1. Destination Choice and Land Use in the Øresund region — A Modelling approach

1.1 Introduction

The Øresund Traffic Model is developed for Øresundskonsortiet by COMVIN J/V. An overall description of the model is given in the paper ”The Øresund Traffic Model — An Introduction” by Karsten S. Pedersen, the paper is presented at Trafikdage på Aalborg Universitet 1998.

The Øresund Traffic Model is designed to forecast the future amount of traffic on the Fixed Link between Copenhagen and Malmö. Some important characteristics of trips crossing Øresund and the effect of introducing the Fixed Link are:

- The destination choice of long distance trips are not likely to be affected by the introduction of the Fixed Link. On the other hand the destination choice of trips in the Øresund region, both trips crossing and trips not crossing Øresund, are very likely to be influenced by the Fixed Link.
- There is an on-going economic integration between the Danish and the Swedish part of the Øresund region. This affects the traffic across Øresund by removing economic barrier effects and perhaps, in the long run, also cultural barrier effects. The Fixed Link will certainly have an impact on these trends.
- The Fixed Link are in the long-term likely to change the land use pattern in the Øresund region, which in turn effects the amount of traffic on the Fixed Link.

The first characteristic implies that the model can be split into two parts: a long distance model with only mode/route of crossing choice involved, and a short distance model where choice of destination also becomes important. Which is the approach used in the Øresund Traffic Model. The second characteristic gives the motivation for including barrier effects in the short distance model for the Øresund region. Finally, the short distance model can be applied to produce both short-term forecast where the Fixed Link is assumed to not alter the land use, and long-term forecast where the Fixed Link is allowed to affect the land use.

The rest of the paper will concentrate on the short distance passenger traffic sub-model of the Øresund Traffic Model.

2. Short distance trips

The short distance trips are those for which the Øresund fixed link does have an effect on the choice of destination. The operational definition of this are trips with both origin and destination in the Øresund region made by residents in this region. The Øresund region is defined as Skåne in Sweden and the Hovedstad region in Denmark, a region which should be considered a labour market region. The region is divided into 53 zones. For short distance trips it is not enough to only consider trips crossing Øresund. These trips will compete with trips made within Skåne and within the Hovedstad region, hence the scope of the short distance model is all trips made in the Øresund region.

This definition of short distance trips excludes trips made by people with residence outside the Øresund region. In the model these trips are treated with a fixed origin-destination pattern taken from the observed survey data, but with a mode/route of crossing choice specification similar to the short distance trips. Only trips crossing Øresund are considered in this sub-model, since there is no destination choice involved.

3. Data used to estimate the model

Two datasets were collected for the passenger model: the RP-data and the SP-data. The RP-data consists of observed survey data where ferry passengers were asked questions about the trip they made. The interviews were made in three periods from the summer of 1995 to the spring of 1996. However, An SP-study was performed to assure that reliable parameters describing the characteristics of the ferry crossings and the Fixed Link could be estimated. The SP-study were made as additional interviews on a subset of the respondents to the RP-survey.

Nearly 23000 RP passenger interviews were collected, 7500 of these were used in the estimation of the short distance model. 728 interviews were made in the SP-study.

4. Overall Structure of the short-distance model

The choice of destination, mode and crossing of Øresund are treated by the demand model which is a nested logit model. Travel cost and travel times and for public transport, the usual waiting and walking times, headway and number of transfers are taken from the traffic network. The network assumes no congestion. The zonesystem for the short distance models has 53 zones, 26 in Skåne and 27 in the Hovedstad region. The model produces average daily trips.

4.1 Trip types

To be able to accurately forecast the trips crossing Øresund, they are divided into trip types according to their purpose.

For trips made by residents in the Øresund region, the following trip types are used:

- Work trips (from home to work or return)
- Business trips
- Shopping trips
- Other trips

Today, only a small share of the total number of trips crossing Øresund are work trips. They are included in the model since their share are likely to increase when then fixed link are opened and also since they are important for the land use

For Short distance trips made by people not resident in the Øresund region, the following trip types are used:

- Shopping trips
- Other trips

There are also some special-purpose trips, namely

- Airport access/egress trips across the Øresund (using SAS services)
- Sailing trips (trips which use Øresund ports, but which do not cross the Øresund itself).

There is no modelling of the special-purpose trips except that the user can apply growth factors to the airport access/egress trips.

The short distance trips were grouped in four sectors:

A Swedish resident traveling within Skåne	B Swedish resident traveling to or from the Hovedstad region
C Danish resident traveling to or from Skåne	D Danish resident traveling within the Hovedstad region

We assume that cost and land travel time are equally perceived by travellers in the sectors A and B, and the same is right for the sectors C and D. This means that one set of parameters are used in sectors A and B and another set of parameters in sectors C and D. The main reason for this grouping is that the barrier effects for crossing Øresund are different between residents in Denmark and residents in Sweden. Therefore, a simpler approach with only one set of parameters for the whole region would yield inconsistent barrier effects.

4.2 Mode and Crossing

The modes considered by the model in sector B and sector C (i.e. trips crossing Øresund) are:

1. car all the way,
2. bus all the way,
3. train all the way ,
4. car on the residence side, disembarkment, car on the opposite side,
5. car on the residence side, disembarkment, public transport on the opposite side,

6. public transport on the residence side, disembarkment, car on the opposite side,

7. public transport on the residence side, disembarkment, public transport on the opposite side.

In sector A and sector D (i.e. trips not crossing Øresund) the modes are:

1. car,

2. public transport.

The different crossings are:

- for car and bus all the way — Helsingør-Helsingborg
Limhamn-Dragør
Fixed Link

- for train all the way — Fixed Link

- for disembarkment — Helsingør-Helsingborg
Landskrona-København
Malmö- København
Limhamn-Dragør.

The choice of mode and crossing is modelled as a nested logit model. The choice hierarchy is with destination choice at the highest level followed by mode and choice of crossing at the lowest level. The model structure is shown in Fig. 1. (mode choice for sectors A and D are not shown).

A more detailed description of the different levels of the model is given in the following sections.

5. Model specification

The following notation is used:

i is for origin

j is for destination

m is for mode

w is for route, i e crossing of Øresund.

u is trip purpose.

The purpose of the model is to produce a trip matrix from which the amount of traffic on the Fixed Link and the other crossings are derived. The trip matrix can be decomposed in the following way:

$$T^u_{ijmw} = T^u_{i...} \cdot p^u{}_{j|i} \cdot p^u{}_{m|ij} \cdot p^u_{w|mij}$$

$T^{u}_{i...}$ is the number of trips of type u generated at zone i. They are taken from the trip generation part of the model.

$p^{u}{}_{j|i}$ is the probability of choosing destination j given origin i.

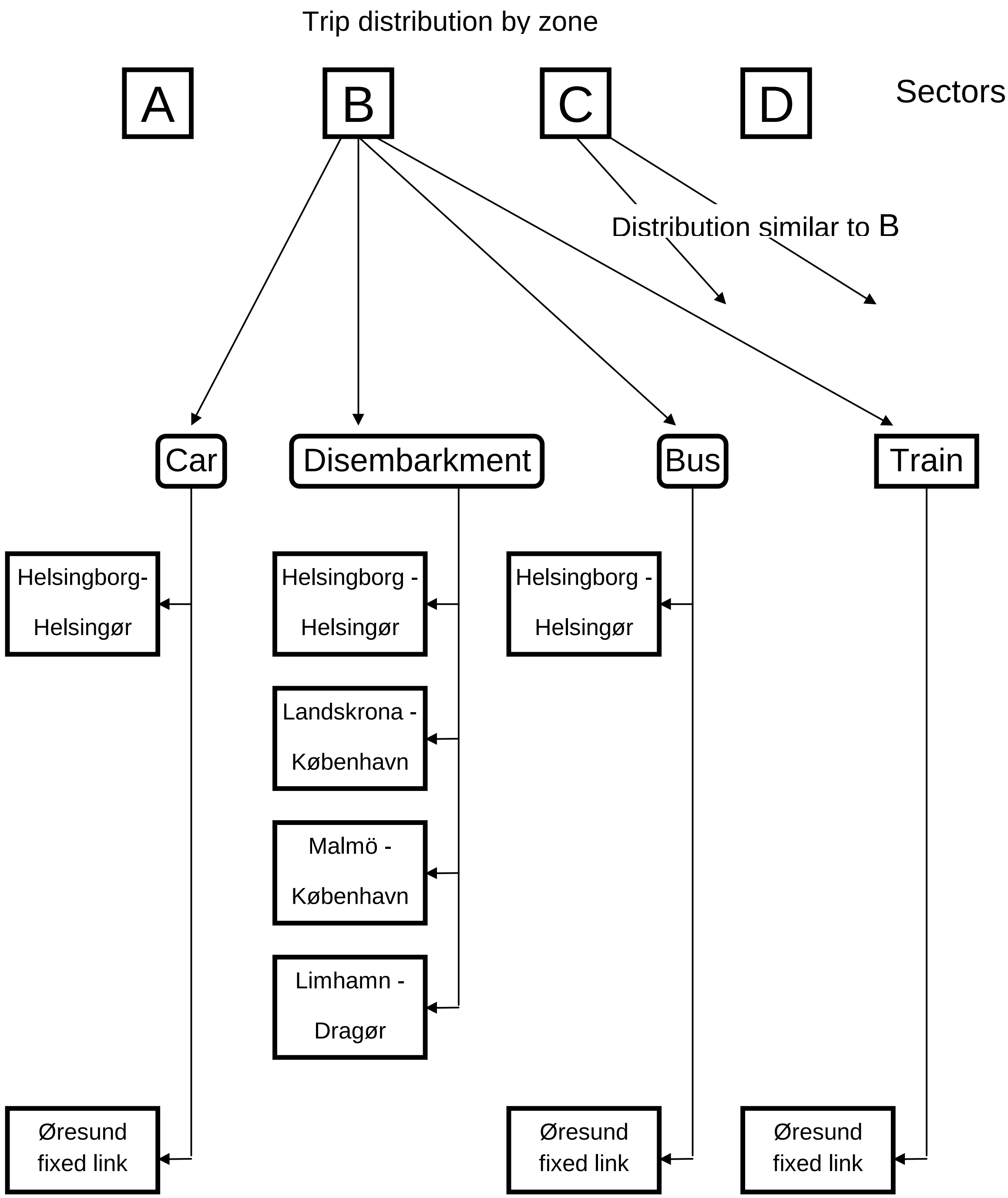
$p^{u}{}_{m|ij}$ is the probability of choosing mode m between origin zone i and destination zone j.

$p^{u}{}_{w|mij}$ is the probability of choosing crossing w when using mode m between origin zone i and destination zone j.

In the sub-model for people with residence outside the Øresund region $p^{u}{}_{j|i}$ are taken from the observed shares in the RP-data, which then are held fixed in the application of the model. For the special-purpose trips (Airport access/egress trips and sailing trips) all probabilities are replaced by observed shares.

Mode and crossing choice were estimated jointly followed by a sequential estimation of destination choice. Parameters derived from SP-data were estimated separately from parameters estimated from observed RP-data. In order to correct for differences in the amount of variation between RP- and SP-data, the SP parameters were scaled into the utilities when the RP-parameters were estimated. See the utility specification below.

Fig. 1. Model structure for the short distance model.



5.1 Choice of Crossing.

The choice of place of crossing Øresund is at the lowest level in the choice hierarchy. Therefore it is conditioned on origin, destination and the mode of the trip. As understood from the sections above, this level is not included in sectors A and D (i.e. trips not crossing Øresund).

Given origin i, destination j and mode m the probability of choosing crossing w is for trips of type u is

$$p_{ijm}^{u} = \frac{\exp(U_{ijmw}^{u})}{\sum_{w \in M_l} \exp(U_{ijmw}^{u})}.$$

Where U_{ijmw}^{u} is the utility for crossing w given i, j, m for trip type u.

The utilities are calculated as follows:

$$U_{ijmw}^{u} = \alpha_{mw}^{ul} + \gamma_{m}^{ul}(d_{ijmw}^{u} + \delta_{m}^{ul} t_{ijmw}^{g} + \beta_{m}^{ul} t_{mw}^{f} + \varepsilon_{m}^{ul} h_{mw} + \eta_{mw}^{u}) + \zeta_{m}^{u} \cdot CAV,$$

where α - mode and crossing specific constants, γ - money value, δ - land travel time value, β - relative cost of onboard ferry travel time, ε - relative cost of waiting time for ferry, t^g - travel time on land (including weighted waiting time, walking time and number of transfers), t^f - travel time onboard ferries, h_m - headway for ferry or headway, d - travel monetary cost and η is a bridge specific constant. ζ is a parameter that alters the level of the utilities for cars depending on whether the traveller has a car available or not, which is indicated by the 0-1 variable -CAV. The standard approach for treating car availability in traffic models is to segmenting the data by car availability and estimating different models for the two segment. This method were not used since there were to few observations available in several trip types.

Only the α 's, γ 's and the ζ 's are estimated from the observed RP-data, the rest of the parameters are estimated from the SP-data.

5.2 Choice of Mode

The mode choice is the next level of the hierarchy. This level consists of logsums brought up from the lower level. Only logsum parameters are estimated at this level.

5.3 Destination Choice and Barrier Effects.

In the destination choice the model is applied in incremental form, i.e. a base trip matrix is constructed and forecasts are computed as changes to the base scenario. Denote the base matrix by $q_{j|i}$. The destination choice can be written as

$$p_{j|i} = \frac{q_{j|i} \cdot \exp(\xi \cdot \Delta U_{ij*} + \lambda^{e} \cdot \Delta B^{e} + \lambda^{c} \cdot \upsilon \cdot \Delta B^{c}{}_{n} + \Delta A_{j})}{\sum_{j} q_{j|i} \cdot \exp(\xi \cdot \Delta U_{ij*} + \lambda^{e} \cdot \Delta B^{e} + \lambda^{c} \cdot \upsilon_{n} \cdot \Delta B^{c} + \Delta A_{j})}$$

Where U_{ij*} is a logsum of the utilities over the modes and crossing in sectors B and C and over modes in sectors A and D . ΔU_{ij*} is then the change in this composite utility compared to the base scenario. ΔA_j is the change in attraction for the business, shopping and other trip types, it is a function of employment in zone j. Work trips which are doubly constrained lacks the ΔA_j term, changes in trip attraction and generation are computed by Cross-Fratar adjustment. ξ is a coefficient estimated from the destination choice of travellers in sectors B and C. For sector A the ξ is set equal to the ξ used in sector B and a similar treatment is made in the sectors C and D. The reason for this is that it is very important for the interpretability of the barrier effects that a traveller living in Skåne has the same sensitivity to utility changes regardless of whether the trip is made within Skåne or crossing Øresund, of course the same is true for residents in the Hovedstad region. It is somewhat arbitrary how this should be achieved. Alternative ways could be to use ξ estimated for sectors A and D respectively or average ξ estimated over both A and B (C and D). However, since the aim of the model is to forecast trips crossing Øresund, the method chosen should be the most appropriate.

Barrier effects for trips crossing Øresund are included as additive terms in destination choice utilities. The economic barrier effect is given by λ^e and the cultural barrier effect by λ^c. The changes in the corresponding barrier effects are modelled by the policy variables ΔB^e and ΔB^c, e.g. if they are set to -0.5 the barrier effects are decreased by 50%. The barrier effects in sector A and D are defined to be zero.

The barrier effects should be interpreted as the extra loss/gain in utility that a traveller perceive when crossing Øresund compared to a trip that is perceived similar with respect to travel cost and travel times but is not crossing Øresund. When the barrier effects were estimated the total barrier effect was estimated. The split into an economic and a cultural component was made later by using information from the RP-data about the nationality of the travellers and by making the following assumptions:

- The cultural barrier effect can not increase the utility derived from trip characteristics.
- The economic barrier effect can both increase or decrease the utility derived from trip characteristics.
- The cultural barrier for Danes travelling to Denmark, and Swedes travelling to Sweden is zero.
- The Øresund region is an homogenous labour market (not segmented with respect to occupation etc.).

Only the last assumption is controversial, however the traffic model it self is based on that assumption.

An example of the importance of the barrier effects is given by the estimated economic barrier effect for work trip, which are: +55 DKK/trip for sector B trips, i.e. people living in Skåne and working in the Hovedstad region and -219 DKK/trip for sector C trips, i.e. people living in the Hovedstad region and working in Skåne. This is supported by the observed data, few Danish residents are working in Skåne but much more Swedish residents are working in the Hovedstad region (at least during 1995). It is also in line with the fact that wage rates and taxes in Denmark and Sweden strongly supports this pattern.

6. Fixed Link and Land Use — Interaction

In the long run reduced generalised travel cost caused by the Fixed Link, and reduced barrier effects will give incentives to an altered land use as for location of workplaces and housing units. To account for this the Øresund traffic model includes the IMREL model, which gives the user the option to realistically model long-term forecasts with the short distance model.

IMREL simultaneously model changes in land use pattern and changes in travel pattern by iterating between two sub-models RES and EMP until convergence land use and travel pattern has been reached . Given the employment location (from EMP) RES determine the housing location of the regional population and the distribution and modal split of the work trips so that the distribution will be consistent with the residential and employment pattern. Given residential location and accessibility to labour force (from RES) EMP allocates the employment location throughout the region. It is possible to apply restrictions on the number of housing units and workplaces on zone level.

IMREL was originally developed to evaluate the so called Dennis project in Stockholm but has been completely re-estimated for the Øresund region. It uses mode/crossing utilities as input from the short-term short distance model and produces updated land use pattern and trip matrix for work trips as output. IMREL consider only work trips but the updated land use are input to the short-term model which in turn can produce long-term forecast for the rest of the trip types.