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Modelling the demand for overnight tours between East and West Denmark: Insights from the update of the *Grøn Mobilitetsmodel*

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Abstract

Overnight travel between East and West Denmark differs substantially from daily travel patterns, necessitating dedicated demand models. This study presents updated overnight travel models for the *Grøn MobilitetsModel* (GMM), one of Denmark's primary tools for evaluating infrastructure projects. Key enhancements include finer geographic resolution, explicit representation of long-distance buses, differentiation of car travel alternatives, and integration of 2023 survey data.

Logit-based discrete choice models are developed to predict tour generation, mode choice, and destination choice for long-distance overnight travel in Denmark. Estimation draws on five travel surveys, updated level-of-service (LoS) data, and revised values of travel time (VTT). The results indicate that travelers between major Danish cities are more likely to choose air, public transport, or long-distance bus over car, compared to those whose trips originate and/or end elsewhere. Higher-income individuals are less likely to travel by public transport, long-distance bus, or as car passengers. Greater car availability increases the likelihood of selecting car travel between East and West Denmark. As expected, longer travel times and higher costs reduce the attractiveness of an alternative. Destination job availability has a strong influence on work/business tours, while hotel capacity and the presence of summer houses at a destination are more decisive factors for leisure tours.

1 Introduction

Accurate appraisal of road infrastructure projects is essential for informed decision-making in transport planning and investment. In Denmark, such evaluations—covering traffic, economic, and environmental aspects—are primarily based on forecasts from the Grøn Mobilitetsmodel (GMM) (Vejdirektoratet, 2025) and the Ørestad Traffic Model (OTM). These models provide a framework for assessing how changes in infrastructure, demographics, and economic conditions influence travel demand and modal shifts nationwide.

The reliability of these assessments depends on the accuracy of the underlying demand models. GMM, which covers the entire country, comprises three demand models—weekday, overnight, and international—each capturing distinct travel patterns and purposes. Overnight tours between eastern and western Denmark differ markedly from daily commuting or short-distance travel. They require a ferry or Storebælt (Great Belt) bridge crossing, often involve tolls or fares, and tend to be less frequent, more deliberate, and planned in advance. As a result, behavioral elasticities for overnight travel differ substantially from those of routine travel.

This paper presents revised overnight models within the GMM, designed to predict tours between eastern and western Denmark involving at least one overnight stay. The updated version incorporates new data on individual travel choices, finer zonal resolution, and a more detailed representation of car travel alternatives—distinguishing solo drivers, drivers with passengers, and passengers only. These improvements aim to enhance behavioral realism and enable more robust analysis of long-distance travel, particularly for evaluating pricing strategies on existing links (e.g., Storebælt Bridge) and assessing potential impacts of proposed projects (e.g., Kattegat fixed link).

2 Data and Methods

2.1 Data

2.1.1 Tour data

The estimation of demand models requires a representative sample of individuals with recorded or reported travel patterns and socio-economic characteristics. Only tours within Denmark that included at least one overnight stay (and no more than 14), crossed the *Storebælt screenline* (between East and West Denmark), did not start or end in Bornholm, and were not collected during the COVID-19 pandemic period (2020–2021) were retained for model estimation.

For estimating the tour frequency models, only data from the TU Standard Survey was used, as it provides a statistical overview of passenger transport in Denmark for residents, covering all types of tours as well as cases where no travel occurred (see Table 1). Moreover, only years that have overnight tour observations were considered, this means the consideration of observations from 2009 to 2024 for work/business and 2008 to 2024 for leisure/others. Only employed individuals were included in the sample for estimating the work/business model, as overnight tours for work/business were not considered available to those who were not employed.

Table 1 – TU dataset observations used to estimate tour generation by purpose

Choice	Work/business	Leisure/other
No overnight tour performed	45011	138279
One overnight tour performed	94	560
Total	**45105**	**138839**

For the estimation of the mode-destination models, five datasets were identified as suitable, as they contain detailed socio-economic information along with sufficient detail on tours and their purposes. The number of observations from each data source, after data cleaning, is presented in Table 2. Data from various datasets was preprocessed to standardize categorical variables across different scales and ensure consistency in continuous variables measured in different units. This step was essential to maintain data integrity and compatibility across all sources before merging.

Table 2 – Number of included observations from each data source in each one of the mode-destination models

Data source	Work/business	Leisure/other
TU standard	90	543
TU overnight special	221	1734
S&B passengers	367	3404
S&B air	41	66
Fjernbus	126	2600
Total	**845**	**8347**

All income and price data were adjusted to 2023 levels to ensure consistency and comparability across different time periods, allowing for a more accurate analysis of income-related trends. Since income was sometimes provided in ranges and other times as a continuous variable in different surveys, all data with income information on ranges was converted to a continuous format, which correspond to the mid-points of each range.

Since some respondents chose not to disclose their precise origin and/or destination location, their data was only available at more aggregated geographical level. In these cases, a conversion to the zoning system used was performed using a weighted probability distribution, based on population data, to estimate the respondent's likely location.

2.1.2 Level of service data

The level of service (LoS) data includes travel times and costs for trips by car, public transport, long-distance bus, and air, categorized by trip purpose and origin–destination pair. Because the overnight models are tour-based, outbound and return travel times and costs were summed for use in modeling individuals' mode and destination choices.

Only generalized travel time was available, meaning that individual components—such as waiting time, transfer time, and in-vehicle time—were aggregated into a single measure in the Level of service files. This measure was scaled relative to the coefficient for bus in-vehicle time, using weights from the route choice model. Access and egress times between each zone and the terminal were also included and adjusted in the same way as bus in-vehicle time.

Although LoS information for cars were provided for SOV (single occupancy vehicle) and HOV (high occupancy vehicles), only information referring to SOV was used and cost-sharing was explicitly estimated and integrated into the model, to differentiate the costs of tours when driving alone or with others.

2.1.3 Zonal data

The zonal data available for estimating the overnight models consist of information on population size, number of full-time jobs, number of parttime jobs, hotel capacity and number of summer houses in each of the 3677 Danish zones. The quantity of both full-time and parttime jobs was summed for obtaining the total number of jobs per zone.

2.2 Method

This section outlines the estimation process for the demand models, detailing the assumptions, tests, and specification decisions undertaken. The models estimated are discrete choice models, for which various structures and specifications were evaluated. All estimations were conducted using ALOGIT version 4.5.

2.2.1 Tour generation models

The tour generation models were estimated using a binary logit framework, in which the two alternatives represent the decision to either undertake or forgo travel between East and West Denmark for tours involving at least one overnight stay. Both alternatives—undertaking an overnight tour or not—were

assumed to be available to all individuals in the sample. For the work/business model, only employed individuals were included; thus, there were no restrictions on alternative availability for those eligible to undertake work or business tours.

The socio-economic variables tested included age, gender, personal and household income level, labor market participation, presence of children in the household, and car ownership. Contextual variables related to the timing of data collection were also examined. Specifically, a "summer" dummy variable was tested to see if it could reveal any potential seasonal effects in data collected during June, July, or August, and a "weekday" dummy variable was tested to identify differences between observations collected on weekdays versus weekends.

2.2.2 Mode destination models

The mode–destination models comprise 22,062 alternatives, derived from the combination of six transport modes and 3,677 geographic zones. Each alternative represents a unique mode–destination pair available to travelers. The six modes considered are:

- Car driver alone (SOV),
- Car driver with passengers (HOV),
- Car passenger (HOV),
- Long-distance bus,
- Train,
- Aviation.

For both the work/business and leisure/other models, multinomial logit and nested logit structures were tested, including mode-above-destination and destination-above-mode formulations.

Because the overnight models only considered tours crossing the *Storebælt* screenline, destination availability was restricted: tours originating in *Sjælland* could not have destinations within *Sjælland*, and tours starting in *Fyn/Jylland* could not have destinations within *Fyn/Jylland*. Zones in Bornholm were excluded entirely, as no tours to or from *Bornholm* were included in the analysis.

Mode availability was also constrained by traveler characteristics and data coverage. The "car driver alone" and "car driver with passengers" alternatives were available to all individuals aged 17 years or older (driving is permitted in Denmark from 17 years and 9 months), while the "car passenger" option was available to all. Train, long-distance bus, and aviation alternatives were available only if full level-of-service (LoS) data existed for the origin–destination pair.

Model specifications tested included both linear and log-transformed travel time and cost. In both work/business and leisure/other models, these forms produced unrealistic values of travel time (VTT), leading to the adoption of a generalized travel time (GTT) formulation, in which cost is converted into time units using purpose specific VTT measures. Allowing VTT to vary with household income improved model performance in both cases.

Cost-sharing was explicitly modeled in the utility functions to differentiate the cost structure of car alternatives. This followed an adaptation of the Rich and Fox (2024) approach, where passenger costs were divided by the number of occupants, based on mean car occupancy from the TU Standard and TU Overnight datasets.

Destination attractiveness was incorporated through size variables, with population used as the reference measure in both models. For work/business models, the "number of cars" variable included privately owned, leased, and company vehicles, whereas in leisure/other models, only owned and leased cars were considered. Car ownership effects were tested for all car-related alternatives, using "no car" as the reference category and distinguishing between households with one car and those with two or more.

Household composition effects were examined through dummy variables indicating the presence of at least one child, to test whether family responsibilities influence mode choice. Income (in thousands of DKK) was also interacted with cost and with alternative-specific constants (ASCs) to explore income-related variations in cost and time sensitivities.

Finally, geographic variables were tested to capture potential differences in travel behavior for tours between Denmark's major cities—Copenhagen, Frederiksberg, Odense, Aarhus, Aalborg, and Esbjerg—compared to less urbanized areas. Approximately 20% of observed tours for both purposes originated and ended within these cities.

3 Results and findings

3.1 Tour generation models

Table 3 presents the estimation results of the tour generation models for both work/business and leisure/other purposes.

Table 3 – Results of work/business and leisure/other models

	Work/business			Leisure/other		
Coefficient	**Estimate**	**Std. Error**	**'t' ratio**	**Estimate**	**Std. Error**	**'t' ratio**
B_Employ				0.5457	0.0844	6.5
B_child	-0.6074	0.227	-2.7	-0.5785	0.104	-5.6
B_AGE				-0.0109	0.0024	-4.6
B_MALE	0.7138	0.229	3.1			
B_Pers_INC	0.0808	0.0212	3.8	0.0440	0.0126	3.5
ASC_Tour	-6.452	0.202	-32	-5.084	0.138	-36.8
ASC_NoTour	0	constrained		0	constrained	
B_logsum	0	constrained		0	constrained	
Final Log-Likelihood (LL)	-663.6874			-3609.3646		
Null Log-Likelihood (LL0)	-31264.4036			-96235.8614		
ρ^2 / McFadden's R^2	.9788			.9625		

The analysis reveals that being employed has a positive effect on the likelihood of undertaking overnight tours for leisure or other purposes. Conversely, the presence of children in the household is associated with a reduced probability of engaging in overnight travel, a finding consistent across both work/business and leisure/other tour purposes. Age was also found to have a negative effect on the propensity to undertake overnight travel for leisure/other purposes, suggesting that older individuals are less likely to engage in such tours between East and West Denmark. To assess the robustness of this relationship, age was tested in multiple model specifications—both as a continuous variable and through categorical dummy variables rep-resenting age groups. However, in the work/business model, age was consistently found to be statistically insignificant, regardless of the specification, indicating that it does not meaningfully influence the decision to undertake overnight business-related tours.

Gender and income also showed significant effects. Being male increased the probability of undertaking an overnight tour for work/business purposes. Furthermore, higher personal income was found to be positively associated with the likelihood of undertaking overnight tours for both work/business and leisure/other purposes. It is important to highlight that personal income, rather than household income, was used in the tour generation models due to the exclusive use of the TU standard dataset, which provides detailed information on individual income levels. Although both personal and household income were tested, the differences in model outcomes were not substantial. However, personal income was retained in the final model specifications, as it provided a slight improvement in model fit, as reflected in marginally better log-likelihood values.

The impact of household vehicle availability was also investigated. Dummy variables representing ownership of exactly one car, at least one car, or two or more cars were tested in both models, but none were found to be statistically significant. Similarly, temporal factors were examined using dummy variables: “summer”, indicating whether the observation occurred in June, July, or August, and “weekday”, distinguishing between weekdays and weekends. These variables also showed no significant effect in either the work/business or leisure/other models.

3.2 Mode destination models

Table 4 presents the mode-destination models results. The coefficients for variables related to travel between major Danish cities suggest a higher likelihood of individuals choosing air, train, or long-distance bus travel over car travel for such tours, compared to tours that start or end in other locations. This pattern reflects the strong transportation links connecting these major cities. An assessment confirmed that including these variables did not significantly affect the generalized travel time coefficient in either model; therefore, they were retained in the final model specification.

Table 4 – Results of work/business and leisure/other models

	Work/business			Leisure/other		
Coefficient	**Estimate**	**Std. Error**	**‘t' ratio**	**Estimate**	**Std. Error**	**‘t' ratio**
B_BMC_Air	0.9271	0.284	3.3	1.012	0.184	5.5
B_BMC_Trn	0.5499	0.204	2.7	0.7859	0.0728	10.8
B_BMC_Bus	1.562	0.201	7.8	1.268	0.0495	25.6
B_misINC_T				0.2586	0.0694	3.7
B_INC_Trn_scaled*				-0.00068	0.000143	-4.7
B_misINC_B	-1.648	0.276	-6	-1.343	0.0717	-18.7
B_INC_Bus_scaled*	-0.00202	0.000275	-7.3	-0.00253	0.000107	-23.6
B_INC_Pas_scaled*	-0.00146	0.000603	-2.4			
B_misINC_P				0.7178	0.073	9.8
Bcar2M_Pas	1.115	0.407	2.7	2.233	0.148	15.1
Bcar1_Pas				1.173	0.14	8.4
Bcar2M_HOV	2.203	0.546	4	2.801	0.136	20.6
Bcar1_HOV	1.228	0.547	2.2	2.104	0.126	16.7
Bcar2M_SOV	2.859	0.497	5.8	3.122	0.332	9.4
Bcar1_SOV	1.699	0.497	3.4	2.698	0.326	8.3
B_GTT	-0.00225	0.000252	-8.9	-0.00158	7.69E-05	-20.6
ASC_Air	1.94	0.508	3.8	1.983	0.345	5.7
ASC_Train	1.551	0.487	3.2	3.308	0.338	9.8
ASC_Bus	2.704	0.548	4.9	5.108	0.33	15.5
ASC_CarP	-0.161	0.644	-0.2	0.5597	0.345	1.6
ASC_CDHOV	-0.479	0.675	-0.7	1.189	0.337	3.5
ASC_CDSOV	0	constrained		0	constrained	
L_S_M	1	constrained		1	constrained	
B_size_pop	1	constrained		1	constrained	
B_size_job**	4.958	1.35	5.9	0	constrained	
B_size_bed**	33.62	10.5	11.3	7.098	0.278	50
B_size_SumH**	0	constrained		1.654	0.125	6.7
D_M	0.952	0.05	19.1	1	constrained	
Final Log-Likelihood (LL)	-6820.3835			-71007.7356		
Null Log-Likelihood (LL0)	-7750.6627			-76581.5769		
ρ^2 / McFadden's R^2	0.1200			0.0728		

* Income in thousands of DKK
** Linear size coefficients

Regarding income, individuals with higher incomes are less likely to travel by train, bus, or as car passengers. In terms of vehicle availability, those with one or more cars in the household are more inclined to choose one of the car-based alternatives. As expected, having two or more cars has a stronger influence on the likelihood of choosing a car option compared to having only one car.

The negative coefficient for generalized travel time indicates that higher travel times and costs reduce the attractiveness of the available alternatives. Additionally, the coefficients for size variables suggest that the number of jobs and hotel beds positively impacts the attractiveness of the alternatives in the work/business model, whereas the number of hotel beds and summer houses plays a significant role in the leisure/other model.

The variable “presence of children in the household” was also tested and found to have a measurable influence on mode choice preferences. However, its inclusion in the model significantly reduced the statistical significance and explanatory power of the car ownership variables. Since car ownership is a key variable in many transport modeling scenarios and policy analyses, the presence of children variable was ultimately excluded from the final model specification to preserve the robustness and interpretability of the car ownership effects.

4 References

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