The Demand Model of the Danish National Model

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Abstract

In the present paper the structure of the demand model framework for the new Danish national model is outlined. It involves a discussion at two levels. At the framework level, we discuss how demand is modelled in a number of parallel sub-models and how these are linked. An issue is to represent all transport but on the other hand avoid double counting. At the sub-model level, special attention is given to the week-day model as well as the international component of the model. The model for week-day traffic represents the most important components with respect to overall mileage and congestion and is therefore particularly important from a policy point of view. The international models are relevant because these are central to the Fehmarn Belt application of the model to be finished in the first quarter of 2012. For the international models we consider segmentation and nesting structure for the international day model, the transit model, and the overnight model. Finally, we discuss how trip chains of higher dimensions can be represented in a matrix form applicable for the assignment procedure.

1 Introduction

In December 2009 the Danish Ministry of Transport initiated the development of a new Danish National and a contract was signed with DTU Transport. The principal objective of the model was, and still is, to establish a unified model framework in order to have a common reference when evaluating infrastructure projects. Analysing two different projects with two different models may not always represent a "fair" comparison between the projects and eliminating this undesirable bias is an important argument for having only one model. Moreover, the model has the whole of Denmark and to some extent Europe as its modelling areas and it becomes therefore possible to investigate nation-wide effects of infrastructure projects. Another benefit of having a single model is that it is possible to put more resources into the development and maintenance of the model. The development of the Danish national model follows what has been seen in a range of other countries including Netherland, Sweden, Norway, UK, and Italy. Also the European Commission has started the development of a unified model framework – the TRANSTOOLS model – to support decision making and infrastructure planning at a European level.

The objective of the present paper is to focus particularly on the structure of the demand model for daily travel and the international models. Special attention is given to the trip-chain specification and the choice set specification as well as the possible nesting structure of the various sub-models. The main objective of the paper is to present the various sub-models, their linkage and how they form transport demand rather than presenting econometrical details.

1.1 Literature

The paper is closely related to a number of other papers that describe other parts of the model framework for the new Danish National Model. Rich et al. (2010a) described the overall structure of the model system with discussions of the zone system and aggregation levels. Rich and Hansen (2010), describes the forecasting methodology of the model, which includes a brief description of the population synthesiser where population forecasts are produced. A more detailed description of the population synthesiser is presented in Rich and Mulalic (2011). Nielsen (2010) and Nielsen and Frederiksen (2010) described the structure and methodology applied in the assignment model. The model is also to some extent built on the shoulders of previous Danish transport modelling activities. This includes modelling activities in connection with large infrastructure projects such as the model developed for the Great Belt project as described in Fosgerau (1996), the Øresund model (COWI, 1998), and the modelling activities related to a previous Fehmarn Belt study – the Femex model described in Tetraplan (1996). Another significant inspiration has been the OTM model, which was initiated in 1996. The model is focused on the Greater Copenhagen region as has been as described in (Jovicic and Hansen, 2003) and later in (Vuk and Hansen, 2009) in an application for the new Metro City line in Copenhagen. Other modelling activities include the PETRA model (COWI, 1994) where a rather advanced trip-chain activity choice model was implemented. A common characteristic of most of these models is that they have been based on the TU data set and the evolution of the TU data set has been partly formed by the experience gained in these modelling activities.

The paper also draws on international experience in that the modelling of daily transport are modelled by proposing an adaptation of the activity-scheduling approach introduced by Bowman

and Ben-Akiva (2001) and Ben-Akiva and Bowman (1988) as applied in the Tel-Aviv model (Cambridge Systematic, 2008). Moreover, we have looked carefully to the Swedish national model (Beser and Algers, 2002) and have as well drawn on experience from the UK (Rohr et al., 2010) with respect to long-distance trips. Finally, the model specification draws on experience from the work on the European TRANSTOOLS model as described in Rich et al. (2009) and Rich and Mabit (2011).

1.2   Overall demand model structure

The passenger model consists of five transport demand models (the models to the right in Figure 1) and a strategic model (the model to the left). The models are linked with a route choice model in order to properly represent congestion effects and the fact that increased demand is counteracted by lowered accessibility due to congestion. The route choice and demand model is iterated until system convergence is reached. The models are linked in a traditional random utility framework[1] in which the *strategic model* at the upper level dictates the choice process at lower levels and where lower levels feed accessibility measures (e.g. logsum variables) to the strategic model. An illustration of the model framework is presented in Figure 1.
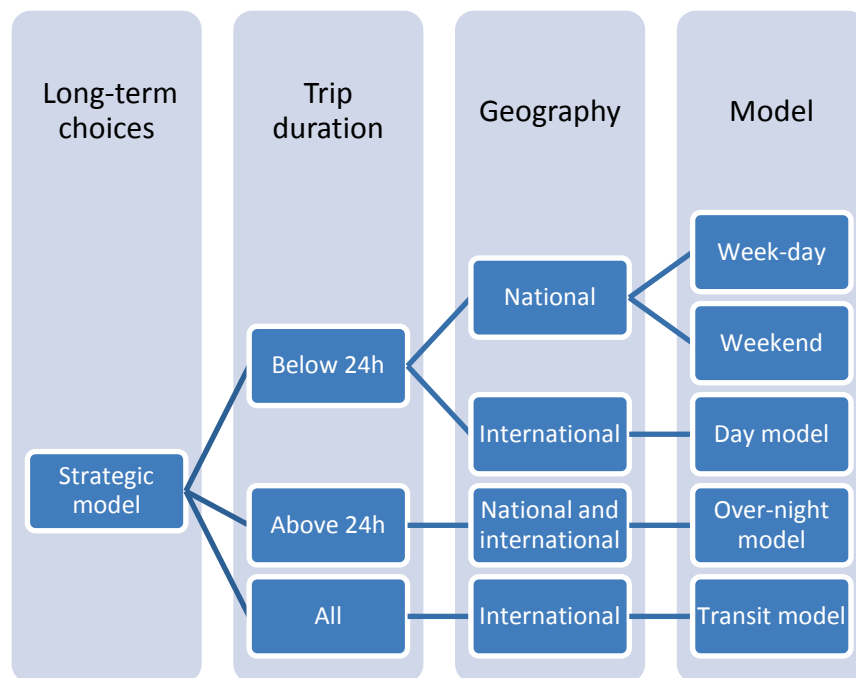
Figure 1: Overall structure of the passenger demand model.

The choice process is decomposed into; (i) strategic choices and (ii) transport related choices. In the strategic model choices are concerned with location and cars. For locations this involves choice of residential zone and work location zones for up to two workers. For the car model we distinguish between the number and type of cars as well as the type of propellant.

The distinction between week-day and weekend trips is based on the fact that the transport pattern is very different in terms of the congestion pattern, the distance, and the destination choice. More

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[1] A set of discrete choice models where the perception of individuals in each model assumes a division into a deterministic indirect utility function and a random component.

importantly, however, there has been a change over time and there is today relative more transport activity in the weekends compared to previous times according to the Danish TU data.

The *international day-model* is largely focused on; (i) business transport (mainly by air), (ii) border traffic between Copenhagen and Skaane (mainly commuting), and (iii) border traffic between Southern Denmark and Northern Germany (mainly shopping and leisure).

The *Transit model* is of particular importance for the Fehmarn Belt model as it will allow us to address route and demand substitution towards the new connection for travellers originating outside of Denmark.

1.2.1 All demand is covered

For the demand model, it is crucial that the different models represent a non-overlapping decomposition of transport demand to avoid double-counting, i.e. that certain demand components are counted twice. In other words, the combined transport demand across all models should be equal to the total demand that comes out of the model. This requirement implies the following distinctions between the different models;

- For the week-day, the weekend model and the international day model, we consider only trips that start at home and end at home before 03.00 o'clock
    o If we allowed non-home based trips, it would conflict with the overnight model where these trips are modelled[2].
    o People that work at night may therefore be addressed in the overnight model.

- For the week-day and weekend model we consider only Danish citizens.

- International day trips, represents only trips that start or end in Denmark and are below 24h.

- International transit traffic represents only foreigners and only trips starting and ending outside Denmark. The trip duration is irrelevant for these trips.

- Overnight trips will cover all trips that start or end in Denmark for Danish citizens as well as foreigners and are above 24h.

The above division into five demand models are non-overlapping and the demand accumulated in all of the five models will add up to the total demand.

1.2.2 Distance versus duration

In the model there is no special segmentation for long trips as in the European TRANSTOOLS model (Rich and Mabit, 2011). There are two main reasons for this choice. Firstly, if we divide models according to distance, it is not possible to represent substitution effects across the distance band. For instance, if the cost of air transport increased dramatically due to increased taxation on air fuel, which would cause people to switch mode and destination, we would only measure substitution

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[2] If a family goes to Odense on vacation, the "satellite" trips from Odense to the nearby locations, will be covered by the overnight survey.

effects to the extent they stay in the "long-distance segment". If people rather than going to the Southern Spain went to Northern Jutland, this effect would not be represented.

Another argument for embedding trip distances within the models is that distances as such should not be considered a choice but rather a mean that facilitate certain destination choices. In principle, we do not care about the distance, but the travel time and cost associated with it. If the travel time between Aarhus and Copenhagen was reduced to one hour, people would start commute at a large scale. However, people would not be staying in Aarhus overnight as this would require housing facilities etc. As a result, it seems more natural to decompose, not on distances but on durations (e.g. whether the trips duration is above 24 hours).

An experience from the Swedish national model (Beser and Algers, 2002) is to consider a more detailed segmentation into trip duration. So rather than considering a 24hour threshold we may consider 1 day, 1-3 days, 3-5 days, and more than 5 days. This will be considered in the estimation.

2   Data sources

The five different model components in Figure 1 will be estimated on a variety of different data sources, which we will briefly consider. As seen in Table 1 below, TU is the main data source for the models representing Danish citizens, whereas models including foreign citizens are based on several specialised data sources.

Data source	Type	Models				
		Week-day	Weekend	Int. Day model	Overnight model	Transit
TU data (2006-2010)	RP, ~ 80-90,000 resp.	**X**	**X**	X		
TU overnight (2010)	RP, ~ 10,000 resp.	X	X	X	**X**	
Fehmarn Belt CPH airport (2010)	RP, ~ 1,300 resp.			**X**	**X**	
Fehmarn Belt (2010)	RP, ~ 3,700 resp.			**X**	**X**	X
Great Belt (2010)	RP, ~ 1,100 resp.			**X**	**X**	X
Øresund Week9 (2009)	RP, ~ 11,000 resp.			**X**	**X**	**X**
DATELINE (2001-2002)*	RP, ~ 1,000 resp.				**X**	
Fehmarn Belt SP (2010)	SP, ~ 5,000 games			**X**	**X**	X
CPH market survey (2009)	RP, ~ 12,000			**X**	**X**	
Other European data	RP, ~1,000				**X**	X
Zone data (Danish register data)		**X**	**X**	X	**X**	X

					X	X	X
Zone data (Tenconnect 2)					X	X	X

Table 1: Description of main data sources for the estimation and calibration of the various demand models. * In the Dateline only the intercepted households in Denmark, Skåne, and Northern Germany are relevant.

The zone data in Table 1 represent "land-use" data as well as population data and are important in the explanation of "attraction". These data is a mix between register data from Statistics Denmark and special dataset describing, e.g. vacation house areas, special attractions and the size of these.

One of the common problems when combining many data sources is that the geographical coding may not conform across all data sets. To facilitate estimation of destination choice we envision a two dimensional choice hierarchy of the destination choice. First we model destination choice at the country level, followed by a more detailed choice of destination classified according to the European zone system of 358 zones. This provides an efficient use of data and make sure that we do not waste data just because they are only coded by country.


3 Modelling daily transport

The modelling of daily transport is dealt with in the week-day model as depicted in the first row in column four in Figure 1. The model will be tour based which means that we consider tours and not single open ended trips as the modelling entity. This leads to a more consistent representation of trips as the dependency across trip chains are incorporated into the model. On the other hand, however, it raises some new challenges in how we deal with trip chains and how bundles of activities in a chain are modelled. This is discussed below as well as in Section 5.

The week-day model will, as the general framework, be structured as a large random utility model consisting of several choice hierarchies to represent different choice dimensions. At the general level, the model structure will be divided into three main sub-models; (i) a tour frequency model, (ii) a model that is concerned with the primary tour activity of the day, and (ii), a model which is defined conditionally on the primary tour activity and will represent intermediate stop activities.

The tour frequency model will be linked with the two demand models through logsum variables and as a result ensure consistency in the estimation phase. The design of the frequency model follows a simple logit model or alternatively a stop-go-model as presented by Daly and Miller (2006). In the following we will not discuss the frequency model in more details.

The trip-chain design is illustrated below in Figure 2.
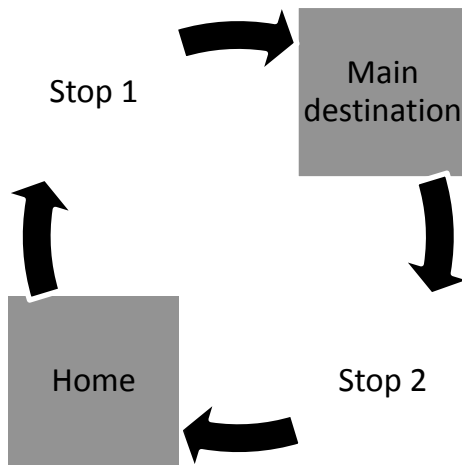
Figure 2: Trip chains with intermediate stop activities.

Among several possible chain structures for activities and tours, the one proposed in the present paper, will impose a limitation in that a potential tour can only consist of a maximum of four possible trips/legs. The four possible configurations are given by

- home-main-home
- home-stop-main-home
- home-main-stop-home
- home-stop-main- stop-home

There will be no limitation on the number of tours individuals might carry out during the day. The primary tour activity includes choice of mode, destination and time-of-day. The model for secondary tour activities represents intermediate stops, intermediate stop activities, and a destination choice for these activities. This model design is inspired by Cambridge Systematics (2008) and will be discussed in details below.
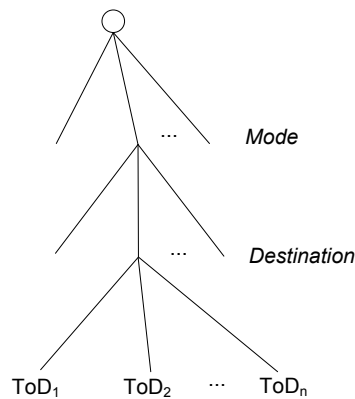
3.1   Primary tour model

The model for the primary tour is segmented by the main trip purpose of the tour. The classification is shown in Table 2.

ID	Tour purpose
1	Business
2	Commuting
3	Education
4	Escort
5	Shopping
6	Leisure/other

Table 2: Purpose classification for the main tour.

In the primary tour model three choices are considered for each of the segment. The choices are arranged in a nesting structure as shown in Figure 3 to facilitate nested logit estimation. These are

choice of primary transport mode, choice of destination, and finally the choice of departure time choice represented as a set of time-of-day alternatives.

Figure 3: Choice model structure for the primary tour model.

The exact nesting structure as depicted in Figure 3 is arbitrary and will be based on empirical evidence.

The primary tour mode choice model explains the choice of the main transportation mode for the tour. As seen from Table 3 it consists of six alternatives with only a single public transport mode. This is because the choice between different public transport modes such as bus, intercity rail, metro and s-tog is dealt with in the assignment. In the assignment people are routes through the complete public network and it is possible to extract the complete history of modes used on the given tour.

ID	Transport mode
1	Walk
2	Bike
3	Public transport
4	Car driver
5	Car passenger
6	Air

Table 3: Transport mode classification for the main tour.

The second choice in Figure 3 is the destination choice. This model determines the probability of each zone being chosen as the primary destination of the primary tour. Which destinations in the tour (there can be as many as three observed destinations) are the main destination is defined according to a ranking scheme based on the purpose and duration of the activity. As there are 3,670 zones in the national model[3] at the most detailed level, the choice hierarchy will be very large. An option that could significantly reduce the choice hierarchy is importance random sampling of the destination choice. This methodology allows that only a sampled subset of the destinations is investigated.

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[3] The first version of NTM will be developed at the L2 zone level with 907 zones.

It should be noted that, as the strategic model deal with choice of work location, this destination choice will only be included as a mean to collect working trips not going to the registered working zone. This will happen in many occasions and is particular relevant for many skilled workers.

An important issue in the destination choice is the form and type of the land-use variables applied. Generally, it is envisioned that the land-use variables (sometime also referred to as zone variables) will differ between different types of individuals. For instance, a person employed in a specific sector will naturally be more attracted to that sector. The match between the different land-use data and the different trip purposes are listed below

- Commuting: Employment by zone and sector/branch (a grouping of 128 branches are applied)
- Business: Employment data by zone and sector/branch
- Shopping
    - Employment data by zone and specific shopping related sectors (retail, super markets, etc.)
    - Possible land-use data such as square-meter floor space, parking space, etc.
- Leisure/Other
    - Employment by zone and specific leisure related sectors (restaurant, cinema, cafe, etc.)
    - Impact of special attractions (visits to Tivoli, Legoland, etc.)
- Holiday
    - Employment by zone and holiday related categories (hotel, bet-place capacity, camping, etc.)
    - Impact of special attractions
    - Specific land-use data for vacation houses

The final choice in Figure 3 regards the choice of departure time, which is divided into ten categories as seen in Table 4.

| ID	Time-of-day interval
1	21-05
2	05-06
3	06-07
4	07-08
5	08-09
6	09-15
7	15-16
8	16-17
9	17-18
10	18-21

Table 4: Time-of-day interval for the main tour.

The time-of-day model estimates the combination of start and end of the tour. In order to simplify the model and not to estimate jointly two models (or an even more complex duration model), the simplest solution consists in defining as alternatives all the possible combinations when considering

p time periods within the day (Vovsha and Bradley, 2004). Given logical constraints (i.e., an activity concludes only after it starts), it is well known that the number of alternatives is equal to p(p+1)/2. Two main issues are the consideration of the sequence of trips within the tours and the time resolution. As for the sequence of trips, the model could consider a sequence of four sub-models for the four types of segments in the tour, namely time-of-day models for (i) the beginning of the tour, (ii) the trip originating at the primary activity destination, (iii) the trip from the intermediate stop to the primary destination, and (iv) the trip from the intermediate stop to home. As for the time resolution, a solution to the problem of balancing between applicability and a fine resolution level could be the implementation of heuristics to help reducing the number of available alternatives (e.g., a tour directed to work is unlikely to start at 3am) while using a fine time resolution. As we first model the departure time for the main trip purpose and then subsequently the timing of the stop-activities the timing of the stop activities can be made conditional on the timing of the primary activities. This will narrow down the choice space. However, an even simpler solution will be to consider only time-of-day choice for the primary activities and the "derive" the timing of the stops from these. In the following discussion of the secondary tour model we will not consider the time-of-day choice.

3.2   Secondary tour activity model

Secondary tour activities are concerned with the existence of intermediate stop activities. These can either occur on the way from home to the primary destination and/or from the primary destination back home, as illustrated in Figure 4. For each intermediate stop, the model system determines the intermediate stop purpose and the destination of the stop.
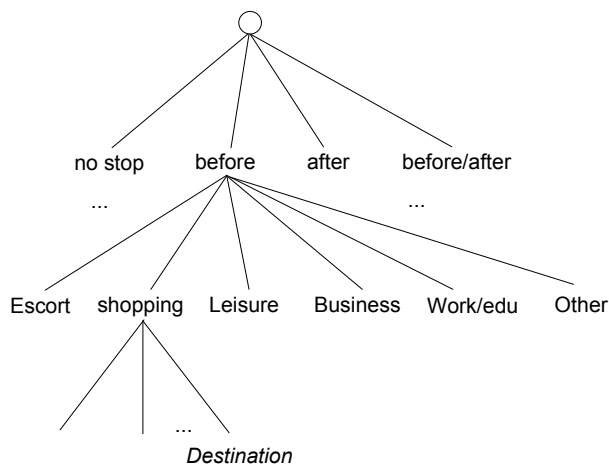
Figure 4: Choice model structure for the secondary tour model.

It will most likely be infeasible to consider all possible combinations of stop activities (and in particular for trips with activities before and after, which will have 6*6 activities) and for practical applications we may need to consider an aggregation. Similarly, the possible sampling for the destination of the intermediate stop activity is conditional on the actual location of the origin and destination of the primary tour. As a result, the sampling will be much simpler as it is largely defined by these conditional destinations.

The decision to model secondary activities endogenously is to some extent non-standard. As we segment according to main purpose, we do not model activities in a more general way; however it is a first step towards activity modelling. From a technical point of view, it is preferable to include the stop activities as model choice because we thereby save important degree-of-freedoms in the model as parameters across the various activities (or some of these) may be similar.

3.3   Linking the sub-models

The complete model structure is formulated within a nested logit framework. Sub models may be estimated using full-information maximum likelihood (FIML) to have consistency and efficiency (the lowest variance possible). However, across sub-models it may not be possible to use FIML due to the large choice sets. It is common to apply sequential estimation in this context. This is facilitated by moving logsum variables from the lower level models to the upper-level models, which is possible because the choice of the lower level is conditional on the choice of the upper level.

For example, representing the decision of an individual to stop for grocery shopping on the way back home from work depends on all the models at higher level including the main activity purpose, the destination, the time-of-day and the mode of the tour.

3.4   Possible extensions to the activity based design

The presented model structure is not an activity based model although it includes certain new principles along these lines.

One limitation of this model design is that activities are revealed by transport activities. In other words, it is only if respondents are engaged in a transport activity it will be monitored. It can be seen as a problem because people may actually be engaged in a range of activities at home, including work. In a scenario context, it means that it becomes slightly more difficult to measure labour market effects of various changes. Say the fuel prices are increasing; it will then infer a substitution so that more people stay at home. In the current model, this effect is captured in the frequency model, which includes the "no travel" alternatives. However, this does not say anything about the effects on the labour supply, which could be interesting from an assessment point of view. In fact, as the TU from 2006 collect home-based activities[4] it would be possible to throw some light on this.

Another issue is that we do not monitor the activities people are engaged in when travelling. Again, if we are interested in a proper modelling of the labour supply this can be seen as a problem. One issue is that the chance of doing work while travelling depends much on the mode of transport. For rail and in particular intercity rail, it may be very easy to work efficiently, whereas for car trips the time cannot be used in the same way.

A third issue is to correctly cope with dependencies between the members of the household. We believe, however, this is a minor problem compared to the other problems mentioned above. The point is that the strategic model is already concerned with the cooperation of the members of the household in a long-term perspective. As a result, dependencies that are reflected at the strategic level will be dealt with, which in turn, will explain most of the day-to-day variability between family members.

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[4] Unfortunately, the question about home-based activities is only collected if the interview person has been at home all day.

4 Modelling of international traffic

An important objective of the set of demand models as referenced in Table 1 is to model international transport and in particular transport crossing the Fehmarn Belt. The Fehmarn Belt model is an integrated part of the demand model and is covered by i) the international day model, ii) the overnight model (only the part that crosses the Danish border), and iii) the transit model.

For all of the international models we consider three destination segments

- DK
- NSF (Norway/Sweden/Finland)
- EUC (European Continent)

As a result there are three main transport flows to consider: DK to/from NSF, DK to/from EUC, and NSF to/from EUC.

4.1 International day model

The international day model will be segmented into four trip purposes. These are

- business, commuting, shopping, and leisure/other

It is worth noting that the duration of holiday trips per definition are above 24 hour. If data sources include holiday trips below 24 hours these are pooled with the leisure/other segment. The choice sets of the international day model are presented below in Table 5 and include a very standard set-up.

Choice	Choice set	Note
Mode	{car driver, car passenger, bus, rail, air}	
Destination	176 DK zones / 358 European zones	
Crossing point	Choice between ferries and fixed links	Depend on the destination

Table 5: Choice set for international day model.

The corresponding choices hierarchy is presented in Figure 5 below.
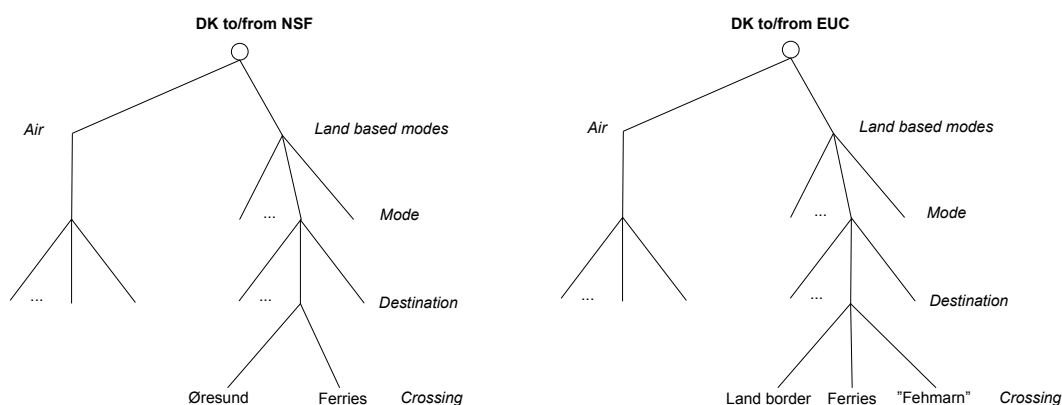

Figure 5: Possible nesting structure of international day model.

As seen, there are differences in the crossing points depending whether trips are going to the NSF segment or the EUC segment. As seen all the different ferry routes are combined in a single alternative. The choice between the different ferry routes is then left to the route choice model, which is much preferable from an application point of view. The point is that ferry routes might change route, frequency, and schedule which is much easterly dealt with in a route choice model. The challenge however, it too "calibrate" the route choice model in the baseline to reflect the observed market shares in the ferry market.

Most likely the different segments for the different trip purposes will have different mode constellations. For instance, it is unlikely that the "bus" alternative will be included in the business and commuter segments. However, it may be a relevant alternative in the shopping category as well as in the leisure category.

The notation "Fehmarn" indicates that the fixed link over the Fehmarn Belt is artificial at the time of the modelling. However, as it decided and will be implemented by 2018-2020 it will be part of the standard 2020 forecast. The market shares will be partly revealed through stated preference interviews.
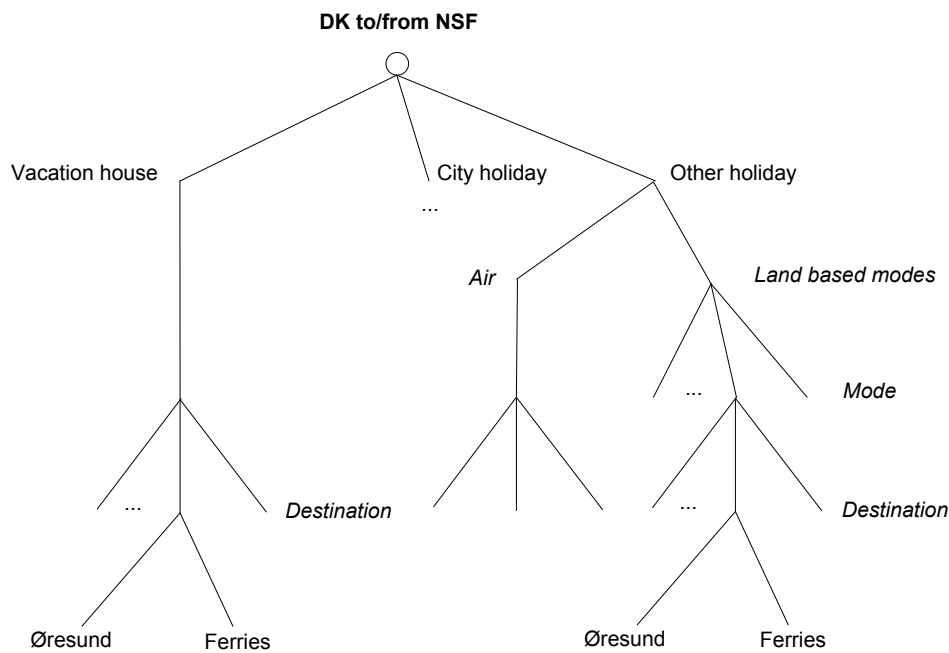
4.2 The overnight model

As described in the introduction in Section 1 , the overnight model will cover both international and national transport. As for the international day model we will apply segmentation on trip purposes although purposes are slightly different. In addition we will also apply segmentation into trip durations inspired by evidence from the Swedish national model (Beser and Algers, 2002).

- Business/commuting, leisure/other, and holiday
- 1 night, 2-3 nights, and 4- nights

Evidence from the TRANSTOOLS model (Rich and Mabit, 2011) suggested that segmentation into trip purpose generated very different parameters.

A possible choice hierarchy for holiday trips in the overnight model for the DK to/from NSF segment is illustrated below in Figure 6.

Figure 6: Possible nesting structure of the holiday segment in the overnight model for the DK to/from NSF segment.

The thing to note is that we distinguish between different types of holidays rather than using different exogenous segments as for the remaining purposes. The reason for making the choice of holiday type endogenous is that these three holiday types may be affected rather differently due to some of the planned infrastructure. For instance, building a new fixed "Fehmarn" link may significantly improve the accessibility to Copenhagen whereas it would not change accessibility to the large vacation house regions on the west coast of Jutland. As a result, the change in level-of-service may in fact affect the choice between holiday types and these should therefore be endogenous.

As seen, it somehow simplifies the structure as vacation houses are not allowed other modes than going by car. If any respondents report they are going to vacation houses by other mean than car these are classified in the "other" category.

It is assumed that the "city holiday" alternative will have a similar nesting structure as the "other holiday" category.

The model segment DK to/from EUC is modelled in similar way as presented in Figure 6 except that the crossing points changes. These changes to the three alternatives are similar to the one shown in Figure 5.

4.3   Transit model

The transit model will be simplified in the sense that we will apply a simpler segmentation of purposes (durations will not be considered). However, we maintain the same mode choice dimensions as in the international day model, i.e. car as driver, car as passenger, bus, rail and air.

What complicates the transit model is the fact that we need to consider combinations of the border crossing from NSF to/from DK and the crossing from DK to/from EUC. This gives rise to the following nesting structure
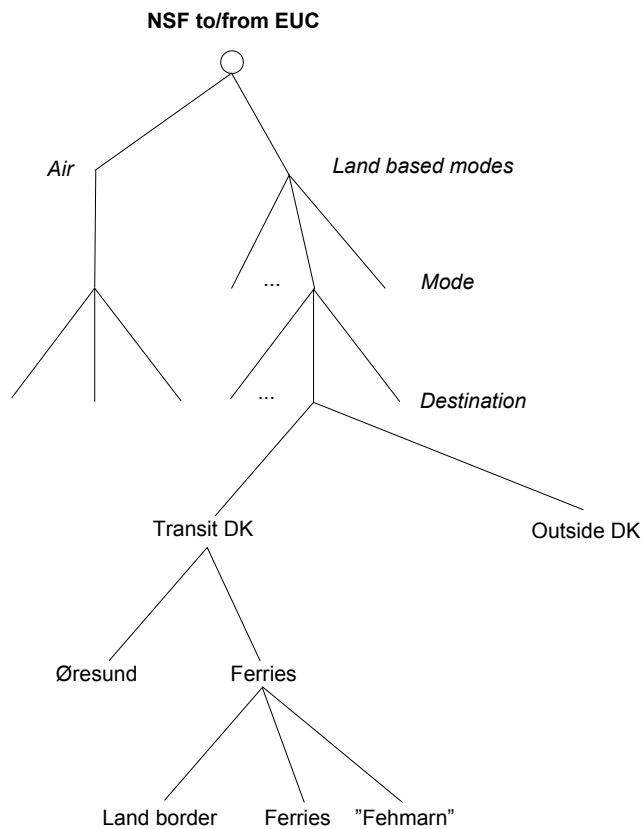
Figure 7: Possible nesting structure for the transit model for the NSF to EUC segment.

The challenge for the transit model is the lack of appropriate data as discussed in connection to Table 1.
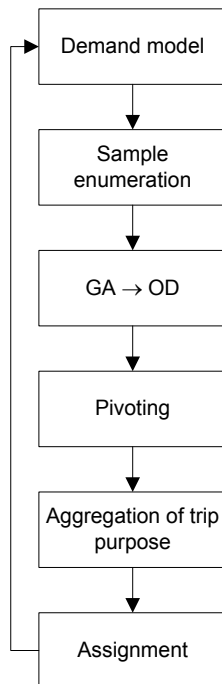
5   The representation of activity chains and matrices

5.1   The baseline matrices

For each of the five model segments considered in Figure 1 there will be a corresponding baseline matrix. This is makes the pivot point step (to be discussed below) where synthetic matrices are compared in a relative sense and scaled with the observed baseline more straightforward.

The baseline matrices will be formulated as OD matrices rather than GA matrices. This means that rather than representing tours, the matrices will represent single open-ended trips. The problem with tour based matrices is that the time-of-day point cannot be represented uniquely. Turning to an OD representation makes it possible to specify a unique departure time for each trip, which can then be fed to the (pseudo dynamic) assignment. The final transport pattern will then be expressed in a set of OD matrices spanned by from zone, to zone, trip purpose, and mode of transport and time of day.

5.2   The calculation setup

The calculation setup is presented in Figure 8. The process starts with the demand model, which for each model segment calculates a GA demand matrix. Note here that the demand model is chain oriented meaning that the output is GA based. The next step is to upscale the matrices to a population level. This is done by applying expansion factors generated in the population synthesizer.

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│  Demand model   │◄─┐
└─────────────────┘  │
        │            │
        ▼            │
┌─────────────────┐  │
│     Sample      │  │
│   enumeration   │  │
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Figure 8: Calculation process in the model framework.

The third step is then to convert matrices from its GA representation to an OD representation. It is notable that the time of day choice will only be considered in the weekday model. For the remaining models there will be no time of day splitting in the demand model, however, in order to distribute the traffic on to the network in a realistic manner we need to allocate traffic to time intervals. In the case where the model does not handle this, we will assign traffic according to a fixed time of day allocation scheme. For the international trips the GA representation includes one or more crossing points in and out of Denmark. The OD representation then consists of the trip from the origin to the entry border cross, the trip from the entry border cross to the exit border cross, and the trip from the exit border cross to the final destination. The reverse trips are then simply added to these three trips.

The fourth step is the pivot point procedure, in which we measure demand changes relative to the baseline matrices. The fifth step represents a possible aggregation of trip purposes. Although there may be differences in route choice preferences due to differences in the value-of-time there is no need to distinguish between, e.g. shopping and leisure. Also, this will reduce computation time slightly.

It should be noted that although the framework will for apply prototypical sample enumeration (PSE) techniques for the weekday model, it may use a simpler matrix forecasting approach for others (the international models). In the PSE technique matrices are formed by up-scale the micro sample (and corresponding choice sets) on which the model is estimated by using appropriate expansion factors[5]. In the matrix approach we simply re-formulate the model at the matrix level, which in turn will produce a synthetic demand matrix. In any of the two forecast methods the process sketched in Figure 8 are more or less similar. The only difference is that the so called "sample enumeration step" will not be needed if the model applies a matrix approach. All other steps are similar including the pivot point step, which ensures that the demand matrices of the model are pivoted relatively to baseline matrices. This has the advantage of making the model invariant to absolute divergence from the baseline matrix.

6 Discussion

It is important to consider the impact of the new Danish National model compared to existing models. What are the answers that we can answer with this model that was not possible before?

One of the most important impacts is that the model will be "the Danish model" and as a result establish a common reference to be used in all projects. At a more detailed level we see the following improvements compared to previous Danish models

- **A nation-wide model:** The fact that the whole of Denmark is covered makes it possible to investigate long-distance trips. This is important from a policy point of view as this is a rapidly growing transport segment. As previous models have only been applied for specific regions and with the application of port zones this is an important extension.
- **More long distance segments:** The fact that the model is extended with an detailed international component and furthermore divide travel activities according to trip duration and purpose makes it possible to investigate substitution effects between national and international trips.
- **Separation of strategic choices and daily choices:** The model proposes a decomposition of strategic choices and daily choices. The strategic choices are modelled at the household level and can be based on register data, whereas the daily choices will represent individuals. A benefit is that strategic choices such as car ownership and work location become integrated with the transport demand. In other words, demand will have impact in the strategic choices and vice versa. The design has not been implemented in many large scale models and represents front research and at least state-of-the-art.
- **Time-of-day switching:** The endogen modelling of time-of-day is new in a Danish context and relative rare in large scale models in Europe. The advantage is that it becomes possible to model how people react to pricing that varies with time, e.g. peak-pricing. Moreover, it is a first step towards understanding activity choice modelling.
- **Prototypical sample enumeration:** The model applies prototypical sample enumeration as a mean to up-scale results to the national level. This method is superior to the simpler matrix

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[5] Factors that up-weight the survey to the population level.

method as applied in TRANSTOOLS and OTM because it reduced the problem of aggregation bias that result from using averages at the zone level.

- **Tour based modelling:** Tour based modelling refer to the fact that the model unit is tours (trip chains) and not single open ended trips. Although tour based modelling has established itself as a modelling standard in recent years, the design in the Danish National model with the proposed two-layer chain design, is state-of-the-art for large scale modelling.

As discussed in 3.4 it has been considered whether a more advanced activity based approach should have been chosen. The main reason for not taking this step is that the primary application of the first version of the model will be to investigate large scale infrastructure projects such as the Fehmarn Belt connection and the Kattegat connection. The impact of an activity based design for these investigations will not be very large. However, in later versions where the model is to be used in the Copenhagen region this is a more relevant addition.

7   Summary and conclusion

The new Danish National transport model will deal with demand for passenger transport carried out by Danish citizens or take place in Denmark or its surrounding area. The model will consist of a series of parallel model in order to address various demand segments. However, having many parallel segments represented in different demand models, raises an issue with respect to double counting. This issue is discussed in details and it is outlined how the various model components cover all transport without doing double counting.

Also the issue of distance versus duration of the trip is discussed. The model will apply a model for durations and will not consider long and short trip segments separately. The reason is that the model should be able to address substitution effects across a potential distance definition that separates short and long trips.

Daily transport activities are modelled by proposing an adaptation of the activity-scheduling approach introduced by Bowman and Ben-Akiva (2001) and Ben-Akiva and Bowman (1988) as applied in the Tel-Aviv model (Cambridge Systematic, 2008). The approach considers tours as the main decision entity, with the choice of tours divided into choices related to the main tour and secondary tour activities or intermediate stop-activities. For each of these sub-models we consider a variety of choice decisions including choice of mode, destination and departure time. The exception to the approach applied in the Tel-Aviv model is that we segment on main tour purpose rather than modelling it endogenously.

In the paper we also consider the international aspect of the model. This involves a discussion of the three sub-models that goes beyond the Danish border; the international day model, the overnight model, and the transit model. For all of these models we present possible nesting structures and preliminary definitions of the choice sets.

Finally, we discuss how the process of going from GA based demand matrices to trips that can be assigned in separate time of day intervals. This involves a process, where we expand GA matrices and later convert these to OD. The OD representation allows the inclusion of a time of day representation. OD matrices are then pivot point adjusted prior to the (pseudo dynamic) assignment procedure.

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