TRAFICOM
Finnish Transport and Communications Agency

Finnish National Transport Model (VALMA): Travel Demand Model

Supponen Atte, Jalovaara Jarkko, Mutikainen Juhani, Sylvin Joni, West Jens

Traficom Publications
XX/2023

Contents

Preface **3**

1 Introduction **4**

1.1 Tour based approach 5
1.2 Travel modes 7
1.3 Time periods 9

2 Data **10**

2.1 Study Area and Zone system 10
2.2 Choice Data 10
2.3 Attraction Data 10
2.4 Level-of-service matrices 11

3 Tour generation **12**

3.1 Tour rates 12
3.2 Travel frequency choice model 13

4 Mode-destination choice models **15**

4.1 Model structure for everyday travel 15
4.2 Model structure for occasional travel 16
4.3 Specification of variables 17
4.3.1 Travel time 17
4.3.2 Travel cost 18
4.3.3 Intrazonal distances 20
4.3.4 Socio-economic variables 20
4.3.5 Availability of alternatives 21
4.4 Estimation results for daily travel 22
4.4.1 Home-based Work Tours 22
4.4.2 Home-based Basic Education Tours 24
4.4.3 Home-based Student Tours 24
4.4.4 Home-based Shopping Tours 25
4.4.5 Home-based Leisure Tours 27
4.4.6 Home-based Visit Tours 28
4.4.7 Home-based Escort Tours 30
4.5 Estimation results for Non-Home-Based Tours 32
4.5.1 Work-based Business Tours 32
4.5.2 Work-based Other Tours 32
4.5.3 Other-based Other Tours 33
4.6 Estimation results for occasional travel 34
4.6.1 Transit access mode choice 34
4.6.2 Home-based Overnight Tours 35
4.6.3 Home-based Business Tours 36

5 Secondary destinations **37**

6 Car ownership model **38**

6.1 Explanatory variables 38
6.2 Household with 1 adult and 1 license 39
6.3 Household with 2 adults and 1 license 39
6.4 Household with 2 adults and 2 licenses 40

7 Route choice models in network assignment **41**

7.1 Transit route choice 41

8 Calibration and validation 43
8.1 Calibration of mode shares 43
8.2 Validation of mode shares 43
8.3 Validation of distance distributions 46
9 Model development 49
Bibliography 50
Appendix 1. Tour building 52

Preface

This report documents the domestic travel demand component of the Finnish National Transport Model (VALMA). The VALMA model was developed during 2021-2027 by the Finnish Transport and Communications Agency (Traficom), and the first version of the model (VALMA 1.0) was released in November 2026.

This report documents the final version of the released model. The development process involved numerous iterations and the testing of alternative variables, model structures, and functional forms. For simplicity, intermediate results are omitted from this report, and only the major choices regarding model specification are discussed.

A large team contributed to the development of the model. This report was authored by Atte Supponen, Juhani Mutikainen, Jarkko Jalovaara, Joni Sylvin, and Jens West. Additional contributions to travel demand model development were made by Petri Blomqvist, Roni Ilmonen, Elias Marttunen, Sami Mäkinen and Ilona Rahnasto.

The authors would like to thank Professor Andrew Daly for his valuable comments and advice throughout the model development process.

1 Introduction

The travel demand model of the Finnish National Transport Model describes the travel behaviour of Finnish residents. Travel choices can be related to everyday activities, occasional business or leisure travel, or holidays abroad. This report focuses on choice models of domestic travel demand. Travel abroad and network assignment model is covered in separate reports.

The domestic travel demand model follows a framework similar to many state-of-practice transport models currently used across Europe (e.g. HSL 2026, Kristoffersson 2024, Fox et al. 2016, Rich 2016, Smit et al. 2021). The domestic travel demand model consists of three parts (Figure 1): tour generation model, mode-destination choice model and car ownership model. The output of the demand models is origin-destination trip matrices, which can be fed to the network assignment model. Route choices of the travellers are in this conceptual framework part of network assignment.

The demand models are based on discrete choice theory (e.g. Train 2002), which represents travel decisions in a manner consistent with economic theory and observed behaviour of travellers. The well-established theoretical framework makes the models suitable for policy evaluation and forecasting.

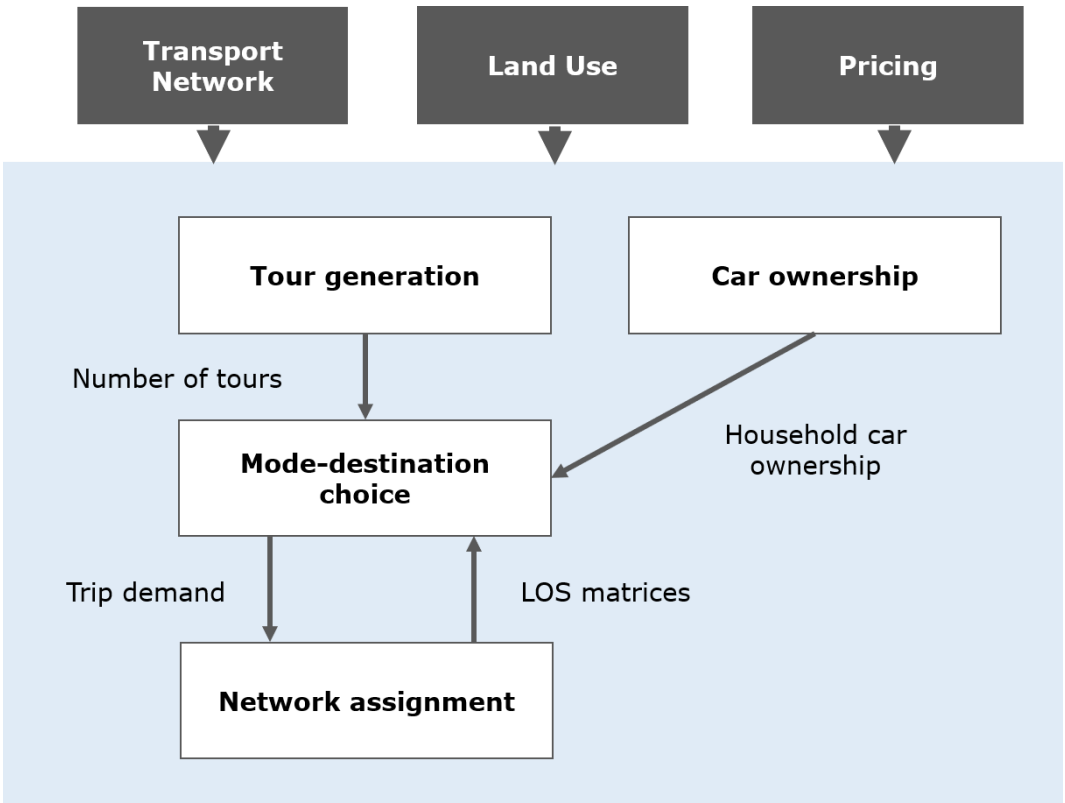


Figure 1. Structure of VALMA travel demand model.

The model system distinguishes between everyday and occasional travel and separate modelling approaches (structure, assignment, time periods) are applied to these components of travel demand.

- Everyday Travel Demand Model represents recurrent travel associated with daily activities such as work, education, shopping and personal business
- Occasional Travel Demand Model represents infrequent travel and non-routine journeys, such as overnight leisure trips and long business trips.

1.1 Tour based approach

The travel demand model was developed using a tour-based approach. The key unit of analysis is the tour rather than individual trip. A trip is defined as movement from one location to another, for example from home to a workplace or shop. A tour is defined as a sequence of linked trips that begins and ends at the same location. An individual may undertake multiple tours within a single day, and the resulting set of tours is referred to as a tour combination.

The tour-based approach models destination and mode choice jointly for both the outward and return legs of a tour, where trip-based approaches model each leg independently. For example, the choice of mode is made for the entire tour, reflecting that if an individual drives to work she is highly likely to drive home again.

The starting point of modelling is full home-based tours, which is series of linked trips starting and finishing at the individual's home. The purpose of a home-based tour is determined by identifying the Primary Destination (PD) of the tour. The primary destination for home-based tours is determined by the following rules:

1. Apply the purpose hierarchy (Table 1).
2. Take the PD as the furthest from origin.
3. Take the PD as the destination at which the most time was spent.
4. Define the PD as the first destination visited.

Table 1. Location type priorities.

Priority	Location type
1	Own home Other permanent residence
2	Own workplace
3	Own school or place of study Own day care or pre-school
4	Others

Tours have several important segmentations, which affect the way they are used in analysis:

- A tour can be a full tour or an open tour. Open means that the person has only visited home once during the tour. This might occur in two ways: the first trip of the day does not start from home (e.g. night shift worker returning home) or the last trip of the day does not end at home (e.g. staying in visiting place for night).
- Tours can be classified as home-based (HB) or primary-destination-based (PD). HB tours either originate from or return to the individual's home. PD tours are secondary tours whose origin is a primary destination of a home-based tour. For individuals who do not visit their primary residence during the survey day, their temporary accommodation (for example, a hotel, second home, summer cottage, or the residence of friends or relatives) is treated as the home location for tour classification purposes.
- An open tour is classified as an overnight tour if it starts or ends at a temporary accommodation location, such as a hotel, second home, summer cottage, or the residence of friends or relatives.

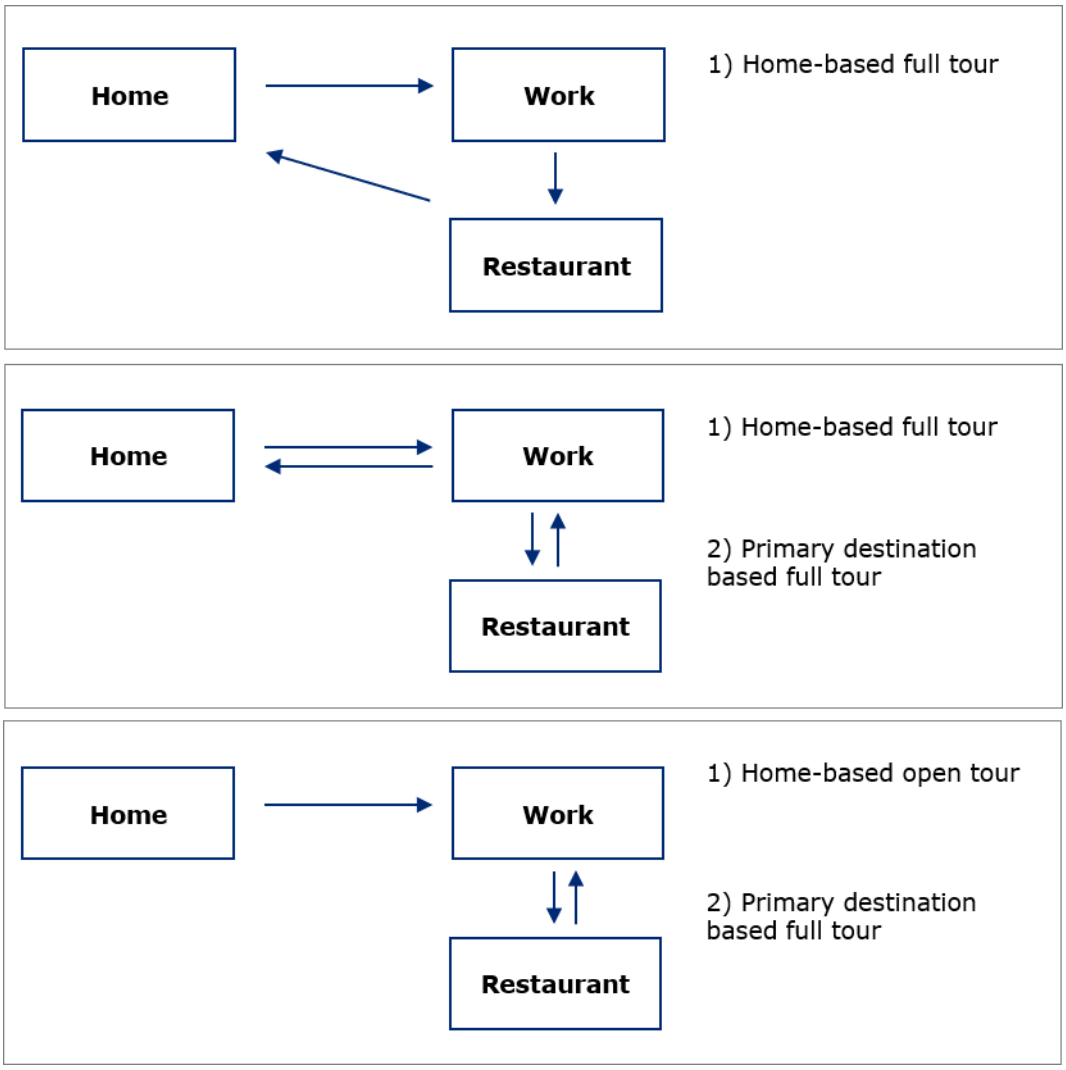


Figure 2. Examples of different types of tours.

The tour purpose determines the modelling approach used for a tour. Separate model specifications, parameter estimates, and choice structures are applied to each purpose to capture purpose-specific travel behaviour. Relationship between purpose, tour origin and tour destination is presented in table below (Table 2).

- Everyday travel has 10 purposes each with own parameters and utility specification.
- Occasional travel contains two purposes where model structure and assignment model is also different from everyday travel.

Table 2. Relationship between tour type, tour origin and tour destination.

Purpose	Origin	Primary destination
HB Work	Own home (Other permanent residence, hotel, summer cottage, or visiting place if home not visited)	Own workplace
HB Basic Education		Own school or place of study Own day care or pre-school (when person age <= 18)
HB Student		Own school or place of study (when person age > 18)
HB Shopping		Place for daily shopping Place for personal business or errand Shopping centre Other place for shopping
HB Leisure		Restaurant, cafe, lunch cafeteria or similar Pub, bar, night club Cultural institution or other location of entertainment Hotel, motel or other temporary place Exercise or recreation facility, park Other place for leisure activities Nature area without facilities
HB Visit		Place to visit relatives, friends or acquaintances Summer cottage or leisure home Other permanent residence
HB Escort		Place to pick up/drop off a person
HB Overnight		Open tours begins or ends to hotel, visiting place, summer house or other home
HB Business		Location related to business trip or work assignment
WB Other	Own workplace	Any other location
WB Business		Location related to business trip or work assignment
OB Other	Any other location	Any other location

Travel survey raw data is based on trip diary data, so data was processed into tours format as a part of modelling process. Tour building is described in appendix of this report.

1.2 Travel modes

Seven main modes for tours are represented in the mode-destination models:

1. Car driver
2. Car passenger
3. Transit
4. Airplane
5. Cycle
6. Walk

The available choice set is based on travel purpose. The everyday travel demand model does not include airplane as a travel option, because daily travel with airplane is rare. The occasional travel demand model has airplane considered as a mode alternative. For occasional travel, bike is combined with walk mode in the choice set for simplicity.

Both models have transit mode modelled as one alternative in mode-destination choice model. Therefore, the choice between train, bus and other transit modes is done in the network assignment phase. This solution was

selected because of difficulties in defining a main mode consistently in LOS matrices produced by network assignment.

Travel survey data has more detailed mode alternatives, so the detailed definition of each main mode is presented in the table below (Table 3).

Table 3. Mode classifications

Mode	Survey travel options
walk	walking, running, kick sled, wheelchair, walker
bike	bicycle (also electric)
transit	local or regional bus long distance bus (coach) chartered bus/coach other bus/coach local train, commuter or regional train, railcar long distance train tram metro other rail mode
car driver	passenger car (as driver) van (as driver)
car passenger	passenger car (as passenger) van (as passenger) moped car
airplane	route/scheduled flight charter flight" other aircraft (for example small aircraft or helicopter)
other (not included in demand models)	taxi, school taxi, taxi for disabled, dial-a-ride taxi ship, ferry, express boat motorcycle, lightweight motorcycle moped, moped scooter motor home/recreational vehicle lorry/truck other mode of travel

1.3 Time periods

The model describes travel demand on an average day of the year. Everyday travel demand uses four within-daytime periods in the models: morning peak, average day hour, afternoon peak and average evening hour. Each of these peak hours or equivalent time periods corresponds to a wider time period (morning hours, day hours, afternoon hours and evening hours). Evening hours are used only for the transit mode, so day and evening hour definitions are mode dependent. Otherwise, all the time period definitions for everyday travel are independent of travel mode and purpose. The model for occasional travel does not include separate peak hours, and its assignment time period is a full day.

Peak hour times and their corresponding travel demand by purpose or mode are determined using the midpoint time of trips from National Travel Survey 2016 (HLT 2016) data. Although the model predicts the total travel volume of average day of a year, peak hour calculations used only weekday travel habits for more distinct peak times and shares.

Morning:

- Morning hours:
  - 6:00-8:59
- Morning peak:
  - 7:30-8:29 (the hour having most midpoint times of outward or return trips within)

Afternoon:

- Afternoon hours:
  - 15:00-17:59
- Afternoon peak:
  - 15:35-16:34 (the hour having most midpoint times of outward or return trips within)

Day:

- Day hours:
  - Transit mode: 9:00-15:59
  - Other modes: Remainder of morning and afternoon hours
- Average day hour:
  - Transit mode: average hourly travel demand of day hours
  - Other modes: average hourly travel demand of 9:00-15:59

Evening:

- Evening hours (transit mode):
  - Remainder of morning, day and afternoon hours
- Average evening hour (transit mode):
  - Average hourly travel demand of 21:00-22:59

2 Data

2.1 Study Area and Zone system

The model system is primarily developed for mainland Finland, which constitutes the main model area. This is also the area covered by the travel survey data and supporting input datasets used for model estimation and application. However, the model area has been extended to cover the Åland Islands and Haparanda (Sweden) to ensure complete representation of national and cross-border travel demand.

The model area is divided into approximately 8500 traffic analysis zones (TAZs) representing the origins and destinations of trips and tours. Zone sizes vary according to population and employment density. The zone system also follows natural barriers, such as major roads, railways, and water bodies, as well as administrative boundaries, particularly municipal borders.

Finland is sparsely populated, with a large land area relative to its population. Consequently, model zone sizes vary considerably across the study area. The minimum distance between zone centroids is approximately 250 meters, while the largest zones extend up to 20 kilometers in size.

2.2 Choice Data

The primary data source for model estimation is the Finnish National Travel Survey 2016 (HLT 2016). Finnish National Travel Survey have been conducted at approximately six-year intervals since 1974. The target group of the survey include all Finnish residents who were at least six years old at the time study, excluding Åland islands.

HLT 2016 database contains national sample and additional regional samples. National sample was drawn from whole Finland, and it was stratified by age, gender and living area. The sample included 22600 individuals, of whom approximately 9300 responded to the survey.

Regional samples were collected from 10 urban regions with similar methodology as national survey. Regional samples are drawn independently from national samples. Survey questionnaire is largely similar, but some questions (income, household driver's license) are missing from regional data. The total size of regional samples was 47600 persons from which 21900 persons responded to survey.

The travel survey data has information about persons background (age, car ownership, education, income level) and tours that person has made during the selected survey date. Data collection conducted during the year 2016 and each respondent was given a random survey date during the year.

Also separate long distance survey was collected in 2016 National Travel Survey. However, this sample was not used in model estimation as data had major limitations in accuracy of destination location and available attributes.

2.3 Attraction Data

The demand model uses separate land-use datasets for estimation and application. Estimation is based on detailed observed land-use statistics, whereas application relies entirely on open data sources, requiring more approximation in the derivation of land-use variables. To ensure consistency between model estimation and application, calibration is performed using the open-data-based dataset employed in model application. Calibration helps account for any systematic differences between the two data sources.

Model estimation uses attraction data from the Grid Database by Statistics Finland (2026a). Database provides key data on the population and workplaces by 250 meters statistical grid in geographic data format. The data describe, for example, the age, income and employment of inhabitants.

The data contains information about:

- inhabitant by age groups
- education level of inhabitants
- income of inhabitants and households
- size and life stage of households
- buildings and dwellings
- workplaces and main activities of inhabitants.

The dataset used for model estimation is from 2018, which closely corresponds to the year of the National Travel Survey used for model development. Data from 2016 was not available during model estimation phase.

For model application, a different data source is used to ensure that the model system relies entirely on open data. Attraction variables are derived from the open postal code area dataset (2026b), which contains information broadly consistent with that available in the Grid Database but at a coarser geographical resolution. To improve spatial detail, the postal code area data are disaggregated to the 250 m × 250 m grid using open building register data (SYKE 2026a).

2.4 Level-of-service data

Level-of-service matrices are produced by the assignment model, which is described in section 7.

The cost of driving is calculated based on the network distance and a unit driving cost, which includes fuel costs, maintenance expenses, and vehicle depreciation. Fuel costs are based on the Valma car fleet model (Traficom 2026).

Fare data for public transport was collected manually for the year 2023. A sample of actual fares were collected for each public transport operator, and linear regression was used to derive distance-based fares for each region. Fare data was collected separately for single and season tickets, but only single ticket prices currently affect modelled choices.

3 Tour generation

Estimating the number of tours is the first step in a travel demand forecasting model and is a key determinant of the total travel volume produced by the model system. Tour generation can be modelled with different approaches, such as linear regression, category analysis and different types of logit choice models (e.g. Jahanshahi et al. 2017).

In VALMA model the primary tour-generation method is category analysis, supplemented by a logit model for the one tour purpose for which a statistically significant relationship between trip-making and accessibility.

3.1 Tour rates

The model is based on tour production rates segmented by age group and household car ownership for each tour purpose (Figure 3). The car owners make on average more tours per day on many travel purposes.

Home-to-home tours (tours without separate destination, e.g. walking a dog) are not included in the tour purposes demand model. These tours are omitted, i.e. the tour rates of other purposes are not increased correspondingly. The omitted tours would have a tour rate of 0.18 tours per day per person.

The combined tour rate average of all purposes included in travel demand model by tour rates is 1.04 tours per day per person. In addition, secondary and higher education tours generated by logit model would correspond to around 0.03 tours per day per person.

Open tours (i.e. only outward or return trip during a survey day) are treated as half tours in tour rate calculations. This concerns mostly overnight purpose tours, which are always open tours.

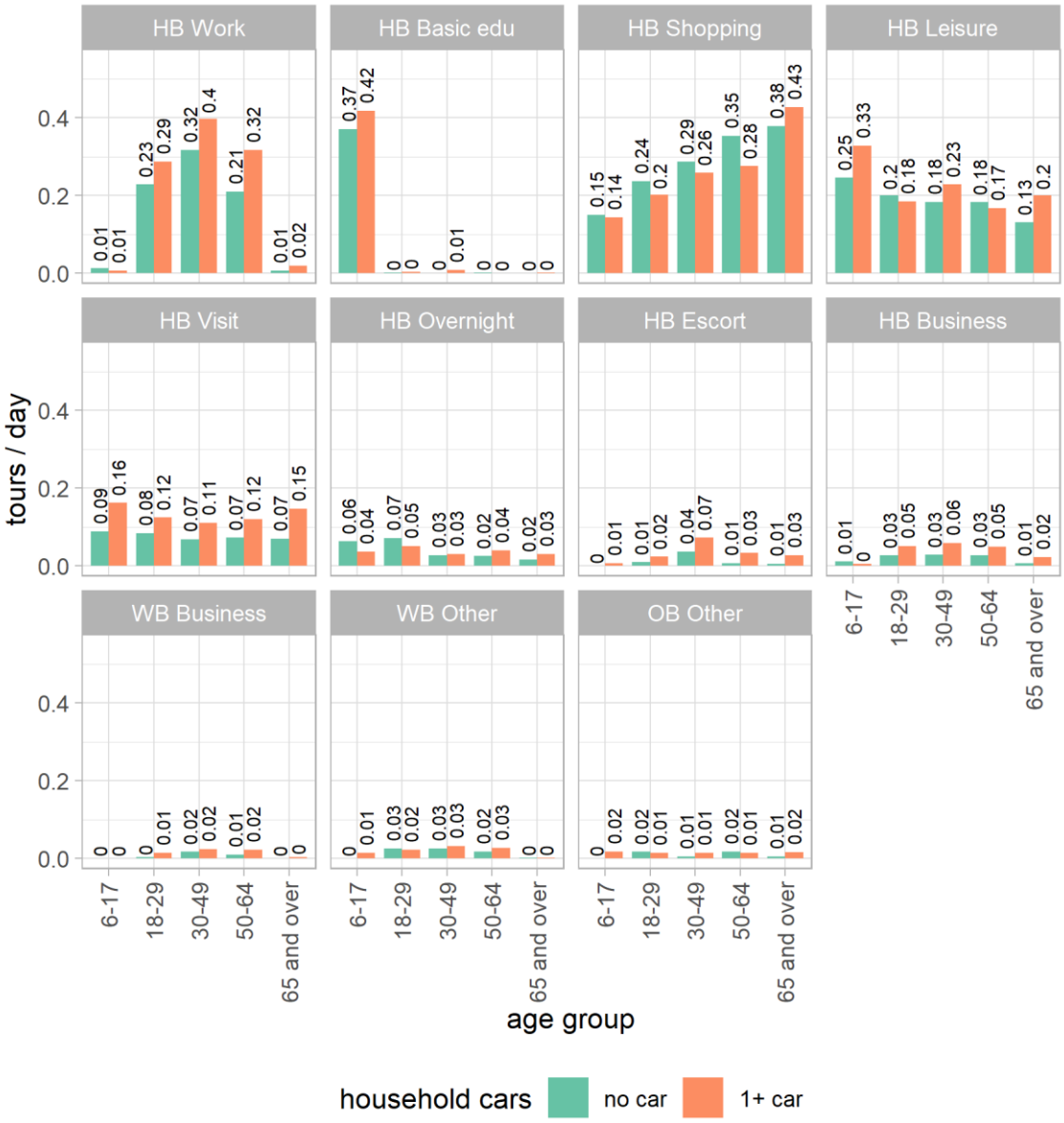


Figure 3. Purpose specific tour rates.

3.2 Travel frequency choice model

Travel frequency choice models were studied for all tour purposes during model development, but significant relationship between accessibility and tour generation was found only for secondary and higher education students. For students in secondary and higher education accessibility has an important role in the generation of education-related tours, because students tend to locate closer to educational institutions or accessibility might influence educational participation decisions. Therefore, logit choice model is used to model tour generation of secondary and higher education tours.

Binary logit model was used to estimate the choice between 0 or 1 daily education tours for students. Zero tour was chosen to be base alternative in choice model. Estimation was done using Biogeme software (Bierlaire 2023).

Explanatory variables include age groups as in tour rate-based models and accessibility (Table 4). Analysis is based on 5482 observations.

- Age groups are main determinants of choice. Only three age groups were significant to student tour generation, others were not different from zero.

- Accessibility is derived from the mode-destination choice model as a logsum measure. It represents the expected maximum utility available from the set of mode and destination alternatives.

Table 4. Estimated parameters for education tours of students.

Coefficient	Estimate	Std. error	T-test
Constant	6.098	0.178	34.312
Accessibility (logsum)	0.146	0.026	5.573
Age 7–17	2.518	0.147	17.142
Age 18–29	3.276	0.141	23.266
Age 30–49	1.414	0.155	9.145

4 Mode-destination choice models

Mode-destination choice models describe the probabilities of choosing among discrete mode and destination alternatives. Previous research has shown that the alternatives are not entirely independent, and therefore a nested logit model specification is used to represent the correlation structure between choices.

The mode-destination choice models were estimated using Alogit software (Daly, 2022), which supports the inclusion of nonlinear size variables in utility functions and can efficiently handle very large choice sets.

4.1 Model structure for everyday travel

The mode-destination choice models for everyday travel demand are specified as nested logit models, where mode choice constitutes the upper level of the hierarchy and destination choice the lower level (Figure 4). This means that the correlation between the utilities of the alternatives and sensitivity to changes in attribute values is higher for the destination choice.

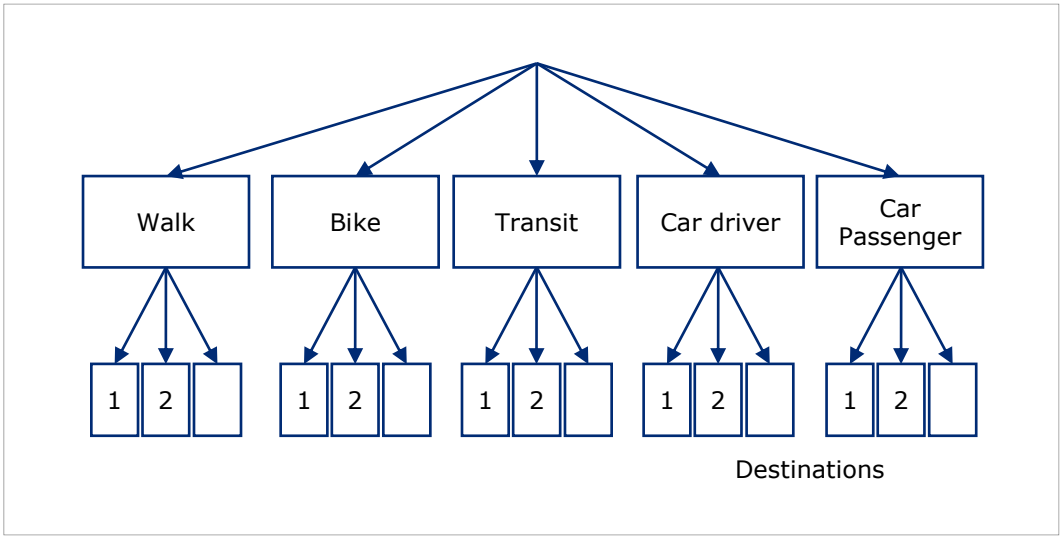


Figure 4. Nested logit structure for everyday travel demand models.

The model structure was confirmed by estimation. The structural parameter value (logsum) parameter was significantly below one for all tour purposes except work-based business tours, where structural parameter was not significantly different from one and was constrained.

Choice probabilities are calculated using the following nested logit formulation:

$$p_{md} = p_m p_{d|m} = \frac{\exp V_m}{\sum_{m'} \exp V_{m'}} \cdot \frac{\exp V_{md}}{\sum_{d'} \exp V_{md'}},$$

where

$$V_m = \theta \, log \sum_{d'} exp \, V_{md'}$$

That is composite utility of choosing mode m and V_{md} is utility of mode m and destination d. The composite utility represents the maximum expected utility associated with a specific mode alternative and is commonly referred to as the logsum, or accessibility measure.

The utility function is defined in form:

$$V_{md} = \sum_{d'} \beta \, x_{md} + \theta y + \emptyset \log S_d$$

where $x\mathrm{md}$ gives the level of service offered by mode m to destination d. These level of services are for example travel time and cost for car and public transport and distance for walk and bike modes. The utility function may also include variables y describing attributes of the decision-maker, such as household car availability.

Latter part of utility function $S\mathrm{d}$ is a measure of the quantity or size of the attraction of zone. This size variable describes the quantity or size of model zones, that larger store would have more value to customer, and is specified inside a log operation so that the destination choice model is not sensitive to the level of zonal aggregation (see Daly 1982, Kristoffersson 2017).

4.2 Model structure for occasional travel

The mode-destination choice models for occasional travel demand are also specified as nested logit models, but a different structure is used. Firstly, an access and egress mode layer is added to transit and airplane main mode choice models, modelling the choice between car, taxi, local transit and walking as access and egress modes to these main modes. Secondly, the hierarchy of choice is defined so that destination choice is the top-level choice, before mode and access mode choice.

Each access and egress mode alternative represents the whole multimodal trip chain, including the main mode. The mode change location (e.g., park-and-ride facility) in the multimodal trip chain is determined by the route choice algorithm. This means that the travel time and cost of the main mode varies across access and egress mode alternatives. The route choice is described in more detail in Kuivalainen 2024.

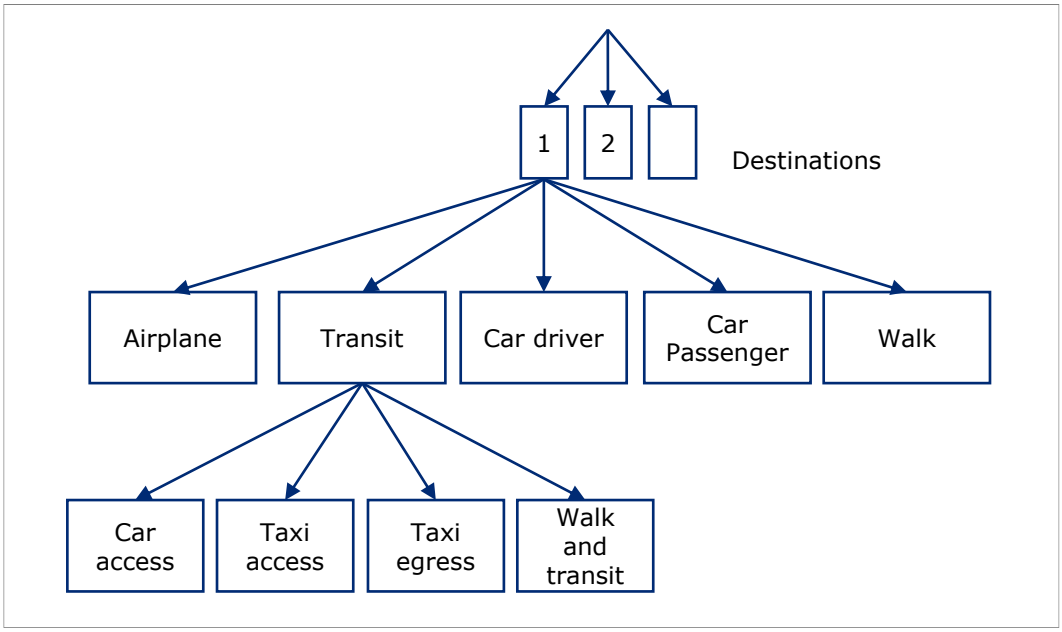


Figure 5. Nested logit structure for occasional travel demand models.

The estimation procedure for access mode choice is sequential and was adapted to accommodate data limitations. First, access mode choice model is estimated using data from all purposes and observations for both airplane and transit. The alternative specific constants are calibrated for airplane and transit separately. Then logsums are calculated for both airplane and transit and used in upper-level choices between main mode and destinations of tour.

Utility function of occasional travel has similar specification as everyday travel demand models with size variables. Explanatory variables are largely similar for both models, including variables related to level-of-service, decision-maker and travel destination.

4.3 Specification of variables

The utility function presented above can include many dimensions affecting the choices. Composition of utility is dependent on travel purpose and mode, but it has following variables common to all tour purposes:

- Travel time (alternative specific coefficients for car driver, car passenger, transit)
- Travel cost (joint coefficient for car driver, car passenger, transit)
- Travel distance (alternative specific coefficients for walk, bike)
- Car available in household (alternative specific coefficients for car driver and car passenger)
- Attraction variables (joint coefficient for all modes)
- Mode specific constants to capture unknown effects

A common travel cost parameter is estimated for the car driver, car passenger, and public transport alternatives. Travel time parameters on the other hand vary between means of transport, which accounts that travel times consist of weighted impedances of the travel time components and that modes have different values-of-times.

Travel time and cost variables are modelled by considering the cost damping effect. Cost-damping means that the sensitivity of demand with respect to transport costs declines as the cost increases. This effect has very strong empirical evidence based on modelling studies where effect has been tested and value-of-time studies (Daly 2010).

Cost damping is represented in VALMA by including the cost variable in both linear and logarithmic form in the utility function. This specification was supported by the estimation results for most travel purposes, providing an improved model fit, as measured by the log-likelihood statistic, while yielding plausible cost elasticities.

For each purpose value-of-time is calculated using cost and time coefficient of models. Logarithmic transformation of cost means that values-of-time are dependent on the actual value of travel costs. The implied value-of-time is calculated with following equation and reported in sections below (adopted from Kristoffersson 2024):

$$VoT = \frac{60 * \beta}{(\gamma_{linear} + \gamma_{log} * \frac{1}{cost})}$$

In the following results, the average value of time is calculated using the observed travel cost distribution from the survey data. This provides a consistency of estimated models in comparison with the values of time recommended in transport appraisal guidelines (Väylävirasto 2024).

4.3.1 Travel time

Travel time is considered for car, transit and airplane modes. Transit travel times are weighted to account for different perception of the trip stages, such as access and transfer walking. These travel time weights come from the route choice model, which is documented in more detail in section 7.

Car travel time is also calculated as weighted travel time, but this does not affect route choices. Unweighted travel times are first calculated using the traffic assignment model, including congestion effects. The difference between free-flow and congested travel times is weighted by a factor of 1.5. Walking and parking time is added based on the origin and destination of tour. Walk time is added to both ends of tour and parking time only to destination.

Walking time and parking-search time for car trips are modelled using a simple density-based approach derived from survey data collected in the Helsinki region (Vesanen 2020). The walk and parking search time increase to the square root of density of origin and destination zones (Figure 6 and Figure 7).



Figure 6. Average parking search time as function of population and workplace density.



Figure 7. Average walk time as function of population and workplace density.

Transit and airplane travel times are calculated by assignment model, which includes all transit lines for Finland and is based on GTFS register data. The assignment model is frequency based, and waiting times are represented using a nonlinear function adopted from the Swedish Value-of-Time study model. Transit line specific headway deviation and boarding penalties are used.

4.3.2 Travel cost

Travel costs are considered for car, transit and airplane modes. Calculation of car costs includes both driving cost, road tolls and parking charges and considers the sharing of costs between drivers and passengers. Parking costs are added to travel cost by using three additional information:

- Zone specific parking fees (eur/h) collected from open data sources.
- Purpose specific activity times from National Travel Survey (Figure 8).

- Purpose-specific shares of travellers required to pay for parking, derived from a dedicated parking-behavior survey.

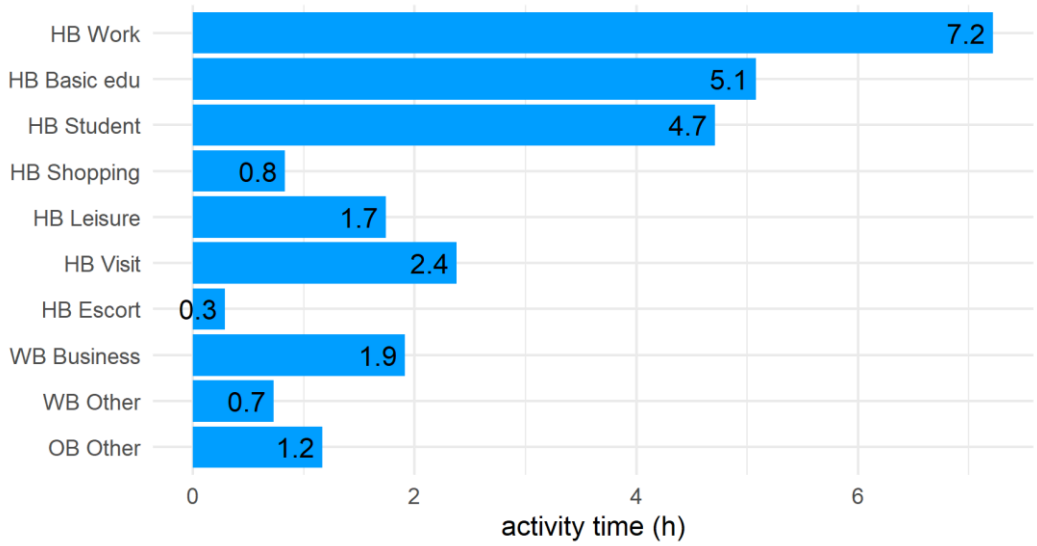


Figure 8. Time spent (h) at primary destination per tour type.

The cost sharing is modelled with method presented in Fox (2009) and Rich and Fox (2024). Assumption is made that the choice decision is taken by the individuals contributing to the cost of the trip. The degree of cost sharing varies by travel purpose and was determined empirically during model estimation.

$$V(cost)_{CD} = \beta_{cost} CarCost(1 - \frac{S(O_{CD} - 1)}{O_{CD}})$$

$$V(cost)_{CP} = \beta_{cost} CarCost(1 - \frac{S}{O_{CP}})$$

where

O_{CD}= Mean occupancy for car driver observations

$CarCost$= Car cost including parking costs

O_{CP}= Mean occupancy for car passenger observations

β_{cost}= Cost parameter estimated along model itself

S = Cost sharing factor

When S takes a value of 0 the driver pays the full cost and value of 1 means that there is equal sharing. Intermediate values of *S* mean that the driver pays a greater share, but both driver and passengers contribute to the cost. The value S is determined in model estimation by using the value that gives the best fit to the observed data. Different values of S are tested iteratively (0, 0.25, 0.50, 0.75, 1) and sharing factors yielding highest utility is chosen.

The mean occupancy for each travel purpose (Table 5) and resulting sharing factors (Table 6) are presented below. Car driver is not represented in the basic education and non-home based purpose models and so no cost sharing tests have been made in these cases.

Table 5. Mean occupancy values by tour purpose

Purpose	Car driver	Car passenger

HB Work	1.15	2.05
HB Students	1.38	2.26
HB Shopping	1.52	2.48
HB Leisure	1.74	2.94
HB Visit	1.69	2.84
HB Escort	1.83	-

Table 6. Sharing factors for car cost

Purpose	Cost Sharing Factor (S)
HB Work	0.0
HB Students	0.5
HB Shopping	1.00
HB Leisure	0.75
HB Visit	0.25
HB Escort	1.0

Transit and airplane cost consist of average ticket prices. Ticket prices are dependent on the origin and destination of tour and public transport operator on this connection. Sample of ticket prices were collected for each operator and average price calculated with linear regression that consists of constant (base price) and kilometer-based part.

The same methodology is applied to both short-distance and long-distance public transport services. Season ticket discounts and dynamic pricing are not considered in current model version, which might affect the model performance.

4.3.3 Intrazonal distances

Transport models work by dividing the study area into traffic analysis zones and considering travel between these zones. However, there is much demand within these zones, when active modes are included in transport model. In context of VALMA model the importance of intrazonal travel is highlighted, because model area includes very large zones in sparsely populated areas.

Usual way of handling intrazonal trips is using either network-based approaches or zonal attribute approaches (Weston and Davidson 2019). The network-based approach is based on the assumption that there is a relationship between the time to travel within a zone and the time it takes to travel to neighboring zones. The simplest assumption is that the intrazonal time is simply a factor of 0.5 of the shortest interzonal time. An alternative approach is to base the intrazonal travel time only on variables that describe the zone itself, where the simplest version of this approach is to assume some function of the area of the zone as (for example zone radius).

Also, there are different approaches to entering intrazonal distance to utility function. Distance can be used to impute the missing level of service to diagonal of matrix (e.g. Fox et al. 2010, Fox et al. 2016) or as its own variable (e.g. HSL 2026, Kristoffersson et al. 2024).

Due to the large variation in zone sizes, neither of the two most common approaches produced satisfactory results in rural areas, particularly in cases where a large zone contained a village center. Therefore, the Valma model uses intrazonal distances calculated from a 250 m land-use grid as the weighted mean distance between grid cells, using population and workplace counts as weights. These intrazonal level-of-service values are assigned to the diagonal of the walking, cycling and car level-of-service matrices.

4.3.4 Socio-economic variables

Socio-economic variables can enter the model in two ways. Travelers can be segmented into groups with distinct travel preferences or separate parameters for certain segments can be estimated. In VALMA only a limited

number of socio-economic variables are included in the first model version because of computational and implementation constraints. First version of the model has separate dummy parameters for car availability in household.

The national and regional travel survey samples contain different information on car availability. As a result, separate car availability coefficients were estimated for the national and regional samples. The final model specification adopts the coefficients estimated from the national sample. In addition, survey-specific mode constants were included to account for systematic differences in unobserved utility arising from the measurement of car availability between the two survey sources.

For the national travel survey sample, car availability is derived from household vehicle ownership, household size and the number of driving licence holders in the household:

- Freely available car: a car is assumed to be freely available for use as a car driver if the number of household cars is equal to or greater than the number of driving licence holders.
- Competing car availability: a car is assumed to be available, but subject to competition from other household members, when the household owns at least one car and the number of driving licence holders exceeds the number of cars.
- Car passenger availability: car availability as a passenger is assumed when the household has at least two members, owns at least one car and contains at least one driving licence holder.

For the regional travel survey sample, car availability is derived from household size and vehicle ownership:

- Freely available car: a car is assumed to be freely available for use as a car driver if the number of household cars is equal to or greater than the number of household members.
- Competing car availability: a car is assumed to be available, but subject to competition, when the household owns at least one car and the number of household members exceeds the number of cars.

Compared with the national sample, the regional survey does not provide information on driving licence ownership. Therefore, household size is used as a proxy for potential competition for vehicle use within the household.

4.3.5 Availability of alternatives

Alternative availability is currently defined through two purpose and mode constraints. First, transit mode is unavailable for intrazonal tours for all purposes. Secondly, distance-based availability is set for everyday travel (Table 7). These intervals are based on analysis of tour data distances. Most observed tours fall within these distance ranges, while observations outside the ranges are relatively rare and may reasonably be treated as outliers.

First version of demand model does not include any availability conditions based on individual attributes of decision maker. These conditions are omitted due to technical reasons as individual conditions require splitting demand matrices by this segment and causes high memory consumption.

Table 7. Availability conditions for travel purposes (km).

Tour type	Walk	Bike	Transit	Car driver	Car passenger	Airplane
HB Work	0-10	0-20	0-300	0-300	0-300	-
HB Basic Education			0-100	0-100	0-100	-
HB Student			0-300	0-300	0-300	-
HB Shopping			0-100	0-100	0-100	-
HB Leisure			0-300	0-300	0-300	-
HB Visit			0-300	0-300	0-300	-
HB Escort			0-100	0-100	0-100	-
WB Other			0-100	0-100	0-100	-

WB Business			0-300	0-300	0-300	-
OB Other			0-100	0-100	0-100	-
HB Overnight	0–10	-	0–1300	0–1300	0–1300	0–1300
HB Business	0–10	-	0–1300	0–1200	0–1300	0–1300

4.4 Estimation results for daily travel

4.4.1 Home-based Work Tours

The home-based work purpose includes all tours that originate at home and have the traveller's own workplace as the primary destination. It is the largest tour purpose in terms of daily tour volume. Analysis is based on 6670 tour observations.

Table 8 presents the estimation results for HB Work travel purpose. All coefficients are statistically significant and have correct signs:

- Availability of car in household increases the probability of choosing car for both car driver and passenger. Exclusive access to a vehicle increases the probability of choosing the car-driver mode more than access to a shared household vehicle.
- The distance coefficients for walking and cycling are negative, as expected. Walking is more common over short distances, while cycling becomes increasingly attractive as distance increases due to its less negative distance coefficient. The breakeven point between walking and cycling is approximately 4 km, beyond which cycling becomes the preferred mode, all else being equal.
- The walking and cycling distance coefficients imply travel speeds of approximately 3.5 km/h and 11 km/h, respectively, when divided by the car driver travel time coefficient. These values should not be interpreted as actual travel speeds, as the coefficients reflect perceived travel time and distance rather than observed physical speeds.
- Cycling has a negative coefficient for destination zone density. This reflects the increased difficulty of finding bicycle parking and the effects of higher traffic volumes and congestion in dense urban environments, which reduce the attractiveness of cycling as a travel mode.
- There are positive public transport authority dummy variables for individuals living in the Helsinki, Turku, and Tampere regions. These capture the higher quality of public transport services in these areas that is not reflected in the level-of-service (LOS) matrices, such as integrated ticketing systems, passenger information services, and other service quality attributes.
- The Oulu region has a positive cycling dummy variable. Since cycling level of service in the current model is represented only by road network distance, this coefficient likely captures factors that are not explicitly included in the model, such as the quality of cycling infrastructure, maintenance standards, and other investments that improve cycling conditions.
- The structural parameter value (logsum) parameter is less than one, indicating that the chosen nesting structure is consistent and captures the correlation between alternatives within the same nest.
- Relationship between travel cost and time is dependent on travel costs (Figure 9). The values imply average value-of-time 14,8 eur/h for car driver and 4,9 eur/h for transit when weighted with demand.

Table 8. HB Work Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car passenger, ref: walk), Regional samples	-4.477	0.336	-13.30
Constant (Car passenger, ref: walk), National sample	-4.505	0.406	-11.10
Constant (Car driver, ref: walk), Regional samples	-4.243	0.338	-12.60
Constant (Car driver, ref: walk), National sample	-3.307	0.348	-9.50
Origin zone is in Turku region (Transit, ref: rest of Finland)	0.445	0.181	2.50
Origin zone is in Tampere region (Transit, ref: rest of Finland)	0.571	0.164	3.50
Origin zone is in Helsinki region (Transit, ref: rest of Finland)	1.320	0.171	7.70
Constant (Transit)	-2.565	0.230	-11.20
Origin zone is in Oulu region (Bike, ref: rest of Finland)	0.874	0.149	5.90
Constant (Bike, ref: walk)	-1.289	0.131	-9.90
Car availability in household (Car passenger), Regional samples	0.982	0.238	4.10
Car availability in household (Car passenger), National sample	0.929	0.352	2.60
Travel time (Car passenger)	-0.059	0.003	-20.50
Competed car availability in household (Car driver), Regional samples	3.682	0.367	10.00
Free car availability in household (Car driver), Regional samples	5.428	0.427	12.70
Competed car availability in household (Car driver), National sample	2.813	0.378	7.40
Free car availability in household (Car driver), National sample	4.243	0.412	10.30
Travel time (Car driver)	-0.029	0.002	-17.40
Logarithm of Travel Cost (Transit, Car Passenger, Car driver)	-0.186	0.029	-6.50
Travel Cost (Transit, Car Passenger, Car driver)	-0.054	0.006	-9.50
Travel time (Transit)	-0.011	0.001	-17.50
Population and workplace density in destination zone (Bike)	0.000	0.000	-2.50
Travel distance (Bike)	-0.142	0.006	-23.80
Travel distance (Walk)	-0.494	0.025	-19.50
Log size multiplier (Normalized to one)	1.00	-	-
Structure parameter (Logsum)	0.80	0.06	14.10
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.20	0.06	-3.60

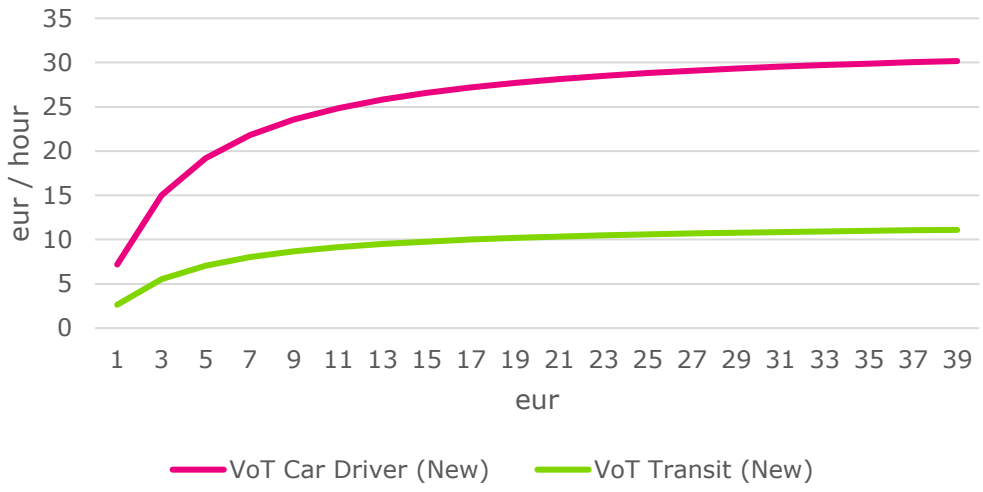


Figure 9. Value-of-time as function of travel cost for HB Work purpose.

4.4.2 Home-based Basic Education Tours

Basic education tours have only car passenger, transit, bike and walk as mode alternatives. Car driver mode is not available because all travellers are under 18 years old and cannot own driver's license. Analysis is based on 1561 observations.

Table 9 presents the estimation results for HB Basic Education travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- Time and distance coefficients were used as measures of travel impedance. Cost parameters did not have a meaningful effect on basic education tours and were therefore not included in the final model specification.
- The size factor is divided into school enrolments within and outside the home municipality. Since attending school outside the home municipality is uncommon, enrolments outside the municipality (S_outside) receive a lower weight.

Table 9. HB Basic Education Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car passenger, ref: walk), Regional samples	-5.277	1.480	-3.60
Constant (Car passenger, ref: walk), National sample	-3.835	2.010	-1.90
Origin zone is in Turku region (Transit, ref: rest of Finland)	0.366	0.461	0.80
Origin zone is in Tampere region (Transit, ref: rest of Finland)	-0.954	0.531	-1.80
Origin zone is in Helsinki region (Transit, ref: rest of Finland)	0.266	0.412	0.60
Constant (Transit)	-4.190	0.369	-11.30
Origin zone is in Oulu region (Bike, ref: rest of Finland)	2.657	0.408	6.50
Constant (Bike, ref: walk)	-1.477	0.236	-6.30
Car availability in household (Car passenger), Regional samples	3.219	1.440	2.20
Car availability in household (Car passenger), National sample	1.585	2.010	0.80
Travel time (Car passenger)	-0.127	0.010	-13.10
Travel time (Transit)	-0.015	0.002	-9.50
Population and workplace density in destination zone (Bike)	0.000	0.000	-2.80
Travel distance (Bike)	-0.399	0.019	-21.20
Travel distance (Walk)	-0.694	0.037	-19.00
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter (Logsum)	0.46	0.05	9.50
Linear conversion of size coefficients			
Student enrollments outside own municipality (Size)	0.09	0.02	
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.54	0.05	-11.20

4.4.3 Home-based Student Tours

Student tours include trips to higher education, upper secondary education, and vocational education destinations. The model is based on 807 observations, resulting in limited estimation precision.

Table 10 presents the estimation results for HB Student travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- Size variables for student tours are based on enrolments in higher education, vocational education, and upper secondary education institutions. The coefficient for higher education enrolments is normalized to one, while vocational and upper secondary education enrolments receive lower weights.
- The overall level for value-of-time is lower than for work tours, which is expected (Figure 10). The values imply average value-of-time 9,6 eur/h for car driver and 3,0 eur/h for transit when weighted with demand.

Table 10. HB Student Education Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car passenger, ref: walk), Regional samples	-3.977	0.593	-6.70
Constant (Car passenger, ref: walk), National sample	-4.131	0.784	-5.30
Constant (Car driver, ref: walk), Regional samples	-5.891	1.350	-4.40
Constant (Car driver, ref: walk), National sample	-4.757	1.330	-3.60
Constant (Transit)	-0.419	0.278	-1.50
Constant (Bike, ref: walk)	-0.712	0.271	-2.60
Car availability in household (Car passenger), Regional samples	1.226	0.486	2.50
Car availability in household (Car passenger), National sample	1.027	0.724	1.40
Travel time (Car passenger)	-0.041	0.008	-4.90
Competed car availability in household (Car driver), Regional samples	4.170	1.340	3.10
Free car availability in household (Car driver), Regional samples	5.084	1.360	3.70
Competed car availability in household (Car driver), National sample	3.368	1.350	2.50
Free car availability in household (Car driver), National sample	4.076	1.370	3.00
Travel time (Car driver)	-0.030	0.007	-4.20
Logarithm of Travel Cost (Transit, Car Passenger, Car driver)	-0.675	0.131	-5.20
Travel Cost (Transit, Car Passenger, Car driver)	-0.052	0.022	-2.40
Travel time (Transit)	-0.009	0.001	-6.70
Population and workplace density in destination zone (Bike)	0.000	0.000	-1.80
Travel distance (Bike)	-0.253	0.021	-12.000
Travel distance (Walk)	-0.426	0.034	-12.600
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter (Logsum)	0.86	0.09	9.30
Linear conversion of size coefficients			
Student enrollments in secondary education (Size)	0.44	0.04	
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.14	0.09	-1.50

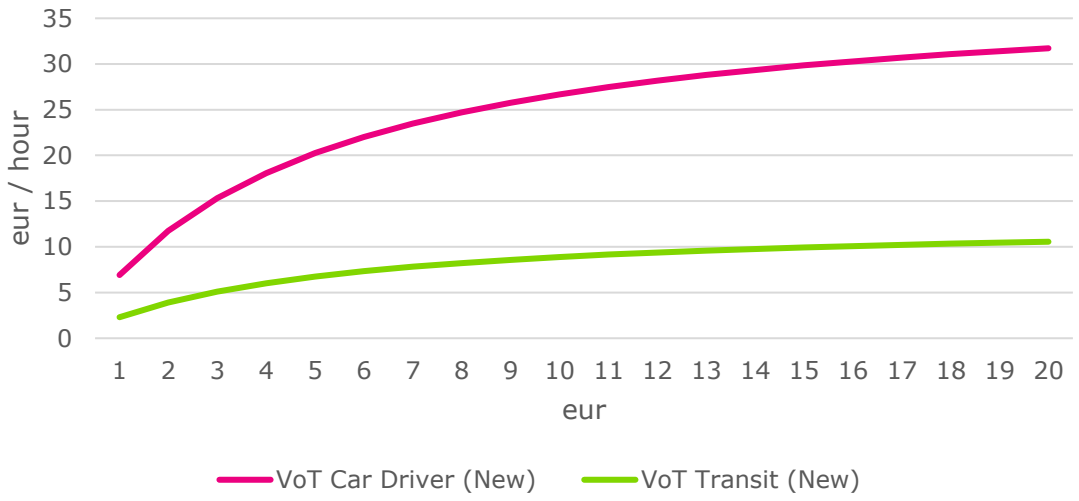


Figure 10. Value-of-time as function of travel cost for HB Student purpose.

4.4.4 Home-based Shopping Tours

Shopping tours include tours to daily shopping destinations, malls and errands. Therefore, purpose includes tours to many type of services, such as healthcare. Analysis is based on 7599 observations.

Table 11 presents the estimation results for HB Shopping travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- Size factor for grocery tours is number of employees in retail trade industry (TOL 2008, G), healthcare industry (TOL 2008, Q) and other services (TOL 2008, N). Size factor for retail is normalized to one, and healthcare industry and other services have lower weight than retail.
- The overall level for value-of-time is lower than for work tours, which is expected (Figure 11). The values imply average value-of-time 6,7 eur/h for car driver and 2,9 eur/h for transit when weighted with demand.

Table 11. HB Shopping Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car passenger, ref: walk), Regional samples	-5.15	0.24	-21.60
Constant (Car passenger, ref: walk), National sample	-5.72	0.36	-15.90
Constant (Car driver, ref: walk), Regional samples	-6.12	0.37	-16.50
Constant (Car driver, ref: walk), National sample	-5.32	0.40	-13.40
Origin zone is in Turku region (Transit, ref: rest of Finland)	0.88	0.28	3.20
Origin zone is in Tampere region (Transit, ref: rest of Finland)	0.61	0.27	2.20
Origin zone is in Helsinki region (Transit, ref: rest of Finland)	1.14	0.25	4.50
Constant (Transit)	-2.68	0.31	-8.70
Origin zone is in Oulu region (Bike, ref: rest of Finland)	1.09	0.18	6.00
Constant (Bike, ref: walk)	-2.79	0.18	-15.70
Car availability in household (Car passenger), Regional samples	2.44	0.22	11.00
Car availability in household (Car passenger), National sample	2.73	0.35	7.90
Travel time (Car passenger)	-0.06	0.00	-17.30
Competed car availability in household (Car driver), Regional samples	4.90	0.42	11.70
Free car availability in household (Car driver), Regional samples	5.47	0.45	12.30
Competed car availability in household (Car driver), National sample	4.43	0.45	9.80
Free car availability in household (Car driver), National sample	4.71	0.46	10.30
Travel time (Car driver)	-0.07	0.00	-18.10
Logarithm of Travel Cost (Transit, Car Passenger, Car driver)	-0.46	0.04	-12.00
Travel Cost (Transit, Car Passenger, Car driver)	-0.013	0.02	-0.70
Travel time (Transit)	-0.03	0.00	-19.20
Population and workplace density in destination zone (Bike)	0.00	0.00	-2.00
Travel distance (Bike)	-0.31	0.01	-20.90
Travel distance (Walk)	-0.65	0.02	-42.50
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter (Logsum)	0.29	0.04	7.70
Linear conversion of size coefficients			
Workers in other services (Size)	0.26	0.03	
Workers in healthcare industry (Size)	0.07	0.00	
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.35	0.04	-8.60

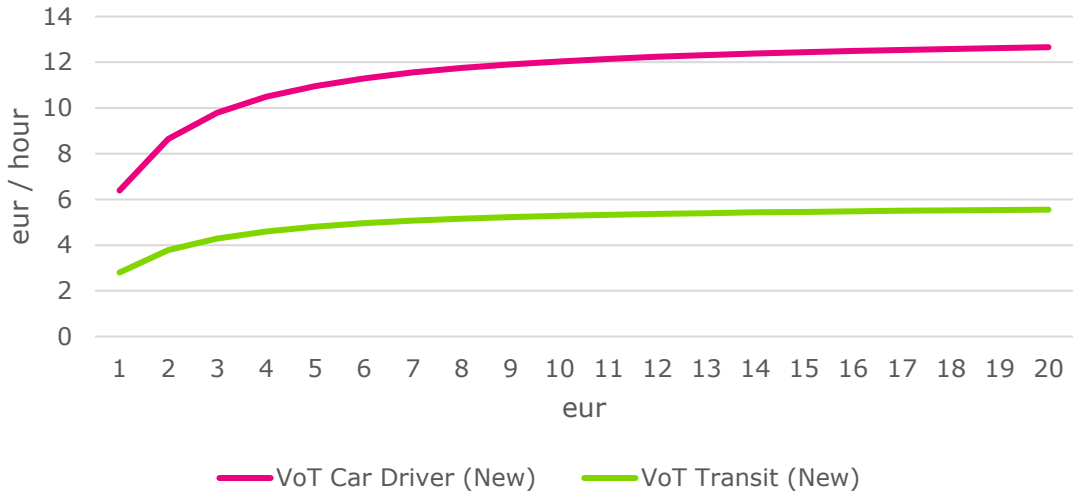


Figure 11. Value-of-time as function of travel cost for HB Shopping purpose.

4.4.5 Home-based Leisure Tours

Leisure tours include tours to several other leisure destinations, such as cultural events, restaurants, cafes and bars. In addition, destinations include exercise or recreation facilities, parks and other places for leisure activities. Analysis is based on 5808 observations.

Table 12 presents the estimation results for HB Leisure travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- Size factor for leisure tours is number of employees in accommodation and food service activities industry (TOL 2008, I) entertainment and recreation industry (TOL 2008, R) and sport facilities separately for both indoor and outdoor (LIPAS-tietokanta). Size factor for accommodation and food service is normalized to one, and recreation industry has higher relative weight in destination choice.
- The overall level for value-of-time is lower than for work tours, which is expected (Figure 12). The values imply average value-of-time 10,5 eur/h for car driver and 4,1 eur/h for transit when weighted with demand.

Table 12. HB Leisure Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car passenger, ref: walk), Regional samples	-5.442	0.436	-12.50
Constant (Car passenger, ref: walk), National sample	-5.642	0.615	-9.20
Constant (Car driver, ref: walk), Regional samples	-7.689	0.859	-8.90
Constant (Car driver, ref: walk), National sample	-8.415	1.280	-6.60
Origin zone is in Turku region (Transit, ref: rest of Finland)	1.880	0.728	2.60
Origin zone is in Tampere region (Transit, ref: rest of Finland)	2.451	0.666	3.70
Origin zone is in Helsinki region (Transit, ref: rest of Finland)	4.000	0.754	5.30
Constant (Transit)	-5.091	0.863	-5.90
Origin zone is in Oulu region (Bike, ref: rest of Finland)	1.867	0.415	4.50
Constant (Bike, ref: walk)	-3.271	0.354	-9.20
Car availability in household (Car passenger), Regional samples	4.095	0.568	7.20
Car availability in household (Car passenger), National sample	3.871	0.705	5.50
Travel time (Car passenger)	-0.022	0.002	-11.10
Competed car availability in household (Car driver), Regional samples	7.209	1.020	7.10
Free car availability in household (Car driver), Regional samples	7.754	1.070	7.30
Competed car availability in household (Car driver), National sample	8.607	1.460	5.90
Free car availability in household (Car driver), National sample	8.915	1.470	6.10
Travel time (Car driver)	-0.019	0.004	-5.30

Logarithm of Travel Cost (Transit, Car Passenger, Car driver)	-0.548	0.028	-19.40
Travel Cost (Transit, Car Passenger, Car driver)	-0.063	0.018	-3.50
Travel time (Transit)	-0.011	0.001	-10.30
Population and workplace density in destination zone (Bike)	0.000	0.000	0.10
Travel distance (Bike)	-0.177	0.009	-18.80
Travel distance (Walk)	-0.332	0.013	-26.30
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter (Logsum)	0.56	0.05	12.40
Linear conversion of size coefficients			
Area of outdoor sport facilities (Size)	0.003	0.000	
Area of indoor sport facilities (Size)	0.022	0.001	
Workers in arts, entertainment and recreation (Size)	1.096	0.073	
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.44	0.05	-9.70

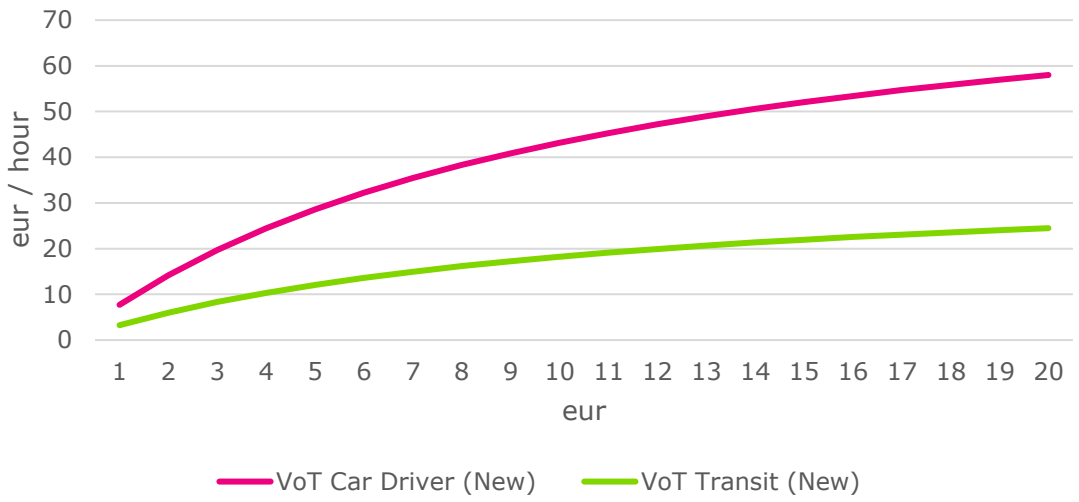


Figure 12. Value-of-time as function of travel cost for HB Leisure purpose.

4.4.6 Home-based Visit Tours

Visit tours include trips to visit relatives, friends, or acquaintances, as well as day trips to summer cottages or second homes without an overnight stay. The analysis is based on 2783 observations.

Table 13 presents the estimation results for HB Visit travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- Size factor for population in destination zone, divided into age groups, and floor area of free-time residential buildings (Classification of Buildings 2018, 02). The size factor for population under 50 years is normalized to one. Population aged 50 years and over has a higher relative in destination choice, reflecting that visits from children to their parents are more common than visits in the opposite direction.
- The overall level for value-of-time is lower than for work tours, which is expected (Figure 13). The values imply average value-of-time 2,3 eur/h for car driver and 1,3 eur/h for transit when weighted with demand.

Table 13. HB Visit Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car passenger, ref: walk), Regional samples	-12.7500	4.6000	-2.8
Constant (Car passenger, ref: walk), National sample	-9.3270	3.2700	-2.9
Constant (Car driver, ref: walk), Regional samples	-16.2000	7.6900	-2.1
Constant (Car driver, ref: walk), National sample	-16.3300	8.4500	-1.9
Origin zone is in Turku region (Transit, ref: rest of Finland)	11.9800	8.0200	1.5
Origin zone is in Tampere region (Transit, ref: rest of Finland)	15.6400	9.8000	1.6
Origin zone is in Helsinki region (Transit, ref: rest of Finland)	28.4600	16.9000	1.7
Constant (Transit)	-27.5300	15.6000	-1.8
Origin zone is in Oulu region (Bike, ref: rest of Finland)	10.1000	5.8700	1.7
Constant (Bike, ref: walk)	-9.5700	4.9200	-1.9
Car availability in household (Car passenger), Regional samples	14.7800	8.5400	1.7
Car availability in household (Car passenger), National sample	12.5200	7.4400	1.7
Travel time (Car passenger)	-0.0244	0.0015	-16.1
Competed car availability in household (Car driver), Regional samples	23.7200	13.7000	1.7
Free car availability in household (Car driver), Regional samples	26.3400	15.1000	1.7
Competed car availability in household (Car driver), National sample	28.7600	16.8000	1.7
Free car availability in household (Car driver), National sample	30.9100	17.9000	1.7
Travel time (Car driver)	-0.0242	0.0032	-7.6
Logarithm of Travel Cost (Transit, Car Passenger, Car driver)	-0.6861	0.0269	-25.5
Travel Cost (Transit, Car Passenger, Car driver)	-0.0180	0.0123	-1.5
Travel time (Transit)	-0.0116	0.0022	-5.2
Population and workplace density in destination zone (Bike)	-0.0001	0.0001	-2.1
Travel distance (Bike)	-0.2924	0.0223	-13.1
Travel distance (Walk)	-0.6838	0.0400	-17.1
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter (Logsum)	0.20	0.04	4.90
Linear conversion of size coefficients			
Floor area of free-time residential buildings (Size)	0.33	0.04	
Population older than 50 years old (Size)	2.64	0.46	
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.80	0.04	-19.90

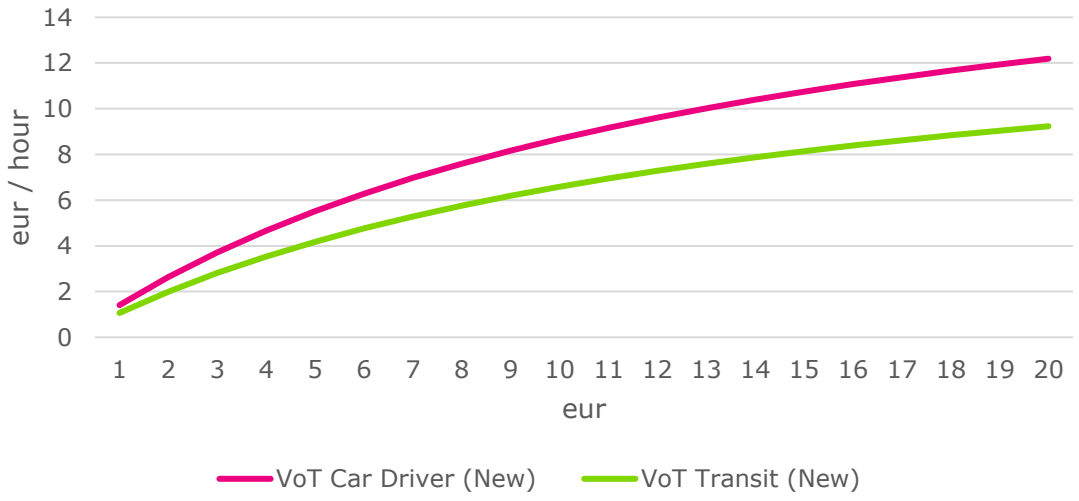


Figure 13. Value-of-time as function of travel cost for HB Visit purpose.

4.4.7 Home-based Escort Tours

Escort tours include trips made to pick up or drop off a person. The actual destinations of these tours vary widely and may include schools, public transport terminals, and places visited by relatives or friends. Mode alternatives include only car driver, bike, and walk, as car passenger is rarely used for escort tours. The analysis is based on 828 observations.

Table 14 presents the estimation results for HB Escort travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- Size factors are population in destination zone and enrolments in comprehensive schools.
- The overall level for value-of-time is lower than for work tours, which is expected (Figure 14). The values imply average value-of-time 2,3 eur/h for car driver and 1,3 eur/h for transit when weighted with demand.

Table 14. HB Escort Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car driver, ref: walk), Regional samples	-7.26	2.07	-3.50
Constant (Car driver, ref: walk), National sample	-4.72	1.65	-2.90
Constant (Transit)	-4.72	1.92	-2.50
Constant (Bike, ref: walk)	-5.44	1.69	-3.20
Competed car availability in household (Car driver), Regional samples	8.44	3.42	2.50
Free car availability in household (Car driver), Regional samples	10.77	4.20	2.60
Competed car availability in household (Car driver), National sample	6.56	2.88	2.30
Free car availability in household (Car driver), National sample	7.49	3.17	2.40
Travel time (Car driver)	-0.01	0.01	-0.80
Logarithm of Travel Cost (Transit, Car Passenger, Car driver)	-0.55	0.07	-7.80
Travel Cost (Transit, Car Passenger, Car driver)	-0.32	0.07	-4.60
Travel time (Transit)	-0.01	0.00	-2.30
Population and workplace density in destination zone (Bike)	0.00	0.00	0.60
Travel distance (Bike)	-0.44	0.12	-3.70
Travel distance (Walk)	-0.73	0.06	-12.00
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter (Logsum)	0.36	0.13	2.90
Linear conversion of size coefficients			
Population size factor (Size)	0.03	0.00	
Student enrollments outside own municipality (Size)	0.37	0.05	
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.65	0.09	-7.40

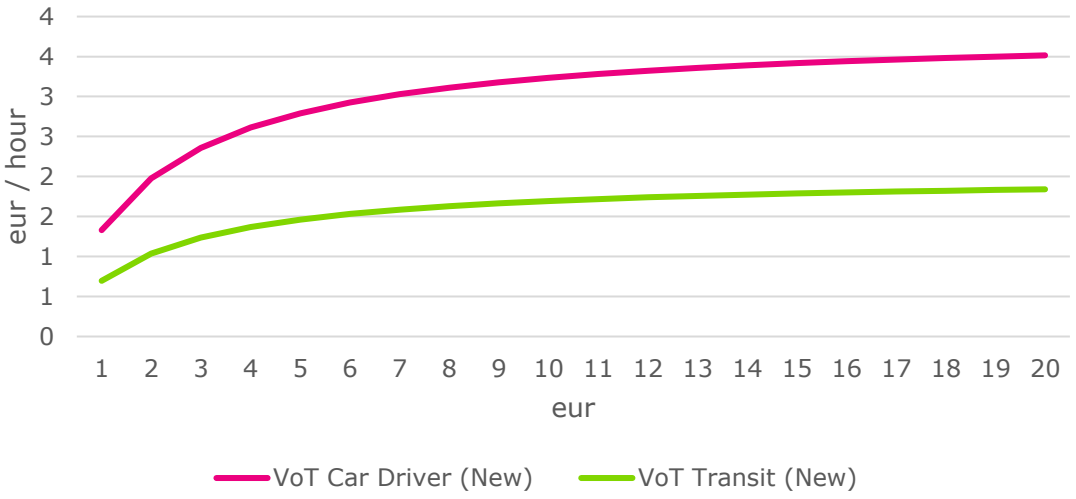


Figure 14. Value-of-time as function of travel cost for HB Escort purpose.

4.5 Estimation results for Non-Home-Based Tours

Non-home-based tours can only originate from the primary destination of a home-based tour. For the NHB tours model, there is a strong correlation between the mode chosen for the home-based tour and that used for the non-home-based tour. Therefore, the effect of car and bike availability is captured indirectly through the linkage to the home-based models.

4.5.1 Work-based Business Tours

Work-based business tours include trips that start from a work location and end at either work or business destination. The analysis is based on 370 observations, which is a relatively small sample and limits the precision of the estimated parameters.

Table 15 presents the estimation results for WB Business travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- Time and distance coefficients were used as measures of travel impedance. Cost parameters did not have a meaningful effect on business tours and were therefore not included in the final model specification.
- Size factors are workplaces in destination zone and are normalized to one.
- Car driver and bike modes of the home-based tour (Home-based tour mode was car driver (Car driver), Home-based tour mode was bike (Bike)) have a strong positive effect on choosing the same mode for the primary destination-based tour.
- The inclusive value (logsum) coefficient was not significantly different from one and was therefore fixed at one.

Table 15. WB Business Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car passenger, ref: walk), National sample	-2.67	0.48	-5.50
Constant (Car driver, ref: walk), National sample	-2.53	0.42	-6.00
Constant (Transit)	-2.42	0.59	-4.10
Constant (Bike, ref: walk)	-2.21	0.64	-3.50
Travel time (Car passenger)	-0.04	0.01	-5.50
Home-based tour mode was car driver (Car driver)	2.73	0.34	8.00
Travel time (Car driver)	-0.05	0.00	-13.50
Travel time (Transit)	-0.02	0.00	-5.40
Population and workplace density in destination zone (Bike)	0.00	0.00	-1.50
Home-based tour mode was bike (Bike)	2.72	0.69	3.90
Travel distance (Bike)	-0.49	0.13	-3.80
Travel distance (Walk)	-0.92	0.15	-6.00
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter (Logsum)	1.00	constrained	

4.5.2 Work-based Other Tours

Work-based business tours include trips that start from a work location and end at a destination other than a work or business location, typically restaurants or shops. The analysis is based on 572 observations, which is a relatively small sample and limits the precision of the estimated parameters.

Table 16 presents the estimation results for WB other travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- Size factors are workplaces in the retail, hospitality, and recreation industries (TOL 2008: G, I, R). Retail workplaces are normalized to one. Hospitality has a higher relative weight, while recreation has a lower relative weight than retail.
- Car driver and bike modes of the home-based tour (Home-based tour mode was car driver (Car driver), Home-based tour mode was bike (Bike)) have a strong positive effect on choosing the same mode for the primary destination-based tour.
- Time and distance coefficients were used as measures of travel impedance. Cost parameters did not have a meaningful effect on basic education tours and were therefore not included in the final model specification.

Table 16. WB Other Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car passenger, ref: walk), National sample	-2.86	0.39	-7.30
Constant (Car driver, ref: walk), National sample	-4.99	0.72	-6.90
Constant (Transit)	-6.29	0.74	-8.50
Constant (Bike, ref: walk)	-5.62	0.88	-6.40
Travel time (Car passenger)	-0.16	0.02	-10.40
Home-based tour mode was car driver (Car driver)	4.45	0.75	5.90
Travel time (Car driver)	-0.15	0.01	-15.60
Travel time (Transit)	-0.02	0.00	-6.10
Population and workplace density in destination zone (Bike)	0.00	0.00	-1.60
Home-based tour mode was bike (Bike)	4.06	0.86	4.70
Travel distance (Bike)	-0.53	0.10	-5.30
Travel distance (Walk)	-1.18	0.09	-13.00
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter (Logsum)	0.82	0.09	9.10
Linear conversion of size coefficients			
Workers in accommodation and food service activities (Size)	1.82	0.32	
Workers in arts, entertainment and recreation (Size)	0.86	0.25	
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.18	0.09	-2.00

4.5.3 Other-based Other Tours

Other-based other tours include trips that start from a primary destination other than work and end at a destination other than a work or business location. These tours may serve a wide range of purposes. The analysis is based on 373 observations, which is a relatively small sample and limits the precision of the estimated parameters.

Table 17 presents the estimation results for OB Other travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- Size factors are workplaces in the retail, hospitality, and recreation industries (TOL 2008: G, I, R). Retail workplaces are normalized to one. Hospitality has a higher relative weight, while recreation has a lower relative weight than retail.
- Car driver and bike modes of the home-based tour (Home-based tour mode was car driver (Car driver), Home-based tour mode was bike (Bike)) have a very strong positive effect on choosing the same mode for the primary destination-based tour.
- Time and distance coefficients were used as measures of travel impedance. Cost parameters did not have a meaningful effect on basic education tours and were therefore not included in the final model specification.

Table 17. OB Other Model variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car passenger, ref: walk), National sample	-3.37	0.70	-4.80
Constant (Car driver, ref: walk), National sample	-4.87	1.13	-4.30
Constant (Transit)	-4.50	1.51	-3.00
Constant (Bike, ref: walk)	-5.51	1.55	-3.60
Home-based tour mode was car passenger (Car passenger)	2.48	0.78	3.20
Travel time (Car passenger)	-0.07	0.01	-8.90
Home-based tour mode was car driver (Car driver)	5.68	1.47	3.90
Travel time (Car driver)	-0.09	0.01	-8.20
Travel time (Transit)	-0.03	0.01	-3.90
Population and workplace density in destination zone (Bike)	0.00	0.00	-1.40
Home-based tour mode was bike (Bike)	7.62	1.99	3.80
Travel distance (Bike)	-0.40	0.08	-4.90
Travel distance (Walk)	-0.69	0.12	-5.80
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter (Logsum)	0.53	0.12	4.50
Linear conversion of size coefficients			
Workers in accommodation and food services (Size)	1.24	0.24	
Workers in arts, entertainment and recreation (Size)	1.19	0.31	
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.47	0.12	-4.00

4.6 Estimation results for occasional travel

Occasional travel purposes home-based overnight and business are tours that include airplane as mode alternative and commonly use car as access mode for airplane and transit modes. Mode choice set and model specification is therefore different from everyday travel.

4.6.1 Transit access mode choice

The access mode choice model was estimated jointly across all tour purposes to ensure a sufficient number of observations for access mode choices. The available access modes are car access (TC), taxi access (TT), taxi egress (TE), and transit access, the latter of which includes walking.

Access mode choice is common for both business and overnight travel. Analysis is based on 2191 observations. Table 18 shows estimation results:

- Car availability increases the propensity to choose car as access mode.
- Access mode choice uses a generalized cost parameter instead of separate time and cost coefficients. Generalized cost is calculated using fixed values of time based on Finnish cost-benefit analysis guidelines (Väylävirasto 2024).
- The generalized cost parameter is specified as linear and logarithmic components, allowing for non-linear sensitivity to travel impedance and decreasing marginal disutility at higher cost and time levels.
- The access mode constants were subsequently calibrated separately for air and transit modes to match the approximated access mode shares for these modes.

Table 18. HB Transit Access variables and estimates

coefficient	estimate	std.error	t.ratio
Constant (Car egress)	-3.036	0.18	-17.20
Car availability in household (Car passenger), National sample	1.578	0.30	5.20
Constant (Taxi access)	-3.313	0.30	-11.20

Competed car availability in household (Car driver), National sample	3.200	1.03	3.10
Free car availability in household (Car driver), National sample	4.218	1.02	4.20
Constant (Car access)	-5.688	1.01	-5.60
Logarithm of Generalized cost (Transit)	-1.982	0.70	-2.80
Generalized cost (Transit)	-0.043	0.02	-2.00

4.6.2 Home-based Overnight Tours

Home-based overnight tours have one end at home and the other at an accommodation location, such as a leisure home, second home, hotel, or the home of relatives or friends. Overnight tours are therefore open tours and are typically much longer than everyday travel. The analysis is based on 1831 observations.

Table 19 presents the estimation results for HB Overnight travel purpose. All coefficients are statistically significant and have correct signs:

- Home-based overnight tours have an additional distance effect compared with other travel purposes. The positive beeline distance coefficient (Beeline distance from tour origin (all modes)) reflects that overnight stays are more common on longer trips and therefore increases destination attractiveness with distance.
- Lapland has a positive county dummy, reflecting its role as a popular destination for long-distance and longer-duration holidays.
- Size factors are leisure home floor area, destination-zone population, and hospitality industry workplaces.
- The logsum coefficient for lower-level access mode choice (Structure parameter for access mode choice (Logsum)) and the logsum parameter for main mode choice both lie between 0 and 1, indicating a valid nesting structure.

Table 19. HB Overnight Model variables and estimates

coefficient	estimate	std.error	t.ratio
Origin zone is in Oulu region (Walk, ref: rest of Finland)	0.64	0.35	1.80
Constant (Walk, ref: airplane), National sample	-4.92	0.82	-6.00
Constant (Car passenger, ref: airplane), Regional samples	-4.82	0.80	-6.10
Constant (Car passenger, ref: airplane), National sample	-4.90	0.81	-6.00
Constant (Car driver, ref: airplane), Regional samples	-7.19	0.88	-8.10
Constant (Car driver, ref: airplane), National sample	-6.10	0.88	-7.00
Constant (Transit, ref: airplane)	-2.26	0.42	-5.40
Travel distance (Walk)	-0.24	0.03	-7.40
Car availability in household (Car passenger), Regional samples	1.47	0.17	8.60
Car availability in household (Car passenger), National sample	1.64	0.26	6.30
Generalized cost (Car passenger)	-0.01	0.00	-5.80
Logarithm of Generalized cost (Car passenger)	-1.56	0.14	-11.30
Competed car availability in household (Car driver), Regional samples	3.80	0.41	9.30
Free car availability in household (Car driver), Regional samples	4.09	0.40	10.20
Competed car availability in household (Car driver), National sample	3.19	0.44	7.30
Free car availability in household (Car driver), National sample	3.26	0.41	8.00
Generalized cost (Car driver)	-0.01	0.00	-6.60
Logarithm of Generalized cost (Car driver)	-1.45	0.13	-11.40
Origin zone is in Turku region (Transit, ref: rest of Finland)	0.18	0.12	1.50
Origin zone is in Tampere region (Transit, ref: rest of Finland)	0.19	0.11	1.70
Origin zone is in Helsinki region (Transit, ref: rest of Finland)	0.31	0.12	2.70
Destination zone is in Lapland (all modes, ref: rest of Finland)	1.07	0.20	5.40
Beeline distance from tour origin (all modes)	0.00	0.00	4.60
Structure parameter for access mode choice (Logsum)	0.75	0.06	12.70
Log size multiplier (Normalized to one)	1.00	constrained	

Structure parameter for main mode choice (Logsum)	0.84	0.07	12.20
Linear conversion of size coefficients			
Population older than 50 years old (Size)	6.51	0.59	
Population size factor (Size)	0.31	0.21	
Workers in accommodation and food services (Size)	48.12	5.40	
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.16	0.07	-2.30
Structure parameter for access mode choice (Logsum)	[ADD]	[ADD]	[ADD]

4.6.3 Home-based Business Tours

Home-based business tours start from home and end in business destinations. These tours vary between short and long tours, but large share of domestic airplane travel consist of business tours and therefore it is included in models that have airplane alternative available. Analysis is based on 1200 observations.

Table 20 presents the estimation results for HB Business travel purpose. Most coefficients have similar interpretations to those found for other tour purposes. The purpose-specific coefficients are described below:

- The size factor is the number of workplaces in the destination zone.
- The logsum coefficient for lower-level access mode choice (Structure parameter for access mode choice (Logsum)) and the logsum parameter for main mode choice both lie between 0 and 1, indicating a valid nesting structure.

Table 20. HB Business Model variables and estimates

coefficient	estimate	std.error	t.ratio
Origin zone is in Oulu region (Walk, ref: rest of Finland)	0.93	0.79	1.20
Constant (Walk, ref: airplane), National sample	-8.47	2.11	-4.00
Constant (Car passenger, ref: airplane), Regional samples	-10.92	2.16	-5.10
Constant (Car passenger, ref: airplane), National sample	-10.01	2.22	-4.50
Constant (Car driver, ref: airplane), Regional samples	-9.17	2.08	-4.40
Constant (Car driver, ref: airplane), National sample	-8.95	2.12	-4.20
Origin zone is in Turku region (Transit, ref: rest of Finland)	0.06	0.55	0.10
Origin zone is in Tampere region (Transit, ref: rest of Finland)	0.48	0.42	1.10
Constant (Transit)	-3.80	1.29	-2.90
Travel distance (Walk)	-0.61	0.13	-4.60
Car availability in household (Car passenger), Regional samples	1.66	0.59	2.80
Car availability in household (Car passenger), National sample	0.53	0.67	0.80
Generalized cost (Car passenger)	-0.05	0.02	-2.60
Logarithm of Generalized cost (Car passenger)	-1.86	0.30	-6.20
Competed car availability in household (Car driver), Regional samples	2.31	0.42	5.50
Free car availability in household (Car driver), Regional samples	3.00	0.42	7.20
Competed car availability in household (Car driver), National sample	2.14	0.57	3.80
Free car availability in household (Car driver), National sample	2.69	0.54	5.00
Generalized cost (Car driver)	-0.03	0.00	-7.00
Logarithm of Generalized cost (Car driver)	-1.45	0.23	-6.40
Origin zone is in Helsinki region (Transit, ref: rest of Finland)	0.60	0.19	3.20
Structure parameter for access mode choice (Logsum)	1.10	0.15	7.50
Log size multiplier (Normalized to one)	1.00	constrained	
Structure parameter for main mode choice (Logsum)	0.80	0.09	9.40
Differences of hierarchy coefficients from 1			
Structure parameter (Logsum)	-0.20	0.09	-2.30
Structure parameter for access mode choice (Logsum)	[ADD]	[ADD]	[ADD]

5 Secondary destinations

Secondary destinations represent detours to locations other than the primary destination of a tour. These tours are modelled using a simplified approach that approximates the additional travel generated by such detours. The methodology applies purpose- and mode-specific adjustment factors to increase the number of trips assigned to the transport network, thereby accounting for the additional vehicle- or passenger-kilometers associated with secondary destinations.

According to the National Travel Survey, secondary destinations increase total travel mileage by approximately 8% depending on tour purpose (Table 21). In the current model implementation, the additional mileage associated with secondary destinations is represented only for car and public transport modes.

Table 21. Secondary destination detour factor for mode mileage.

Purpose	Car driver	Car passenger	Transit
HB Work	1.0830	1.0841	1.0643
HB Basic Education	-	1.1273	1.0374
HB Students	1.0678	1.0338	1.0366
HB Shopping	1.0484	1.0349	1.0325
HB Leisure	1.0619	1.0377	1.0702
HB Visit	1.1009	1.0628	1.0570
HB Escort	1.0133	-	1.0429
HB Business	1.0752	1.0819	1.0253
HB Overnight	1.0519	1.0323	1.0433
WB Business	1.0819	1.0243	1.0000
WB Other	1.0158	1.0367	1.0000
OB Other	1.0273	1.0826	1.0876

An explicit secondary destination choice model would likely produce more realistic travel patterns and network demand. However, its implementation would pose significant computational challenges. With large number of zones in the model system, calculating secondary destination choices for all trips would require evaluating a very large choice set, resulting in substantial computation times and memory requirements in model runs.

6 Car ownership model

Household car ownership is a major determinant of mode choice and an essential component of forecasts relating to future vehicle fleet development. Car ownership model was developed to predict and understand the factors influencing the development of car fleet size and the car ownership of households.

The household is the primary unit of analysis in the car ownership model. The model is segmented by the number of adults and driver's licences within the household. This segmentation enables forecasts of changes in driver's licence ownership to be explicitly incorporated into future-year predictions, reflecting the important role that licence ownership plays in determining both vehicle ownership and car use.

A logit-based choice modelling framework is used for the car ownership models. Three separate models were estimated for the adult population. For single-person households, a binary logit model was estimated with two alternatives: owning a car or not owning a car. Households with more than one adult are modelled using a multinomial logit formulation, with alternatives corresponding to ownership of 0, 1, or 2+ vehicles. The maximum number of household vehicles is constrained not to exceed the number of adults in the household.

National Travel Survey 2016 was used as primary data source. The data includes information about car ownership of respondents as well as relevant personal and household information. The data includes required household license information only for national subsample, so model estimation uses only these responses.

The model is MNL logit choice model, and it was estimated with Biogeme software (Bierlaire 2023).

6.1 Explanatory variables

Explanatory variables used in the models are explained below

- Household income group
- Land-use density
- Residence in detached or row house
- Children in household

Household income is major determinant of car usage. Here income is modelled for six different groups included in travel survey (Table 22). Usually, only subset of groups had differences to median income group and only dummies with significant difference to base alternative are kept in utility functions.

Land-use density is used as a proxy variable for accessibility of home location. Proxy variable was used for practical reasons, as using logsum accessibility would increase running times and complexity of transport model runs.

Table 22. Income group classifications in car ownership models.

Income group	Household income / year
1	0–19999 eur
2	20000-39999 eur
3	40000-59999 eur
4	60000-79999 eur
5	80000-99999 eur
6	>100000 eur

Residence in row or detached house was included in two car household alternatives. This variable describes possible extra costs caused of having two cars in apartment buildings, where room for two cars is not always available.

6.2 Household with 1 adult and 1 license

Model for one person households is MNL choice for 0, 1 or 2+ cars in household. Zero car alternative is used as base group for choice.

Estimation statistics:

- Sample size: 1388
- Excluded data: 0
- Final log likelihood: -621.9356

All coefficients have correct signs and most are statistically significant (Table 233):

- Children in household increase probability of owning cars.
- Higher density in household's home zone leads to lower car ownership.
- Lower income groups have negative coefficient respect to higher income groups, meaning that lower income decreases probability for owning a car.

Table 23. Estimated parameters for households with 1 adult and 1 license.

Coefficient	Estimate	Std. error	T-test
Constant, 1 car	3.253	0.223	14.603
Children in household, 1 car	0.711	0.314	2.262
Density of home-zone, 1 car	-1.579	0.217	-7.274
Income group 1, 1 car	-0.782	0.215	-3.644
Income group 2, 1 car	-0.025	0.002	-13.001

6.3 Household with 2 adults and 1 license

Model for households with 2 adults and 1 licence is MNL choice for 0, 1 or 2+ cars in household. Zero car alternative is used as base group for choice.

Estimation statistics:

- Sample size: 1388
- Excluded data: 0
- Final log likelihood: -621.9356

All coefficients have correct signs and most are statistically significant (Table 244):

- Children in household increase probability of owning cars.
- Higher density in household's home zone leads to lower car ownership.
- Lower income groups have negative coefficient respect to higher income groups, meaning that lower income decreases probability for owning a car.

Table 24. Estimated parameters for households with 2 adults and 1 license.

Coefficient	Estimate	Std. error	T-test
Constant, 1 car	3.424	0.265	12.910
Children in household, 1 car	0.022	0.296	0.074
Income group 1, 1 car	-0.925	0.307	-3.012
Income group 1, 2 cars	-0.273	0.279	-0.980
Density of home-zone, 1 car	-0.023	0.003	-8.514

6.4 Household with 2 adults and 2 licenses

Model for households with 2 adults and 2 licenses is MNL choice for 0, 1 or 2+ cars in household. Zero car alternative is used as base group for choice.

Estimation statistics:

- Sample size: 5482
- Excluded data: 0
- Final log likelihood: -3507.655

All coefficients have correct signs and most are statistically significant (Table 255):

- Children in household increase probability of owning cars. There could be correlation between the number of children and number of cars in household, but due to source data limitations this is not modelled.
- Higher density of household's home zone has negative effect on car ownership, as other modes of transport are available. Choice of owning second car is more sensitive to accessibility than for one car ownership.
- Lower income groups have negative coefficient respect to middle income groups, meaning that lower income decreases probability for owning a car. The effect of income is stronger for two car ownership than for one car.
- Highest income groups have significant positive coefficient for two car ownership.
- Share of detached or row houses in home-zone has positive coefficient for two car ownership. This indicates that household living in detached or row houses have higher probability of owning more than one car.

Table 25. Estimated parameters for households with 2 adults and 2 licenses.

Coefficient	Estimate	Std. error	T-test
Constant, 1 car	4.014	0.199	20.159
Constant, 2 cars	4.339	0.255	17.015
Children in household, 1 car	0.375	0.239	1.569
Children in household, 2 cars	0.542	0.240	2.256
Income group 1, 1 car	-1.657	0.259	-6.402
Income group 1, 2 cars	-2.616	0.289	-9.044
Income group 2, 1 car	-0.221	0.239	-0.927
Income group 2, 2 cars	-0.829	0.247	-3.354
Income group 4, 2 cars	0.361	0.085	4.231
Income group 5, 2 cars	0.571	0.108	5.275
Income group 6, 2 cars	1.105	0.121	9.112
Share of row or detached houses in home-zone, 2 cars	0.842	0.148	5.673
Density of home-zone, 1 car	-0.021	0.002	-10.827
Density of home-zone, 2 cars	-0.047	0.003	-15.874

7 Network assignment models

Valma network assignment models consist of assignment of walk, bike, transit and car assignments. All route choices are based on deterministic weighted shortest-path calculation, influenced by different factors such as distance, travel time, cost, and for transit and multimodal travel, the number of transfers. The assignment uses Bentley OpenPaths EMME software.

The road and public transport network database is described in detail in Traficom (2026c).

7.1 Route choice for walk, bike and car

Walk and bike route choices are influenced only by travel time, which is currently directly determined by distance. For practical reasons these modes do not have separate assignment network, but use only same network as car and transit, which might lead to overestimated travel distances.

Car route choices and travel times are affected by the level of congestion on roads and streets. The route choice models do not account for brief intermediate stops, for example at a service station or kiosk, and their potential effect on route choice. The weighting of travel time and cost in route choice is mode-dependent and based on the Finnish cost-benefit analysis guidelines (Väylävirasto 2024).

Cars, bicycles and pedestrians can use ferries as part of their route. In this case a fixed waiting time, coded on the network, is added to travel time. Ferries can also be part of a transit trip chain.

7.2 Route choice for transit

Transit travellers' route choice is based on the so-called Optimal Strategy (OS) algorithm (Spiess & Florian 1989) in Bentley OpenPaths EMME. The OS algorithm is based on transit lines and their service headways (i.e. a frequency-based assignment approach). This approach work well on urban transit systems, where passengers' choices are not always based on exact timetables. An alternative would be schedule-based assignment based on individual departures. However, modelling more than 100000 individual services across a national network would be computationally intensive and impractical for most planning purposes.

Valma model uses version of the OS algorithm where the impedance of a transit line (weighted travel time and cost) determines whether the line is considered attractive or not for reaching the destination. The choice model of Valma is structured so that the choice between different types of transit modes is done in assignment model. To reflect the different quality of services and the different preferences for modes, different types of travel time weight need to be used for different stages of trip: access, waiting, boarding, transfers and in-vehicle time.

The walking distances associated with access, egress and transfer stages of transit trip are calculated from network and weighted using a separate time-equivalent coefficient of 1.75 (Metsäranta & Pesonen 2007). For airplane trips the access and transfer walking time coefficient is 2.5. Transit access legs (transit-to-transit) are not weighted separately. The time coefficient for park-and-ride and taxi access is 7.5 (Kuivalainen 2024).

The impact of service frequency (waiting time) is calculated using a nonlinear disutility function, with separate coefficients for urban transit modes and long-distance services. The coefficients applied in the assignment model are shown in the following tables and are based on Finnish cost-benefit analysis guidelines (Väylävirasto 2024).

In general, the disutility associated with the headway of the first boarded transit service in a trip chain differs from that associated with transfer boardings. At transfers, headway directly affects waiting time (except when transfers are synchronized), whereas for the first boarding an infrequent service affects the realized departure time relative to the desired departure time. However, for high-frequency public transport services, the distinction between waiting before the first boarding and at transfers is largely negligible.

Here the same coefficients are applied to weight headways both before the first boarding and at transfer boardings. As a result, transfer waiting-time disutility may be overestimated for long-headway services when transfers are synchronized and underestimated when transfers are not synchronized.

Table 26. Headway disutility for local transit services

Headway	Coefficient
0-10 min	1,1
11-30 min	0,9
31-60 min	0,5
61-120 min	0,3
121- min	0,2

Table 27. Headway disutility for long-distance transit services

Headway	Coefficient
0-60 min	0,5
61- min	0,3

Differences in the perceived quality of transit mode options are represented through three coefficients:

1. Expected delay factor to reflect service reliability.
2. In-vehicle time coefficient to reflect quality attributes associated with time spent on board.
3. Boarding penalty to reflect quality attributes that are experienced as a one-time disutility when boarding a service.

Expected delay of vehicle is a function of cumulative travel time and distance on the boarding location and defined for each transit mode separately. This expected delay is weighted with coefficient 3.5. Calculation of delay is described in more detail network assignment report (Traficom 2026c).

The in-vehicle time coefficient is set to 1.0 for most transit modes. However, for rail-based modes, including tram, light rail, metro and long-distance rail services, in-vehicle time is weighted by a factor of 0.8. This lower coefficient reflects the generally higher ride quality of these modes, including lower levels of acceleration, stopping, sharp turning and vehicle vibration. For long-distance rail services, the lower coefficient also reflects the greater opportunities for productive and leisure activities while travelling.

The boarding penalty value (10 minutes in time-equivalents) is based on HSL 2015 and is selected to represent relatively sparse and irregular services, as the situation in Finland is on average. Additional boarding penalties are applied for coach buses, long-distance trains, long-distance ferries and airplanes to forbid the transfers between long-distance lines mid journey which are generally unusual in the trip data used in the model estimation.

The quality and preference weighting factors (boarding penalty and in-vehicle time) were determined through an iterative calibration process in which modelled passenger volumes and mode shares were compared with observed statistics. The statistics used for calibration and validation are presented in the demand model validation report (Traficom 2026a).

Table 28. Boarding penalties for the transit modes in the model

Transit mode	Boarding penalty (min)	Long distance boarding penalty (min)
Local bus	5	5
Coach bus	5	25
Trunk bus	3	3
Tram	0	0
Light rail	0	0
Metro	0	0

Local Ferry	0	0
Long-distance ferry	5	25
Commuter train	0	0
Long-distance train	0	25
Airplane	0	25

8 Calibration and validation

The model-development process included both formal and informal validation procedures, including statistical tests, behavioural plausibility checks, and forecasting assessments.

8.1 Calibration of mode shares

The mode choice model was recalibrated to match better the validation data from National transportation survey (HLT 2016). The calibration of the model was done by calculating the mode choice constant for transit modes in every tour type by using following formula (Train 2002, p. 39–40):

$$C(I) = C(0) - \ln(\frac{p(model)}{p(survey)})$$

where:

$C(I)$ = new mode-specific constant

$C(0)$ = mode-specific constant produced by estimation

$p(model)$ = mode choice probability calculated by the model

$p(survey)$ = mode choice proportion calculated from the Finnish National transportation Survey extended data (HLT 2016).

The calibration procedure ensures that modelled national mode shares are consistent with those observed in the survey data, but differences might still exist in regional level. Therefore, model users are recommended to recalibrate the constants by using mode share data from the study area.

8.2 Validation of mode shares

The national purpose specific mode shares are calibrated to fit the survey data, so validation shows nearly perfect fit between model and survey (Figure 15). More interesting prediction test is to take a market segment (subarea, population segment) for which model is validated. Market share validation was done for two subareas: urban subareas and urban-rural classification.

Urban subareas are model areas from where additional survey sample was collected and therefore have good sample to calculate survey statistics. These are largest urban areas in Finland. Prediction test (Figure 16) shows that model can capture areal variation, but some specific features are not well represented, such as the high transit mode share in central Helsinki. If regional predictions are made, model should be calibrated with additional information.

The urban-rural classification used in the analysis was developed by SYKE (2026b). It classifies areas in Finland according to their urban or rural character based on indicators such as population, employment, commuting patterns, building stock, and land use. Although the original classification consists of seven categories, only a two-class urban-rural distinction is applied in this study.

The prediction results (Figure 17) indicate that the model performs well in urban areas. However, systematic prediction errors are observed in rural areas. These may be attributable to the relatively coarse zonal structure in sparsely populated regions or to limitations of the headway-based public transport level-of-service measures. In

rural areas, public transport services are often operated irregularly rather than according to a regular timetable pattern, reducing the suitability of headway-based service indicators.

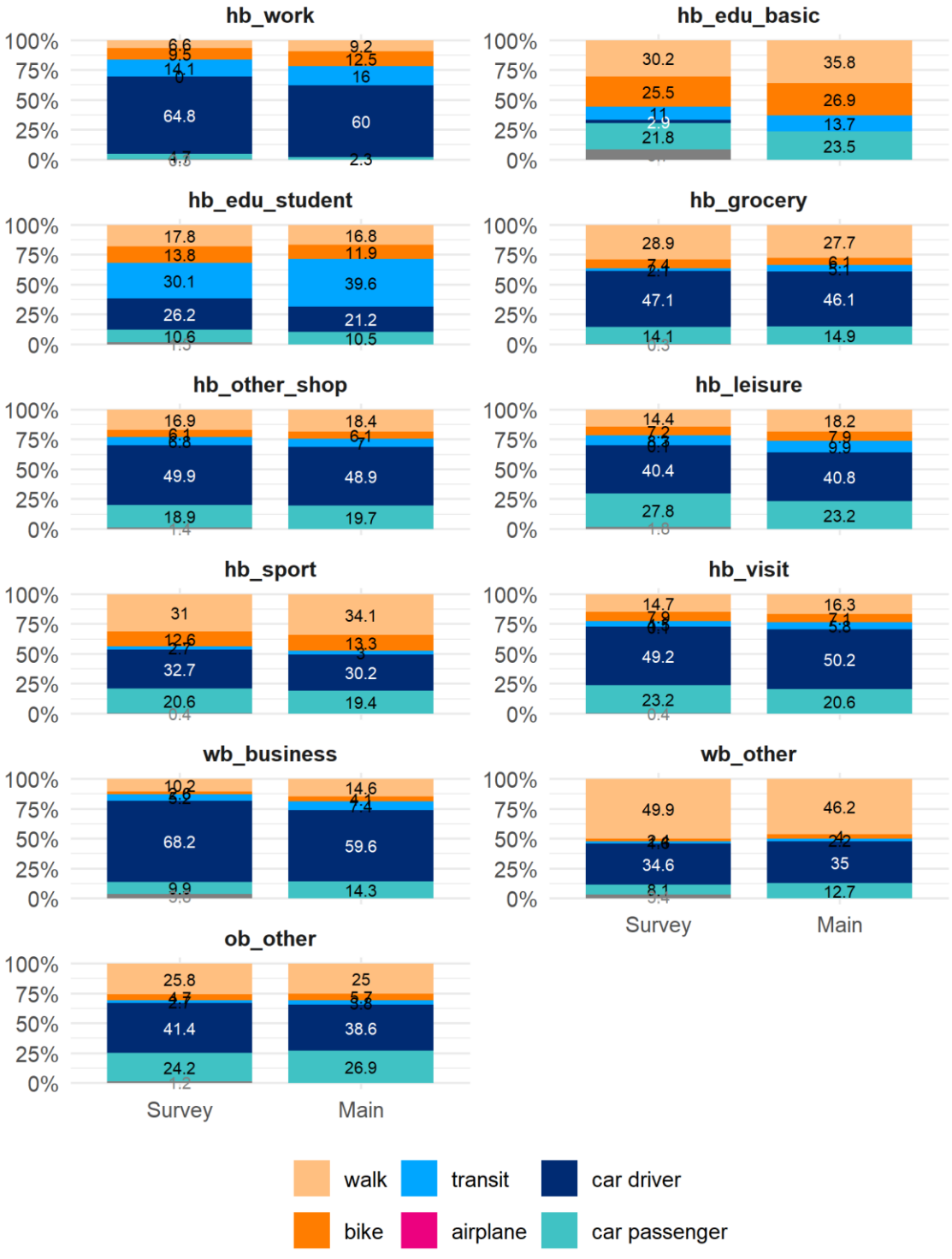


Figure 15. Calibrated mode shares by purpose.

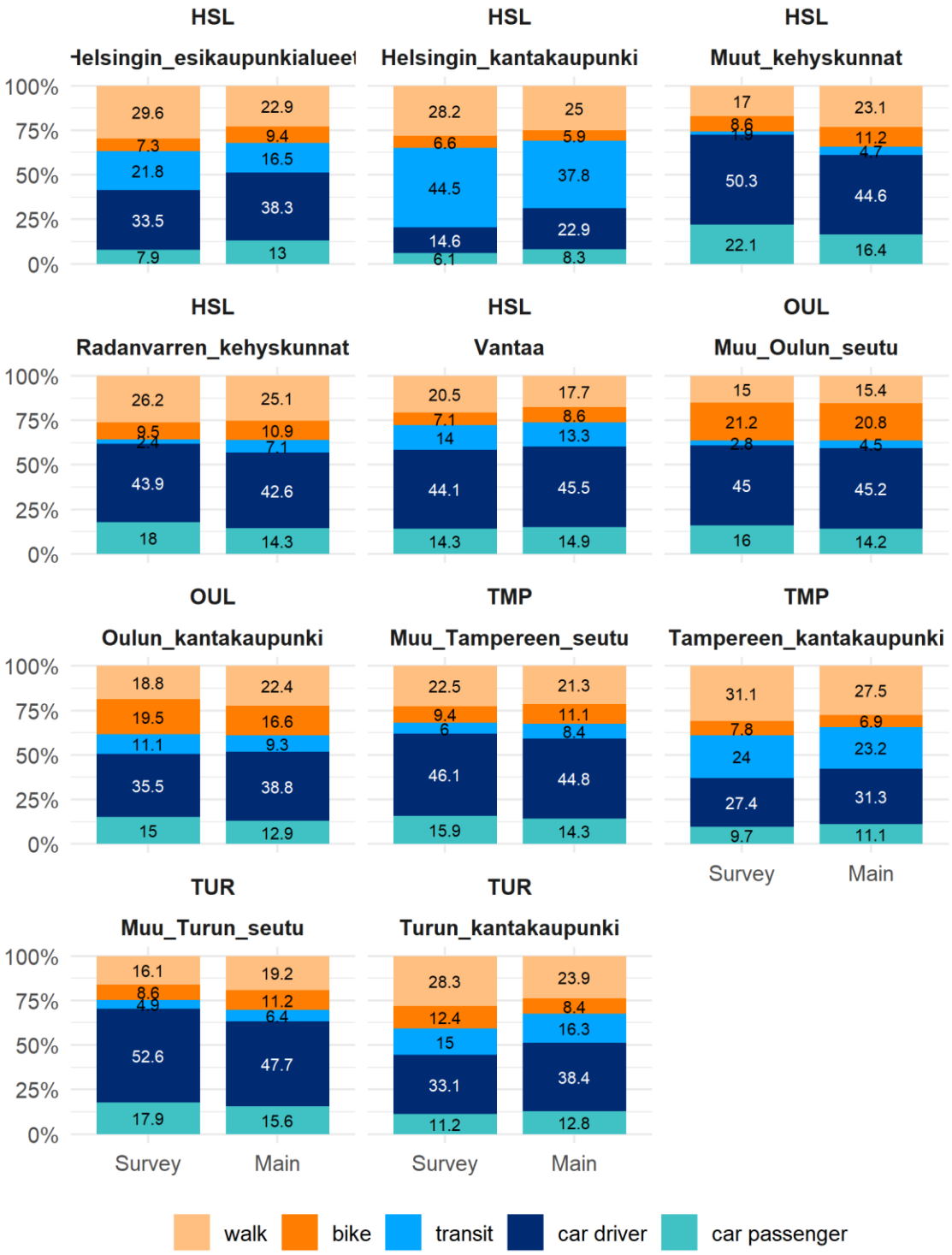


Figure 16. Mode share validation on urban subareas.

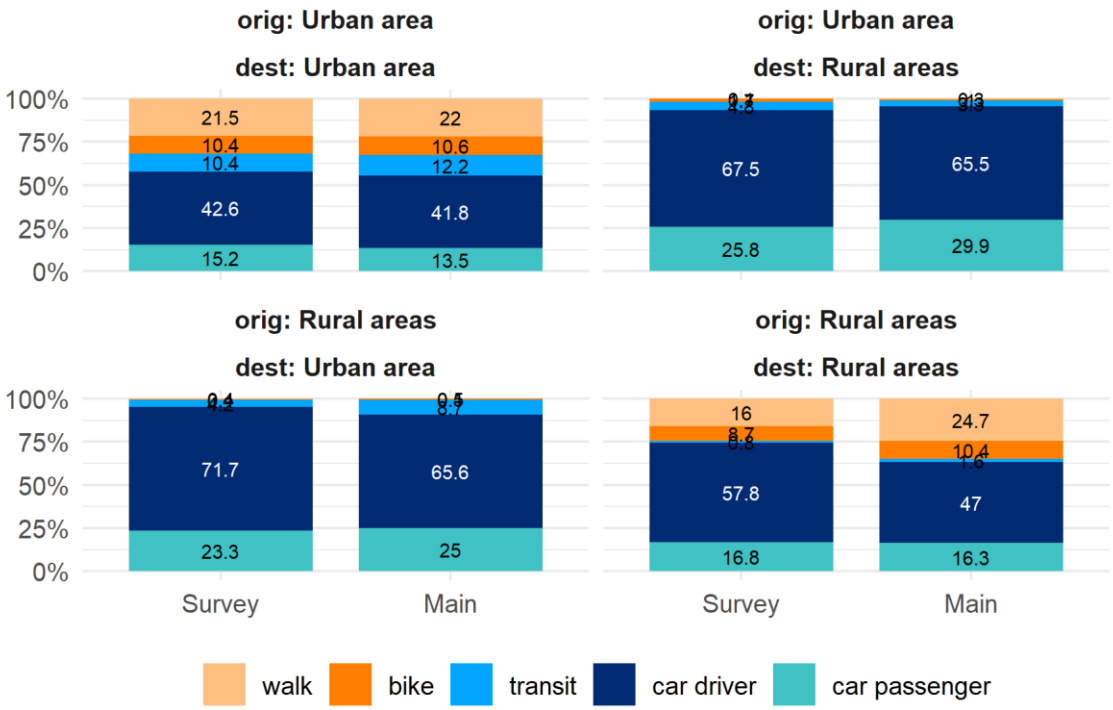


Figure 17. Mode share validation on urban-rural classification.

8.3 Validation of distance distributions

The ability of the models to reproduce observed tour lengths by travel mode has been evaluated by comparing observed and predicted tour length distributions. The analysis was conducted for each mode and for both everyday and occasional travel separately.

The primary source of observed travel behaviour is the National Travel Survey 2016. However, due to the limited number of air travel observations in the travel diary data, additional data sources were used for the analysis of air travel. These include Telia mobile network data and long-distance travel survey data, which provide a more robust empirical basis for modelling air travel patterns.

The distance distribution for daily and occasional travel generally shows a good fit with survey data, although some differences are observed. The model predicts air trips for distances below 200 km, whereas such trips are not observed in survey data.



Figure 18. Distance distribution for everyday travel.

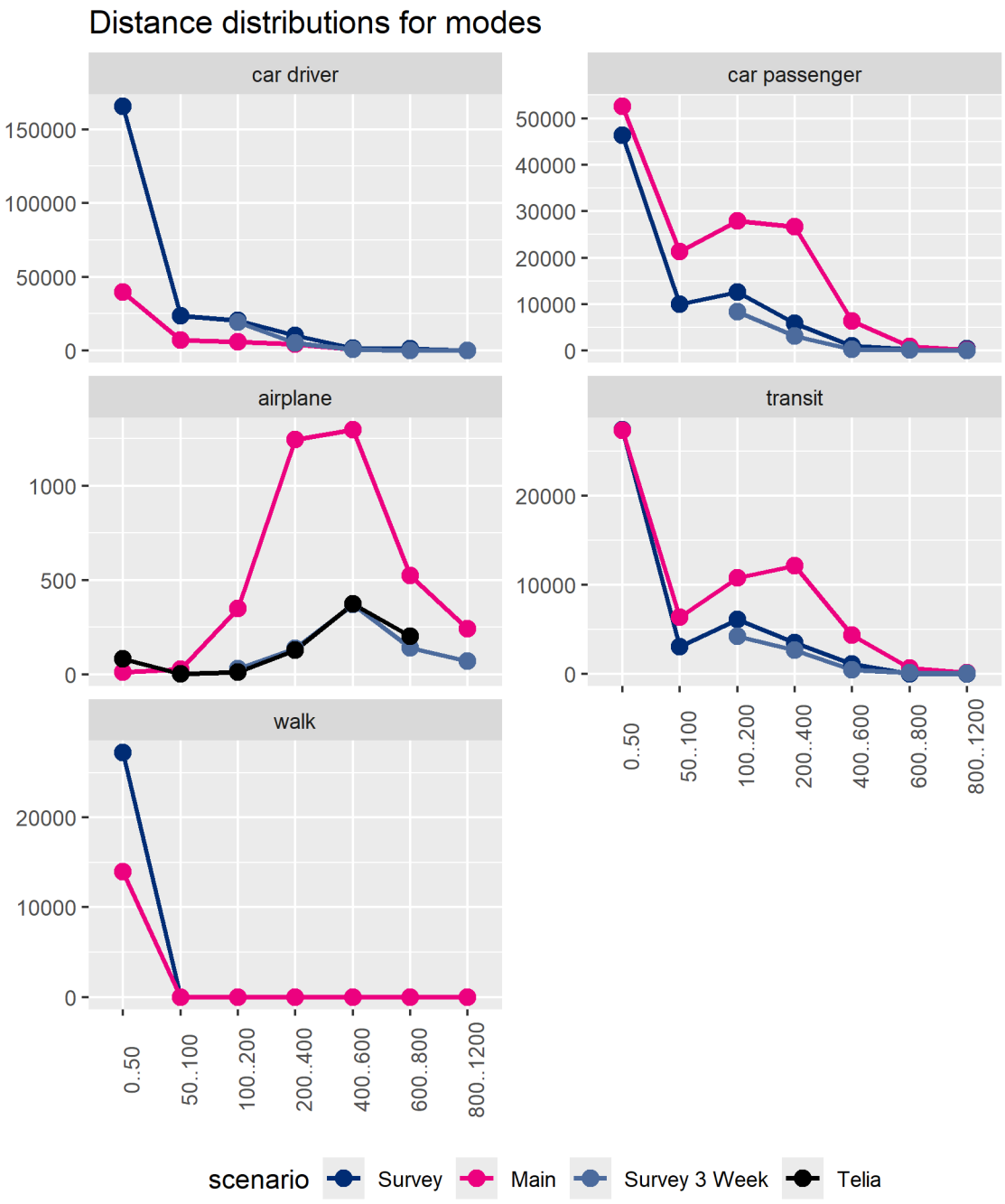


Figure 19. Distance distribution for occasional travel.

9 Model development

During model development several omitted effects were found and these should be regarded as future development options for the model.

Tour generation:

- Recent changes in travel behavior in Finland raise questions regarding the suitability of the current tour-generation approach. Number of trips per person over time was constant for decades, but after global pandemic started in 2020 caused permanent or long lasting effect to the number of trips or tours per person (Traficom 2025). However, currently used data source does not allow studying this effect and it is therefore left for future model versions.
- Logit type models are commonly used in tour generation to link accessibility with tour generation. In this work this link was significant only for education travel purpose. However, this problem might be related to modelling secondary destinations, as better accessibility might have two direction effect. Greater accessibility can lead to more tour or less tours, if secondary destination are more accessible.

Mode-destination choice models:

- Most significant drawback of current model is the modelling of occasional travel and long distance domestic travel. Estimated models are based on few observations on for example airplane mode choices and access mode choice model was done with practical approach. New long distance public transport and airplane survey dataset was collected during first model version estimation with choice-based samples. This data allows better modelling the long-distance transport choices, when model is re-estimated with new National Travel Survey 2025 data.
- Season ticket holding in transit utility could not be distinguished due to survey data. New National Travel Survey 2025 data has this information about respondents, making it possible to link season ticket holding to transit choices.
- Walk and bike distances are calculated with road network and does therefore not include all links and shortcuts. Development of new assignment model based on more detailed in ongoing at the time of this report is published.
- Travel cost parameter interaction with income was not included in this model version due to data limitations. Question of household or personal income was presented only for subset of respondents.
- Many additional socio-economic dimensions, including age, gender, household composition, dwelling type, and income, have been shown to influence travel behaviour in previous studies (e.g. Kristoffersson 2024) and agent simulation approach with rich set of socio-economic variables is option for next development versions of the demand model.

Bibliography

Bierlaire, M. (2023). A short introduction to PandasBiogeme. Tech. Rep. TRANSP-OR 200605, Transport and Mobility Laboratory, ENAC, EPFL.

Daly, A. (1982). Estimating Choice Models Containing Attraction Variables. Transportation Research Part B: Methodological Volume 16, Issue 1, February 1982, Pages 5-15.

Daly, A. (2010). Cost Damping in Travel Demand Models Report of a study for the Department for Transport. RAND Europe.

Daly, A. (2022). ALOGIT 4.5 User Documentation.

Fox, J. Patruni, B. Daly, A. (2010). Sydney Strategic Model Re-estimation: Mode-Destination Modelling. RAND Europe.

Fox, J. Patruni, B. Daly, A. (2016). A new travel demand model for London. Estimation of the mode and destination choice models. RAND Europe.

HSL (2015). Selvitys joukkoliikenteen vaihtovastuksesta. HSL julkaisuja 18/2015. Helsingin seudun liikenne.

HSL (2026). Helsingin seudun työssäkäyntialueen liikenne-ennustemallijärjestelmä 2025. HSL julkaisuja 5/2026. Helsingin seudun liikenne.

Jahanshahi, K. Daly, A. Patruni, B. Rohr, C. How can we model travel frequency? A Critical Review of Current Practice. Conference Paper: European Transport Conference.

Kristoffersson, I. Daly, A. Algers, S. (2017). Modelling the attraction of shopping centres. CTS Working Paper 2017:1. Centre for Transport Studies.

Kristoffersson, I. Berglund, S. Samuelsson, S. Almström, P. (2024). Sampers4 – Skattning av regionala efterfrågemodeller (Implementationsversion). Trafikverket.

Kuivalainen, V. (2024). Modelling of connection modes to mass transit in long-distance travel. Aalto University.

Metsäranta, Heikki, Pesonen, Hannu (2007). Joukkoliikenteen vaikutusten arviointi. Yleisohje. Liikenne- ja viestintäministeriö.

Rich, J. Overgaard Hansen, C. (2016). The Danish National Passenger Model –model specification model specification and results. European Journal of Transport and Infrastructure Research Issue 16(4), 2016, pp. 573-599.

Rich, J. Fox, J. (2024). Cost sharing in passenger transport models: specification, implementation, and impacts. Transportation Research Part A 179 (2024).

Smit, R. Zondag, B. Willigers, J. (2021). Growth Model 4: The New Dutch National Passenger Transport Model. European Transport Conference 2021.

Spiess, H. and Florian M. (1989). Optimal strategies: A new assignment model for transit networks. Transportation Research Part B: Methodological.

Statistics Finland. 2026a. Grid Database. Webpage. [https://stat.fi/en/services/statistical-data-services/geographic-data/grid-database]

Statistics Finland. 2026b. Paavo database. Webpage. [https://stat.fi/en/services/statistical-data-services/statistical-databases/paavo]

SYKE. 2026a. Paikkatietorajapinnat. Webpage. [https://www.syke.fi/fi/ymparistotieto/avoimet-rajapinnat/paikkatietorajapinnat]

SYKE. 2026b. Kaupunki-maaseutuluokitus. Webpage. [https://www.ymparisto.fi/fi/rakennettu-ymparisto/kaupunkiseudut-ja-kaupungistuminen/kaupunki-maaseutuluokitus]

Traficom. (2025). Henkilöliikennetutkimus syksy 2024: Suomalaisten liikkuminen. Traficomin tutkimuksia ja selvityksiä 20/2025.

Traficom. (2026). Valtakunnallinen liikenteen mallijärjestelmä: Ajoneuvokannan malli. Traficomin julkaisuja YY/2026.

Train, K. (2002). Discrete Choice Methods with Simulation. Cambridge University Press. Version dated March 8, 2002.

Vesanen, S. (2020). Parking private cars and spatial accessibility in Helsinki Capital Region: Parking time as a part of the total travel time. Master's Thesis. University of Helsinki.

Väylävirasto. (2024). Tie- ja rautatieliikenteenhankearvioinnin yksikköarvot 2022, Päivitys 20.12.2024. Väyläviraston ohjeita 44/2024 v2.

Appendix 1. Tour building

Finnish Transport and Communications Agency Traficom
PO Box 320, FI-00059 TRAFICOM
Switchboard: +358 29 534 5000

traficom.fi

ISBN 000–000–000–000–0
ISSN 0000–0000 (e-publication)

TRAFICOM
Finnish Transport and Communications Agency