting environmental impacts. In this paper, we investigate international long-distance travel preferences related to travel between Scandinavia and Central Europe with particular focus on the Fehmarn Belt fixed link between Germany and Denmark to be opened in 2021. To facilitate long-term demand forecasts for the future fixed link, stated preference data were collected in 2011. Based on these data a discrete choice model for long-distance travellers was developed in order to estimate the value of travel time savings (VTTS). The final model, which was formulated as a nested logit model and included Box-Cox transformed travel time and cost attributes, revealed several interesting findings. Firstly, we found damping effects in both cost and time - most strongly in cost. Secondly, we found significant interactions among travel cost and time, and journey characteristics, such as distance and duration. This had direct impact on the VTTS, which was shown to decrease with distance and duration. Thirdly, we found that air travel implies a higher average VTTS, which is to be expected but rarely supported by empirical evidence.

Keywords

Long-distance travel; discrete choice modeling; stated choice; value of travel time; Central Europe; Scandinavia.

1 Introduction

Transport geography may be defined as the investigation of transport systems and their spatial impact (Hoyle and Knowles, 1992). A common approach to the investigation of transport systems includes the valuation of non-market goods provided by the system, e.g. the valuation of travel time. The value of travel time savings (VTTS) is one of the most important figures when modelling travel demand (Mackie et al., 2001). It measures the willingness to pay for achieving a certain travel time reduction and constitutes travellers' fundamental trade-off between travel time and travel cost. Measurement of VTTS is crucial to any transport demand projection; in particular when analysing the impacts of new infrastructure that would fundamentally change travel times or would help overcome natural geographical barriers, and for appraisal of infrastructure improvements at the national level. Estimation of national-level VTTS has been standard in many countries, for example Fosgerau et al. (2007) and Börjesson and Eliasson (2012). The latter study shows that long-distance VTTS is higher than short-distance VTTS for an average national trip.[1] This is supported by Jara-Diaz (1998) who shows that given a time constraint, the VTTS should increase with the duration of the trip.

For long-distance travel, the amount of literature on travel time savings is limited. The main reason is that urban and short-distance travel adds up to the largest share of travel in our daily life and is more exposed to externalities such as congestion, local air pollution and accidents. Another reason for this may be that long-distance trips introduce additional challenges in the measurement of VTTS. More specifically, a consequence of dealing with long distances is that time and cost attributes become more correlated. An explanation for this is that long-distance trips tend to be relatively less affected by local trade-offs in the route choice resulting from congestion, bottlenecks, or geographical barriers. As a result, econometric estimation of VTTS becomes difficult and a common approach is to exogenously impose the VTTS by looking at relevant studies within the same travel context or national standards (Erhardt et al., 2007; Rich and Mabit, 2012). Beyond the econometric challenge of dealing with correlation, which in turn affects the identification of VTTS, another challenge is that VTTS may be correlated with other travel aspects (Rohr et al., 2010). Long-distance trips have a more heterogeneous mix with respect to travel distance and duration, which is likely to affect the VTTS. The representation of a large distance band in a model can be challenging as the functional form also has an impact on the estimated VTTS (Gaudry et al., 1989). The work by Gaudry et al. (1989) considers how the model specification influences VTTS and in particular how various non-linear functional forms will tend to affect VTTS. In more recent work by Daly (2010), it is emphasised that cost damping is generally found in applications. Here cost damping refers to the effect that the cost sensitivity in a model is reduced with increasing distance.

Another challenge is data availability. It is generally reported in the literature that there is a lack of systematic collection of appropriate data for studying long-distance travel (Kuhnimhof et al., 2009). The problem is that the majority of existing surveys (in many cases national or regional trip-diary surveys) include only very few of these trips. These surveys may also be less detailed in terms of information when trips are between countries and long-distance specific attributes such as trip duration and group size may not be available. Many of these data sources are revealed preference (RP) data and the correlation issues are predominant.

A solution as taken in the current paper is to step away from RP data and collect

[1] In their study, long-distance travel is defined as a trip above 100 km.

(hypothetical) stated choice data instead. An example of a recent stated choice study concerned with long-distance travel is presented by De Lapparent et al. (2009). Their study focuses on a choice experiment conducted in the Czech Republic, Portugal, and Switzerland to assess heterogeneity across countries.

The lack of knowledge concerning long-distance VTTS cannot be justified with reference to the importance of these trips. Although long-distance travel adds up to only a small share of trips made by households they represent a major share when measuring mileage and therefore environmental effects. At the European level, trips above 100 km represent more than half of the total mileage (Rich and Mabit, 2012). The same tendency is found in various national surveys, e.g. the Danish National Travel survey shows that trips longer than 100 km account for only 2.2% of the trips but 23% of the mileage and in UK, trips above 80 km account for about a third of all distance travelled but only 2.3% of the trips (Rohr et al., 2010). These figures reflect the importance of long-distance travel that has motivated a growing interest related to modelling of long-distance travel. The majority of the literature on long-distance travel is based on domestic/national level long-distance travel. Typically these studies focus on the mileage consumption (Georggi and Pendyala, 2001; Mallett, 2001; Dargay and Clark, 2012), generation (Limtanakool et al., 2006a) and mode choice (Sethi and Koppelman, 2001; Limtanakool et al., 2006b). The overall conclusion from these works is that long-distance travel in its nature is different from daily (short-distance) travel. This motivates the argument that valuation of travel time savings could also be different in the context of long-distance international travel when compared to the settings within which most VTTS surveys have been conducted.

Moreover, all projections for future market shares of long-distance travel indicate that even more miles will be carried out on longer distances. A global market forecast (Airbus, 2012) for the aviation industry predicts that revenue passenger kilometres[2] will increase by 150% globally between 2011 and 2031. For expanding regions including China, Middle East, South America, and Africa the expected annual growth rate is as large as 6% while for Japan, Western Europe, and North America it is around 4%. These growth rates may seem large, however, it should be remembered that aviation passenger kilometres grew 53% between 2000 and 2011 irrespectively of two global financial crises (Airbus, 2012). Although the outlook for high-speed rail market shares is less optimistic in a global perspective, there are many examples of high-speed rail having significant regional impact. European examples include Madrid-Barcelona and Paris-Lyon. An example from Denmark is the Great Belt project in 1998, which lead to a substantial increase in long-distance travel by rail between the eastern and western part of Denmark and more or less outcompeted the domestic aviation on this corridor.[3]

The background of the current study is a project for The Femern[4] Belt Consortium undertaken by DTU Transport and RAND Europe in the period 2010-2012. The objective was to develop a demand model for the Fehmarn corridor to support decision making related to the new 4 Billion Euro fixed link to be opened in 2021. The new link - one of the priority projects in the European Core network – is expected to have a significant impact on long-distance travel patterns between Scandinavia and Central Europe.

This paper makes a contribution to the current transport-geography research and in particular, on the debate regarding the impact of new infrastructure on trip making (e.g.

[2] A revenue passenger kilometre is flown when a revenue passenger is carried one kilometre.

[3] A discussion of the success of three large infrastructure projects – the Great Belt, the Øresund Bridge, and the Channel Tunnel project – is offered in Knudsen and Rich (2013). It is concluded that in particular the competitive edge towards aviation has been a decisive factor.

[4] Although the correct English translation is Fehmarn (and will be used throughout the paper) the official English name of the consortium is spelled as “Femern”.

Garmendia et al., 2011). Our study focuses on the impact of trip making under the existing transport infrastructure (ferries) and a scenario of being able to travel on the Fehmarn Belt fixed link (motorway tunnel or bridge) between Germany and Demark, a main route for caravans, holiday makers and business across Germany, Denmark and Sweden. Figure 1 presents the geographical area highlighting the existing ferry routes and Figure 2 shows the annual trend of average-day car traffic across the ferry line to be replaced by the fixed link.

<Insert Figure 1 and Figure 2 >

The paper reports on a practical and rather realistic approach on how to collect data on travellers' mode and route choices for international long-distance travel while the focus of the analysis is on examining the factors influencing mode and route choices. Its core contribution comes from the empirical evidence; the estimates of VTTS, a key element to assess the cost and benefits for constructing new transport infrastructure and assessing transport planning policies or other transport investments. The paper further demonstrates how to examine for potential sources of observed heterogeneity in the estimates of VTTS including cost damping, and factors such as travel distance and duration.

The remainder of the paper is organised as follows. Section 2 describes the design of the stated choice experiments and the administration of the stated choice data collection. In section 3, we discuss the modelling approach and present the estimation results. The final section 4 provides a summary and a discussion of the findings related to VTTS for long-distance travel.

2 Data

2.1 Survey design

The stated choice survey was developed to facilitate analysis of future transport demand for the new Fehmarn Belt fixed link and in particular, to obtain VTTS by various modes. An important consideration was that respondents should have been familiar with the available travel options across the Fehmarn Belt area. We therefore recruited participants who had previously participated in intercept interviews (an RP travel survey) at several ferry-crossing points across the Fehmarn Belt area, the Great Belt Bridge, the only competing crossing that does not include a ferry, and Copenhagen Airport, the main hub from Denmark and Southern Sweden and transfer airport for travel from/to Norway and Northern Sweden.[5] This approach allowed us to use background information regarding the observed mode and possible ferry-crossing alternatives in the stated choice experiment. As a practical comment, De Lapparent et al. (2009) suggest developing experiments as generic as possible across countries so that any design differences are not confounded with behavioural differences in the countries. This practice was taken into considerations when designing the experiment in the current study.

The travel options in the choice scenarios included air, bus, car, and rail with the latter three combined with the available ferry crossings. Participants were allocated into groups according to the observed mode of travel (i.e., car, bus, air, or rail) and the

[5] *Our reason not recruit at Oslo or Stockholm airports was that we did not consider these as realistic alternatives to the Fehmarn Belt link. We did consider to recruit at Malmö and Göteborg airports. One may argue that the sample might be slightly biased by the omission of these airports. However, considering their size relative to the Copenhagen airport this bias is deemed to be minor. Furthermore, Malmö Airport has no flights to Germany which are the routes of most importance.*

Scandinavian segment of origin/destination of their trip, namely: Norway, Northern Sweden, Southern Sweden, or Denmark, as that was reported in the RP survey. This approach allowed us to introduce a higher degree of realism for the alternatives presented in the experiment (e.g. ferry crossings from/to Norway were only available to respondents who previously travelled from/to Norway). This customisation helped participants relate to their previous journey and the available travel options and therefore provide more informed choices when presented with the new fixed-link option in the stated choice experiments. Finally, all choice exercises included a 'Would not make journey' option in case respondents would not find any of the available travel options offered acceptable.

We did this to create a realistic survey by pivoting the stated choice experiments around actual trips. This was necessary in order to make the stated choice experiments credible for the respondents. Especially for long-distance travel there is a risk that there is only little competition among alternatives for some origin-destination (OD) pairs. So the drawback is that credible choices may create many non-traders as the base levels of the various alternatives are not chosen to maximise trading but to be realistic. Clearly this is an area where the analyst needs trade-offs when designing a survey.

The variations in attributes used in the experiment are shown in Table 1. The use of pivoting created the need for a reliable network from which to extract appropriate estimates for journey times and costs. Although reliable networks may be easy to get for urban areas they can pose a challenge when it comes to long-distance travel. This is particularly true when considering travel across Europe, for example. While we managed this based on the network used in the European TRANSTOOLS model (see e.g. Rich and Mabit, 2012) this was quite a laborious task.

Table 1
Attributes and levels in the stated choice experiment.

Attributes	**Levels (relative to the base value)**
Access/Egress time, Travel time (bus, car, ferry, rail, air), Waiting time, and Travel cost (bus, car, ferry, rail)	-25%, -10%, +10%, +25%
Air cost	-35%, -15%, +15%, +35%
Toll cost	-10%, -5%, +5%, +10%.
Interchange (number of)	0,1,2

Each respondent was asked to participate in two stated choice experiments with eight choice scenarios each. The first experiment presented all existing travel options, whereas in the second experiment the Rødby-Puttgarden ferry crossing was replaced with the fixed-link option. An illustration of a choice exercise in Experiment 1 is shown in Figure 3.

<Insert Figure 3>

Different experimental designs were specified based on the combinations of observed mode and Scandinavian segment of the origin or destination of the trip to account for the different number of crossing alternatives within scope for each segment. Respondents were presented with all crossing options within their own Scandinavian segment and any other located to the south of that segment. This assumption was made on the basis that travellers may drive south to take advantage of a shorter crossing and also that they were less likely to drive north to undertake a longer ferry crossing.

D-efficient designs based on the multinomial logit model (MNL) were specified to generate the design matrices in the pilot study using zero priors, i.e., parameters in the model underlying the design were assumed to be zero a priori. For the main phase of the survey, the design of the scenarios was based on the estimated parameters from the pilot sample. This approach helped to further improve the efficiency of the design allowing for a more precise estimation of the model parameters of the main survey data (see for example, Rose et al., 2008). Both experiments were developed using the software Ngene (ChoiceMetrics, 2010).

2.2 Data collection

As described in Section 2.1, we applied a “pivoting” approach in which the alternatives offered in the SP experiments were specified relative to an observed trip from the RP data. The RP survey was based on intercept interviews of 2192 individuals with relevant travel across the Fehmarn Belt. To make the results representative for both peak and non-peak travel, the RP data were collected in two waves one in the spring to capture average non-holiday travel conditions and another during summer holidays to capture peak travel. Incorrect and unreadable e-mail addresses reduced the group of possible respondents to approximately 1700 individuals. To encourage participation we gave out 10 gift certificates worth of €40 each. Approximately, 20% of the RP survey participants responded resulting in 5070 stated choices made by 340 individuals. Similar internet surveys have reported a response rate around 30% (see, e.g. Potoglou and Kanaroglou, 2007). So while we are on the low side we are still close to the same level of response.

Compared to our initial RP data, we experienced a huge loss of respondents as many were missing key information in the RP interview, had unrealistic OD combinations reported in the RP data, and missing/unreadable e-mail addresses. Of those that we could use we experienced a relatively low response rate. The latter may be due to the low importance the Fehmarn Belt may have for the many low frequency users.

The mode shares and other descriptive statistics of the sample used for modelling are presented in Table 2. We compare these shares to the full RP sample as this gives the best picture of how well our sample represents the population of potential travellers across the Fehmarn Belt.

Table 2
Descriptive statistics

Variable		**Sample shares (% of 340)**	**RP shares (% of 2192)**
Mode	Air	16.2	22.6
	Car/ferry	72.4	65.0
	Other/ferry	11.5	12.4
Purpose	Business	18.2	15.5
	Commute	2.1	3.7
	Holiday	56.5	51.3
	Shopping	11.5	12.2
	Other	11.8	17.4
Duration of stay	< 24 hours	15.9	15.4
	1-3 days	25.6	27.7
	4-7 days	17.4	19.9
	2 weeks	21.5	20.0
	3+ weeks	17.4	12.8
	Did not respond	2.4	4.3
Trip frequency	Daily	0.3	0.6

	Weekly	2.7	2.5
	Monthly	12.7	11.0
	Annually	49.7	42.7
	Less often	34.7	42.7
	Did not respond	0.0	0.6
Cars in household	No cars	3.2	6.5
	1 car	46.8	43.8
	2 cars	39.7	38.1
	3+ cars	9.7	10.3
	Did not respond	0.6	1.3
Household income (€)	0-53,333	20.3	23.8
	53,333-80,000	23.2	24.7
	80,000-106,667	18.5	17.6
	106,667-133,333	20.6	14.3
	133,333+	7.7	6.3
	Unknown/no response	9.7	13.2
Home country*	Sweden	23.4	24.1
	Denmark	33.5	31.9
	Germany	18.5	20.6
	Norway	3.2	4.7
	Poland	0.9	2.7
	Holland/ Belgium/Luxemburg/France	8.0	4.6
	Not available	12.7	11.5

*This was asked indirectly in the survey. This caused the high share of unknown home countries.

An overview of the various alternatives and statistics on choice frequency is presented in Table 3. The share of bus passengers was low leading to few choice exercises related to the various bus alternatives. In the model estimation, this restricted the possible alternative-specific constants (ASCs) that could be estimated for these alternatives.

Table 3
Number of choices and availability across alternatives.

Alternatives	**Number of choice exercises where the alternative was available**	**Observed number of choices made for each alternative**	**Share**
No travel	5070	475	0.09
Air	5070	895	0.18
Rail and RP ferry	2628	172	0.07
Rail and Fehmarn link	2442	226	0.09
Bus and Fehmarn link	128	12	0.09
Car and Fehmarn link	2314	733	0.32
Car and Great Belt bridge	4541	552	0.12
Bus and ferry			
Rødby-Puttgarden (RP)	145	17	0.12
Gedser-Rostock	273	13	0.05
Oslo-Kiel	32	4	0.09
Trelleborg-Sassnitz	104	3	0.02
Göteborg-Kiel	72	6	0.08

Trelleborg-Travemünde	104	3	0.03
Trelleborg-Rostock	104	7	0.07
Ystad-Swinoujscie	104	6	0.06
Car and ferry			
Rødby-Puttgarden	2483	767	0.31
Gedser-Rostock	4797	622	0.13
Oslo-Kiel	256	22	0.09
Trelleborg-Sassnitz	2104	167	0.08
Göteborg-Kiel	1140	46	0.04
Trelleborg-Travemünde	2104	105	0.05
Trelleborg-Rostock	2104	166	0.06
Ystad-Swinoujscie	2104	51	0.02

3 Modelling approach and estimation results

3.1 Modelling approach

We apply a discrete choice model based on random utility maximisation (RUM). Since there could be shared unobserved similarities across alternatives with the same mode and/or route we apply a nested logit (NL) model (Ben-Akiva and Lerman, 1985).

In each choice situation, we assume that an individual, indexed $n = 1, \dots, N$, chooses an alternative from a choice set C_n with J_n alternatives. For every individual n, every choice alternative $i \in J_n$ and for every choice exercise t, we define a utility function U_{int}. Following RUM, we assume that individuals choose the alternative with maximum utility. Furthermore, we assume each utility function to have a functional form in which specific variables are expressed using a non-linear Box-Cox transformation f and others using a linear-in-parameter form:

$$U_{int} = V_{int} + \varepsilon_{int} = \beta_n{}' f(x_{int}; \gamma) + \delta' z_{int} + \varepsilon_{int}, \quad \forall i, n, t \tag{1}$$

where x_{int} is a vector of attributes specified according to a Box-Cox functional form f,
z_{int} is a vector of attributes that are specified in linear form,
β_n is a vector of parameters to be estimated and depend on individual characteristics,
γ, δ are vectors of parameters to be estimated, and
ε_{int} are error terms assumed to follow a multivariate extreme value distribution that corresponds to the NL model (see e.g. Ben-Akiva and Lerman, 1985).

In the NL model, the set of alternatives, $i \in J_n$, is partitioned into K nonoverlapping nests, $B_1, \dots, B_K$. Each nest B_k has an associated nest coefficient, μ_k. Based on these assumptions it is possible to derive choice probabilities for the NL model (t suppressed for notational simplicity) as:

$$P_{in} = P_n(i|B_k) P_n(B_k) = \frac{e^{V_{in}\mu_k}}{\left(\sum_{j \in B_k} e^{V_{jn}\mu_k}\right)} * \frac{\left(\sum_{j \in B_k} e^{V_{jn}\mu_k}\right)^{\frac{1}{\mu_k}}}{\sum_{1 \le l \le K} \left(\sum_{j \in B_l} e^{V_{jn}\mu_l}\right)^{\frac{1}{\mu_l}}}, \tag{2}$$

where the coefficients, μ_k, μ_l, are nest coefficients belonging to the nest that includes alternatives i, j, respectively. In Equation (2) each nest B_l has a corresponding nest coefficient μ_l. The parameterisation corresponds to a NL model normalised from above with upper scale fixed to 1 and a nest coefficient for each nest. If these nest coefficient are equal to or above 1 the model is indeed a RUM model.

Given the probabilities in Equation (2), the model may be estimated by maximising the following log-likelihood function:

$$LL = ln \prod_{nt} P_{int} = \sum_{nt} \ln(P_{int}) \quad (3)$$

which is the sum over the probabilities of the chosen alternatives, i, by individual n over all choice situations t.

The NL model assumes that the error terms are independent across observations obtained from the same individual. This is a strong assumption when modelling panel data (i.e., in this case multiple stated choice responses from the same individual). If correlation across responses by the same individual is independent of the exogenous variables we will get consistent estimates but biased standard errors. A simple way to correct the standard errors for correlation across individuals is to use the sandwich estimator as discussed by Daly and Hess (2012) and is based on the maximisation of the following log-likelihood function:

$$LL = ln \prod_{nt} P_{int} = \sum_{n} \ln(\prod_{t} P_{int}). \quad (4)$$

The log-likelihood functions in Equations (3) and (4) have the same maximum but the derivatives are not the same and therefore the standard errors will be different. The conclusion by Daly and Hess (2012) is that estimation based on Equation (4) is robust toward serial correlation in the same way as standard errors based on the re-sampling methods bootstrap and Jack-knife.

3.2 Specification and estimation results

As explanatory variables, we included attributes in the stated choice experiment and their interactions with trip characteristics and the socio-economic and demographic characteristics of the respondents. Based on preliminary model estimation, we estimated a NL model with the following specification (t suppressed for notational simplicity) of the utility functions:

$$V_{in} = \alpha_{in} + \delta' z_{in} + \beta_{n,cost} \ln(x_{in,cost}) + \beta_{in,time} \frac{(x_{in,time})^{\gamma_{time}-1}}{\gamma_{time}} \quad (5)$$

where $x_{in,cost}$ is the individual travel cost for a one-way trip,
$x_{in,time}$ is the travel time for a one-way trip, and
z_{in} is a vector of the other attributes,
γ_{time} is the Box-Cox parameter related to time, and
δ is a vector of parameters for the other attributes.

The parameters, $\alpha_{in}, \beta_{n,cost}, \beta_{in,time}$, to be estimated depend on individual characteristics and are defined as follows:

$\beta_{n,cost} = \sum_k \beta_{k,cost} s_{nk}$, $\beta_{ni,time} = \beta^0{}_{i,time} + \sum_k \beta_{k,time} s_{nk}$ and $\alpha_{in} = \sum_k \alpha_{ik} s_{nk}$

where s_{nk} is the kth element in a vector, s_n, of trip and household characteristics including: trip distance, journey duration, purpose, household income, car ownership, and travel group size. While s_n is the same vector for all three parameters many of the interactions tested were statistically insignificant in the preliminary estimation so the interactions reported are different for the three parameters.

We specified cost at the level of the individual traveller, i.e. we used ticket cost for air, bus, and rail, and car cost divided by group size for car (with maximum group size equal to five). Tests showed that the Box-Cox cost coefficient was not significantly different from zero resulting in the use of the natural logarithm in the final specification in Equation (5). Two travel time coefficients were estimated one for car (car time) and another for other modes (on-board time) including short-duration ferries (sailing time below 2 hrs.). Furthermore, we tested different nesting structures based on mode/route combinations. The final structure was chosen on the basis of the best model fit. In this final model the various nests were:

1. No travel
2. Air
3. Rail
4. Great Belt Bridge (GBB)
5. Buses via ferries in Norway and Northern Sweden (BusNNS)
6. Buses via ferries in Southern Sweden (BusS)
7. Buses via ferries in Denmark (BusDK)
8. Cars via ferries in Norway and Northern Sweden (CarNNS)
9. Cars via ferries in Southern Sweden (CarS)
10. Cars via ferries in Denmark (CarDK)

The top five nests, no travel, air, rail, Great Belt Bridge, and BusNNS, were included in separate nests with each of the nest coefficients fixed to one. Merging these alternatives into other nests let to poorer model fit. The tree structure is depicted in Figure 4.

<Insert Figure 4>

The model was estimated with Biogeme version 2.0 (Bierlaire, 2003). The estimation results are presented in Table 4. The time variables are single-trip time measured in hours. The cost variables represent one-way costs measured in thousands of Euros. In Table 4 we report the parameter estimates for attributes and interaction effects as well as the most important ASCs. The remaining parameters are other ASCs, i.e. parameters that represent the crossings other than the Fehmarn and RP crossing.

Table 4
Estimation results for the final NL model.

Variable	Estimate	Robust t-test	Panel t-test
Air access	-0.18	-4.6	-1.7
Air wait	-0.12	-0.5	-0.6
ln(Cost)	-1.26	-13.0	-5.0
ln(Cost)* less than 24 hours travel	0.93	9.9	3.8
ln(Cost) * 1-7 days travel	-0.11	-1.2	-0.5
ln(Cost) * distance/1000	-0.39	-5.5	-2.1
Ferry wait	-0.01	-0.1	-0.1
Transfers	-0.00	-0.1	-0.1
Time – car	-0.33	-6.9	-2.9
Time – long-duration ferry	-0.01	-0.9	-0.5
Time – air, bus, rail, short-duration ferry	-0.26	-8.5	-4.5

Time * less than 24 hours travel	0.01	0.5	0.2
Time * 1-7 days travel	-0.08	-3.0	-1.3
Time * distance/1000	0.07	5.8	2.5
γ_{time}	0.52	8.0	3.4
No journey	-0.72	-4.8	-2.1
Air	-1.90	-6.9	-4.6
Air * business	1.80	15.6	5.5
Air * high income	0.96	10.4	3.5
Car * Fehmarn	-0.17	-3.0	-1.8
Car * No cars	-2.55	-4.2	-1.2
Car * 2+ cars	0.28	3.8	1.3
Car * week	0.41	3.7	1.4
Car * week * business	-0.38	-2.4	-0.9
Car * Ferry (RP)	0	-fixed	-fixed-
Rail * Fehmarn	-1.86	-11.3	-5.0
Rail * Fehmarn * business	1.13	6.4	3.7
Rail * Ferry (RP)	-1.84	-11.5	-4.9
μ_{BusS}	3.75	2.2*	1.5*
μ_{BusDK}	3.43	2.1*	1.9*
μ_{CarNNS}	1.62	1.0*	0.5*
μ_{CarS}	2.38	7.0*	4.0*
μ_{CarDK}	2.23	9.1*	5.3*
Obs	5070		
Individuals	340		
DoF	41		
Final LL	-7737.3		
Adj. Rho2	0.243		

*t tests are against the value of 1, not zero.

The coefficients of cost, car time, and on-board time were significant and negative as expected. The latter variable included in-vehicle rail and bus time, on-board air time, and ferry time for ferries with sailing time below 2 hours. We found that car time was valued the most (negative), while on-board time was valued slightly lower, and with the sensitivity to changes in time for ferries with sailing time above 2 hours being insignificant. These long-distance ferries had sailing times from 5 to 20 hours.

A Box-Cox transformation of cost was tested with the result of a coefficient that was not significantly different from zero. Therefore we included $ln(cost)$ in the final model corresponding to a Box-Cox transformation with a coefficient of 0. This showed that we had large cost damping, i.e., the marginal utility of cost decreases numerically as cost increases (Daly, 2010). The Box-Cox transformation of time had a coefficient of 0.52. The reported t-test is against 0 but since the coefficient was close to 0.5 a t-test against 1 would give a similar result. So we also have time damping but the damping is smaller than the cost damping.

The model included various interaction effects to capture observed heterogeneity among travellers in the marginal utility of time and cost. The effect of duration was that same-day travel had less negative time and cost coefficients compared to travel of more than one week but only the cost interaction was significant. Weekly travel had more negative time and cost coefficients but none of the interactions were significant in the panel t test. Also distance had significant interactions showing that sensitivity to the Box-Cox transformed time attribute decreased by distance while the sensitivity to $ln(cost)$ increased. Since time, cost, and distance are correlated the direct effect of distance on the time and cost sensitivities is less evident from the model.

The interactions with the ASCs showed that air is preferred over other modes for business travel and by high income travellers. The Fehmarn link was more attractive to business travel for rail compared to the existing situation with combined rail and ferry.

Given the specification of the NL model presented in Equation 2 we expect nest coefficients to be above 1 if nesting is supported by data. The nest coefficients showed that we have significant nesting both for car and bus using similar ferry crossings. Some of the nest coefficients are insignificant but high. These nests have few observed choices and we would expect the nesting to be significant in the case of a larger sample size. Originally, we included interactions with purpose. Following the introduction of non-linear cost and time coefficients these became insignificant with the wrong sign. This showed that the higher VTTS for business is captured by the non-linearity so that further interactions are unnecessary. We included income interactions with cost and ASCs but the only significant effect of income was on the ASC for air.

We calculated the average VTTS in €/hr by applying sample enumeration. As time and cost variables, we used the individual-specific reference values that were applied in the design of the stated choice experiments. Car, bus and rail reference values were based on the Fehmarn crossing. The average was calculated using the formula in Equation 6:

$$VTTS = \frac{1}{N}\sum_{n}^{N} \frac{\beta_{ni,time} * x_{ni,cost}}{\beta_{n,cost} * (x_{ni,time})^{1-\gamma_{time}}} \qquad (6)$$

The average VTTS measures are presented in Table 5. It should be noted that the interaction effects in principle make possible for the VTTS to become negative. Given the characteristics of the respondents this did not happen in the sample. For comparison we have reported average VTTS estimated in the previous Fehmarn study (HCG, 1998) and the most recent Danish value-of-time study, DATIV (Fosgerau et al., 2007). For Sweden we report the average sample values for national long-distance travel in the recent Swedish value-of-time study (Börjesson and Eliasson, 2012). Other values from Denmark, Sweden, Norway, the UK, and the Netherlands are similar to the reported Danish and Swedish values as they vary from €4.5 to €14 when business travel is excluded (Axhausen et al., 2006).

Table 5
Average individual VTTS in the sample in €/hr.

Model	**Statistic**	**Average [€/hr]**	**Min**	**Max**	**Fehmarn (1998)**	**Denmark (2007)**	**Sweden (2012)**
NL	VTTS car	10.8	1.2	56.6	26.6	13.1*	10.9
	VTTS bus	7.5	1.6	14.9			3.9
	VTTS rail	7.2	0.9	19.7	13.3		7.4
	VTTS air	27.9	1.2	119.4	53.3		

*with VTTS distribution truncated at 133.3 €/hr.

As shown in Table 5, air travel had the highest VTTS followed by car that also had a noticeably higher VTTS than bus and rail. The variation in VTTS within each mode was seen to be large with air having the largest variation between 1.2 and 119.4 €/hr. HCG (1998) also calculated VTTS for travel across the Fehmarn Belt. We see that we have the same pattern among modes but with values that are approximately 50% lower. On the other hand a comparison to the most recent Danish value-of-time study, DATIV (Fosgerau et al., 2007), showed average VTTS more similar to our results.

We also evaluated the VTTS in car for the business travellers alone. This gave an average VTTS of 15.9 €/hr compared to 9.5 €/hr for the non-business travellers. So even though business is not included directly in the VTTS formula in Equation (6), the model estimates a business VTTS that is 50% higher than VTTS for other purposes when evaluated in the sample.

The interactions with distance showed that VTTS decreased as distance increased at constant cost and time. This is also seen in Table 6 where we have calculated VTTS for car at several combinations of distance and duration. The pattern shows that VTTS decreased along both dimensions, i.e. VTTS decreased with both duration and distance.

Table 6
Average individual car VTTS in €/hr relative to distance and duration of journey.

Model	**Duration vs. distance**	**200 km**	**900 km**	**1600 km**
NL	<1 day	37.0	18.9	11.0
	1-7 days	13.5	10.0	7.5
	8+ days	11.6	8.3	5.8

4 Discussion and Conclusion

In this paper, we have designed and implemented a stated choice experiment to facilitate subsequent analysis and support forecasting of future transport demand for the Fehmarn Belt fixed link, a permanent connection between Germany and Denmark to be delivered by 2021. The analysis of the respondents' choices for different routes and modes was based on a NL model and allowed us to capture observed heterogeneity among travellers. We have identified that duration of stay, car availability and business travel significantly influenced the marginal utility of car. Also, respondents expressed different levels of sensitivity on travel time depending on travel distance and the duration of their stay. Most of the heterogeneity was explained as cost damping and to a lesser degree time damping as many of the parameters related to individual characteristics became insignificant when we allowed Box-Cox transformations of cost and time.

The core of the analysis in the paper focuses on the estimation of average values of travel-time savings for car, bus, rail and plane, respectively. We found that travelling by plane had the highest VTTS followed by car, train and bus. The pattern in the VTTS per mode has remained unchanged when compared to the 1998 Fehmarn Belt study (HCG, 1998). On the other hand, the magnitude of the average values of VTTS across the different modes were lower than the 1998 study, but more in line with values found in recently undertaken VTTS studies in the region (Fosgerau et al., 2007; Börjesson and Eliasson, 2012).

Our paper empirically confirms previous assertions that the determinants influencing long-distance travel are different than those involved in urban daily travel. Therefore, the associated VTTS are not transferable from the urban to long-distance travel context. For example, we found that VTTS decreases with distance of the journey and travellers' duration of stay whereas for typical daily travel the VTTS usually increases with distance (Daly, 2010); this observation is possibly due to different levels of time constraints between the two contexts. While the average values may appear similar between the two contexts the variation in the measures is much higher and depends on other factors when it concerns long-distance travel. These findings justify the need for empirical investigation of the VTTS using stated choice experiments tailored to long-distance international travel.

Research on long-distance international travel and its determinants has been disproportional to its effect on miles travelled and the emissions generated. Even more limited are the empirical investigation and the valuation of travel-time savings across different modes concerning long-distance international travel. This paper makes an attempt to fill this gap in the literature and bring evidence regarding travellers' choices for long-distance international travel. This is particularly important as urban-level daily travel has fundamental differences with long-distance travel, especially on international long-distance travel.

Long-distance travel is an important element for creating opportunities for economic development, regional and social interaction (Limtanakool et al., 2006b). On the other hand, it presents considerable challenges when it comes, for example, to addressing its environmental impacts, and particularly the emissions generated. Better understanding of the factors driving international long-distance travel and the valuations of travellers across different modes has significant implications on creating opportunities for employment and foreign tourism among others (Frändberg and Vilhelmson, 2003). The topic becomes timely when long-distance travel is considered at the international level as it is likely to involve debate and collective decision-making across different countries.

Of particular interest becomes the evaluation of large-scale transport infrastructure and its provision, such as the project examined in the paper, the Fehmarn Belt fixed link. The results have wider implications in determining the level of spatial interaction between Scandinavian countries, Germany and the rest of Europe. The estimated model and related VTTS savings feed into a forecasting modelling system that enables decision makers to predict travel patterns over long distances under different pricing scenarios; for example in determining a competitive price for crossing the fixed link as well as the capacity and size of such transport infrastructure.

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Fig. 1. An overview of Denmark, Southern Sweden, and Germany with main ferry connections.

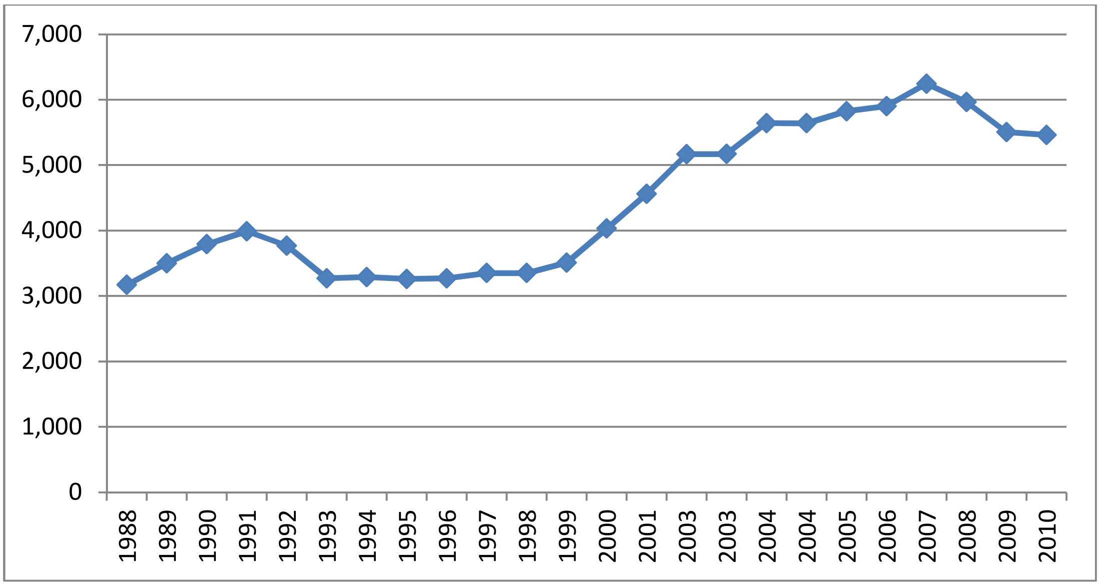

Fig. 2. Annual trend of average-day car travel across Rødby-Puttgarden. (source: Danish Road Directorate)

Choose one of the following journeys:

There are 10 possible ways to travel from **Oslo** to **Hamburg**.
Alternatively, you can indicate that you would not make the journey by clicking at the very last option of the list.

Flight	**Travel time to airport**	**Waiting time in airports**	**Flight time**	**Travel time from airport**	**Total duration**	**Total cost**
flight via Oslo - Hamburg	20 min	1hr 20 min	1hr 30 min	15 min	**3hr 25 min**	**DKK 850,00**

Car and Ferry	**Driving time to ferry**	**Time on ferry**	**Driving time from ferry**	**Total duration**	**Car cost**	**Ferry ticket cost**	**Total cost**
crossing via Røby-Puttgarden	1hr 40 min	45 min	8hr 0 min	**10hr 25 min**	DKK 540,00	DKK 300,00	**DKK 840,00**
crossing via Gedser-Rostock	8hr 20 min	1hr 45 min	1hr 55 min	**12hr 0 min**	DKK 560,00	DKK 430,00	**DKK 990,00**
crossing via Oslo-Kiel	15 min	20hr 0 min	1hr 5 min	**21hr 20 min**	DKK 560,00	DKK 600,00	**DKK 1.160,00**
crossing via Trelleborg-Sassnitz	6hr 40 min	4hr 0 min	3hr 5 min	**13hr 45 min**	DKK 560,00	DKK 450,00	**DKK 1.010,00**
crossing via Götheborg-Kiel	3hr 40 min	14hr 0 min	1hr 5 min	**18hr 45 min**	DKK 240,00	DKK 2.250,00	**DKK 2.490,00**
crossing via Trelleborg-Travemünde	6hr 40 min	7hr 30 min	1hr 0 min	**15hr 10 min**	DKK 410,00	DKK 790,00	**DKK 1.200,00**
crossing via Trelleborg-Rostock	6hr 40 min	6hr 0 min	1hr 55 min	**14hr 35 min**	DKK 470,00	DKK 600,00	**DKK 1.070,00**
crossing via Ystad-Swinoujscie	6hr 50 min	7hr 0 min	3hr 40 min	**17hr 30 min**	DKK 580,00	DKK 700,00	**DKK 1.280,00**

Train and Ferry	**Train time to ferry**	**Time on ferry**	**Train time from ferry**	**Total duration**	**Total cost**
crossing via Røby-Puttgarden	12hr 10 min	1hr 5 min	1hr 35 min	**14hr 50 min**	**DKK 1.000,00**

Car	**Total duration**	**Car cost**	**Toll for crossing**	**Total cost**
crossing via Great Belt	**11hr 0 min**	DKK 640,00	DKK 220,00	**DKK 860,00**

Do not make journey
I would not travel given the options above

Fig. 3. An illustration of a choice exercise in Experiment 1 for a trip between Oslo and Hamburg.

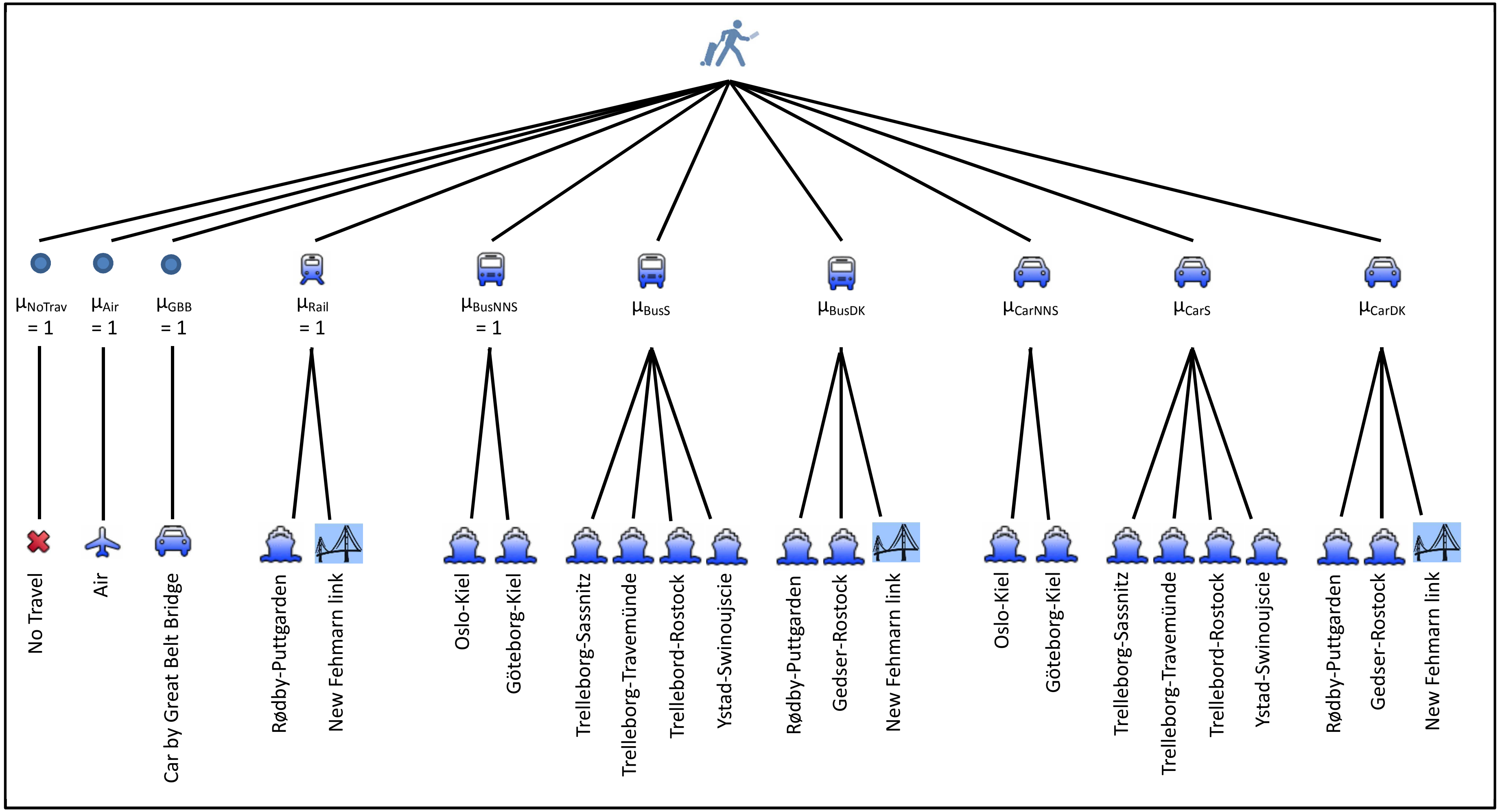

Fig. 4. Tree structure of the NL model.