models developed. This is one of the key differences between the specifications of the two models developed for work tours.

Destination choice for education tours turns out to be somewhat limited in scope, since two thirds of the tours have origin and destination in the same zone. The modelling is therefore largely concerned with judging those people who are likely to make longer tours. The most useful information proved to be the level of education: broadly those seeking higher education are expected to be prepared to travel further. A separation of school places was attempted for students of different ages (parallel to the separation of workplaces for workers in different professions) but the data was limited.

For both (usual) work tours and education tours, it is of course quite common that a repeat tour is made, the traveller returning home briefly in the middle of the day. In such a case it is reasonable intuitively and evidenced by the data that the second tour does not involve a new destination. To incorporate repeated tours in the modelling would therefore be inappropriate, since the assumption of independence is obviously not valid in this case. Repeated tours were therefore excluded before the estimation of these models. These tours are handled by the frequency models described in the following section.

5.6.2 TOURS TO FIXED WORKPLACES

The model developed for tours to fixed workplaces is shown in Table A6.2. The immediately striking feature of this model is that 19 of the 34 parameters estimated are balancing factors. These factors are the result of competition in the labor market, but give little behavioural information because it is the differences between the parameters rather than the absolute values that are important. As explained in the previous section, these variables are included in the estimation solely to avoid biases appearing in the other coefficients. They should also be included forecasting to avoid biased forecasts.

More important from a behavioural viewpoint are the variables (12-15) representing particular connections between an origin area and a destination area. In the case of Rotterdam and Delft, the results show a strong tendency for residents of those towns also to work there. The other variables show the use of North Brabant as a dormitory area for Rotterdam and the strong connection between Zoetermeer and The Hague. These latter two effects may well be due to migration in the last few years from the cities to the respective areas.

The basic variables representing accessibility are the logsum and distance variables (1-2). The results show that although the logsum (representing the disutility of the journey as given in the mode choice model) is a significant influence on choice, a further separation effect is also necessary to obtain a proper representation. The distance variable may be interpreted as incorporating those effects that are highly correlated between modes and do not therefor appear in the mode choice model. Alternatively or additionally, it may represent the information availability of jobs distant from the home. The intrazonal variable (11) is a compensation for non-linearity and/or measurement error in these separation measures.

The remaining separation variables (3-10) apply only to certain classes of tours. From them it may be concluded that higher education increases the willingness to accept distant jobs (or the level of information about them) (variable 4), whereas lower education naturally has the opposite effect (variable 7). Women are more resistant to taking distant jobs (variable 3), as are people who go the work in the evenings (variable 10). Both these effects are probably connected with part-time working and are therefore natural. The "long-Hours" variable (5) is probably a correction for these effects, as well as reflecting the fact that people who work genuinely long hours travel shorter distances to work (or vice versa). A well-established feature is that people living in less dense areas travel less far to their work than would be expected from the paucity of opportunities nearby (variables 6, 8 and 9).

For its kind, the model is rich in detail and gives a rather good fit to the data. However, with such a complicated issue as the relationship of work and home locations, it cannot be argued that the model could give a perfect representation of urban development over time. It does provide a representation of trip length preferences conditional on a distribution of accessibility.

Zonal Model

The zonal version of this model is shown in Table B6.2. Most of the important variables from the disaggregate model have been incorporated into a "utility" variables (variable 1). The increased variance in this zonal model is shown by the much lower coefficient of this variable compared with its value equivalent to 1 in the more disaggregate version. Among the variables not preserved in the zonal version is the separate attraction for farmers, dropped because information on the number of farmers living in the study area zones was not available.

In addition to the utility variable, distance and intra-zonal corrections were re-estimated to reduce biases arising from the different basis of level-of-service measurement.

Finally, a reduced set of balancing factors was found to be adequate. Note that in application of a zonal model, the predictions of the model give a reasonable estimate of the total number of work tours arriving in each zone of the study area. It is possible therefore to calculate detailed balancing factors (one for each zone) as part of the application process. The balancing factors appearing in the estimation should be seen as approximations to these detailed factors.

5.6.3 THE UNUSUAL WORK TOURS MODEL

The destination choice model for work tours to unusual work places is shown in Table A6.3. There are substantial differences between this model and the model for work tours to usual work place. For example, in this model, only one socio-economic indicator is included for professional occupations. No balancing factors are included because the nature of these work trips does not include fixed constraints on potential travel. Two size variables are included (employment and population) since it is reasonable to suppose that these tours are attached to residences as well as places of employment (e.g., house painters). Note that the two time-of-day variables both capture the same basic effect: if time is short (tour leaves the destination before 12:00 noon, or arrives at the destination after 14:00), then closer destinations are more likely than otherwise. Note also that the logsum variable coefficient has been constrained to take the value of 0.265. This value was the best unconstrained estimate of this coefficient, derived from a previous specification of this model. Unfortunately, the previous specification yielded undesirable interactions between the logsum variable and other (distance) variables. Constraining the logsum coefficient was the only method available to deal with this problem.

The quality of this model is a little lower than that of most of the other models. This is due to the small number of tours observed and the generally unpredictable choice of destination for this purpose.

The Zonal Model

The zonal model is shown in Table B6.3. It includes a variable containing most of the variables from the disaggregate model, together with two variables correcting the distance distribution. There are no apparent problems with this specification.

It was not found possible, however, to predict correctly tours over 100 km in length. Many of these tours leave the study area, and the information about them is therefore less accurate. Further, with the small amount of information available for this purpose, a few coding errors can have a disproportionate effect. A final problem was that it was not possible to select a sample of alternatives specifically for this purpose, and the sample used was not fully appropriate. For these reasons, the best procedure appeared to be to exclude the 15 longest tours, which otherwise caused many difficulties.

The quality of this model is generally comparable with that of the disaggregate version.

5.6.4 EDUCATION TOURS

The model for education tours is shown in Table A6.4. Apart from the logsum variable (1), the key variables are those that represent the variation of tour length with the level of education (variables 3-8). These show a natural trend of increasing lengths with increasing level. A correction to these variables is the intrazonal variable (2). A further correction, given by variable 12, is that older students are willing to travel further, even for the same kind of education.

The sex variable (9), indicating the males travel further than females, is somewhat surprising, but this effect was observed even amongst the youngest children. The "lunch" variable (10), effectively identifying those who are at the school for a whole day, illustrates that those in full-time education are willing to travel further than part-timers. This effect is emphasized by variable 11.

On the whole, the coefficients of the model are quite accurately estimated. This is slightly surprising, because the fact that the overwhelming majority of the tours are intrazonal reduces the amount of real information available. The accuracy of estimation therefore suggests that the model specification is quite good.

Zonal Model

Table B6.4 shows the zonal version of the destination model of education choice. The specification has been altered somewhat - for example, since educational status is not available in the zonal data, age was used in its place. Again, as age increases, trip lengths to school also increase. Males and higher income travellers also make longer educational trips. Other variables also show patterns similar to the disaggregate specification.

5.7 FREQUENCY CHOICE

5.7.1 TOPICS IN FREQUENCY CHOICE MODELLING

For each tour purpose, two separate models of frequency were developed, as mentioned in Section 4.1. The more important of these represents the choice whether or not to make any tour for that purpose on the specified day: because this is a choice between making zero tours and making one or more tours, this is called the 0/1+ model. The other frequency model for each purpose represents the choice, given that a tour was made, between making just one tour and making repeated tours for the same purpose: two different approaches were taken for this model. For most tour purposes, "ordered" binary logit models (see Section 4.1) were developed. These models represent the choice given that a positive number of tours has been made for a given purpose between stopping at that number of tours and going on to make one or more further tours: these models are called STOP/REPEAT models. For education tours we found that almost no adults (other than students) made more than one tour in a day, and no repeat tour model was developed. Education tours by children and students were frequently repeated, but very infrequently did they make three tours. For these people we developed a model of choice only between one tour and two or more tours: the 1/2+ model.

The data sets for frequency choice modelling are straightforward in concept, although the calculation of accessibility by logsums is complicated. Essentially, all individuals in the data set can be used for estimating the 0/1+ frequency models for each purpose. For the STOP/REPEAT and 1/2+ models, only those individuals who were observed to make one or more tours give information to the estimation data set. For educational tours, the data set was split into two parts: children (and students) on the one hand and (other) adults on the other hand.

The variables included in the models for the frequency of work tours were:

- occupation:	Naturally the most important variable governing the frequency of work tours is whether or not the individual is employed (as opposed to being a housewife, student, etc.).
- age:	Children below the age of 15 are not permitted to work, so these individuals were eliminated entirely from consideration for work models.
- education:	Because entry into the labor force is often delayed until one's education has been completed, a gradual entry period (age 15 to 25, for example) is reasonable.
- retirement:	Similarly, a gradual exit period between the age of 55 and 65 can be expected.
- family size:	All else held equal, one might expect that in large households, more family members of working age might choose to work to assist in supporting the family. Also, large families will have more people at working age than small families.
- sex, marital status:	In the Netherlands, societal presusses place great emphasis on males working, and also place similar pressures on unmarried females. Conversely, married females may be under pressure to leave the labor pool.
- qualifications and education:	Individuals with low levels of education may tend to be unemployed.
- accessibility:	When work and home locations are highly accessible to each other, travel to home for luch is more likely. Thus, accessibility may influence the number of tours per day reported.

Different measures of accessibility were used for 0/1+ and STOP/REPEAT models. In the first case, accessibility to <u>all</u> potential workplaces was used, i.e., the logsum from the destination choice model. In the second case, however, it is reasonable to assume that repeat tours will be to the same workplace, and so the more accurate accessibility to the <u>specific</u> workplace was used, i.e., the logsum from the mode choice model. In other words, the STOP/REPEAT frequency model for work tours is conditional on the work place.

For education models, similar types of variables were employed. Education variables naturally became more prominent and household income was also included (which not have been reasonable in the work models). As for work tours, the two measures of accessibility were used.

Factors of importance for non-work and non-education frequency models also included:

- working and education status: Full-time workers or students may have less time available for non-work or non-education activities, and therefore may travel less for these purposes.
- age: Children seem, a priori, less likely to make shopping or personal business trips, and may make many social and recreational trips. Elderly individuals who have much free time may also be likely to travel frequently.
- household structure: The presence of other individuals of specific types in the household may influence the frequency of tours (e.g. for shopping).
- income: High income may relate to the frequency of recreational travel.
- accessibility: Travel from easily accessible locations is more likely to occur more frequently than travel from difficult-to-reach places.

For these purposes, only the accessibility to all destinations was used, i.e., it was acknowledged that repeat tours might well be to different destinations.

5.7.2 0/1+ MODELS

5.7.2.1 USUAL WORK TOURS

The disaggregate and zonal frequency choice models of the binary choice between no tours per day and one or more tours per day to one's usual workplace are shown on Tables A7.1 and B7.1. The specification of the disaggregate version includes household size, two age variables, and indicator variables for occupation and education. The zonal version includes two accessibility variables (logsum and licensed driver indicator), and age, sex, and income indicator variables. Over half and under a third of the initial choice uncertainty are accounted for by the estimated disaggregate and aggregate versions respectively.

5.7.2.2 UNUSUAL WORK TOURS

Tables A7.2 and B7.2 show the 0/1+ frequency choice models for travel to unusual work places. The specification of both models are very similar: both contain indicators for sex, age and car availability; both sets of coefficients are accurately measured; both models explain about three-qua of the initial choice uncertainty. In both models the accessibility coefficients (i.e. of the logsums) were not significant.

5.7.2.3 EDUCATION TOURS MADE BY CHILDREN AND STUDENTS

The 0/1+ disaggregate and zonal frequency choice models for student-made education travel are displayed in Tables A7.3 and B7.3. The disaggregate version contains a logsum variable*, three "single" age variables, an age/sex variable, two age/car availability interacted variables, a measure of residential density, and a measure of the number of non-workers in the student's household. The aggregate version of the model contains only three variables: a logsum, age indicator, and density indicator.

5.7.2.4 EDUCATION TOURS MADE BY NON-STUDENTS

The 0/1+ disaggregate and zonal frequency choice models for non-students are documented by Tables A7.4 and B7.4. In its disaggregate version, the model relies on three age variables and indicator variables of education and household income. The aggregate version's specification contains a logsum accessibility measure, a single age variable, and two indicators of car availability interacted with age (one for licensed drivers; one for non-drivers). Between 76 and 84 percent of the initial choice uncertainty is explained by the models.

5.7.2.5 SHOPPING TOURS

The disaggregate and zonal choice models of 0/1+ tours per day for shopping tours are shown in Tables A7.5 and B7.5. In its disaggregate version, the specification contains a logsum variable, the number of adults in the traveller's household and indicators for employment status, age under 17, age over 64, education, sex, and low-density residential area. The specification of the zonal model also includes a logsum accessibility measure, and six indicator variables (for sex, age under 12, age over 64, car ownership, retired males, and low-income residential area). The explanatory powers of both versions are very comparable and quite good.

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* It is perhaps surprising that the frequency of trips to school is shown to be sensitive to the transportation level of service between the home and school.

5.7.2.6 PERSONAL BUSINESS TOURS

Tables A7.6 and B7.6 contain the disaggregate and zonal versions of the 0/1+ frequency choice models models for personal business tours. The variables in these specifications are quite similar to those found in the frequency models for previously reported purposes. Note that although the values of the logsum coefficients in these versions are quite small, they are nevertheless measured accurately enough to be statistically distinguishable from zero.

5.7.2.7 SOCIAL TOURS

Tables A7.7 and B7.7 show the disaggregate and zonal versions of the 0/1+ frequency choice model for social tours. The disaggregate specification includes a measure of the size of the traveller's household and four binary indicator variables: two for age, one for non-working occupation; and one to indicate residence within either of the two major cities in the Zuidvleugel region. The zonal version uses one age indicator, the same city residence indicators, an indicator for sex, and an indicator for "retired" work status.

5.7.2.8 RECREATION TOURS

Both the disaggregate and zonal recreation tours models of 0/1+ frequency choice are shown on Tables A7.8 and B7.8 As in many previous specifications, logsum variables, indicators of age, sex, occupation, car availability, income, household size, and residential type are included in the model's two versions. The coefficients are all quite accurately measured.

5.7.2.9 MISCELLANEOUS TOURS

Tables A7.9 and B7.9 contain the disaggregate and aggregate versions of the 0/1+ frequency choice model for miscellaneous tours. The variables included in these specifications are similar to those contained in previously reported frequency models. Furthermore, the coefficient estimation accuracy is, in general, reasonably good.

5.7.3 STOP/REPEAT MODELS.

5.7.3.1 USUAL WORK TOURS

Tables A8.1 and B8.1 show the disaggregate and zonal versions of the

STOP/REPEAT frequency choice model for work tours to usual work places. The disaggregate version includes just one age variable and one accessibility measure. The age variable suggests that, when elderly people do work, they will go home for lunch more frequently. The zonal version segments travellers by sex (and finds that females travel less frequently than males for this purpose) and origin (residents of North Brabant make more frequent work trips than average, while workers who reside in Rotterdam or The Hague travel less frequently than average). The logsum variable was again used as the single accessibility measure, and proved very strong, so that in the zonal model the coefficient was constrained to its theoretical maximum value of 1.

5.7.3.2 UNUSUAL WORK TOURS

The disaggregate and zonal versions of the STOP/REPEAT frequency choice model for work tours to unusaual work places are contained in Tables A8.2 and B8.2. Both models contain only an alternative-specific constant, and a logsum accessibility variable, and are estimated with a relatively small number of observations for frequency models. Again the logsum variable is constrained in the model.

5.7.3.3 SHOPPING TOURS

Tables A8.3 and B8.3 document the STOP/REPEAT frequency choice models for shopping tours. The disaggregate version includes a "youth" variable (children under 17 shop less frequently than older people), and an income measure (as income increases, the frequency of shopping trips declines). The zonal version of the model contains only an alternative-specific constant and a logsum accessibility measure.

5.7.3.4 PERSONAL BUSINESS TOURS

Table A8.4 shows the disaggregate STOP/REPEAT frequency choice model for personal business tours, composed of just an alternative-specific constant term and a non-worker binary indicator variable. The aggregate choice share was used in place of an ordered logistic model, for the aggregate version of this model. The aggregate share is 0.1016 (87 go; 769 stop). This is equivalent to the estimation of an ordered logistic model with only an alternative-specific constant (GO-CONST); the coefficient estimate would be -2.19, and the values of $L^*(0)$, $L^*(\beta)$, ρ^2 and ρ_c^2 would be -593.33, -281.33, 0.474 and 0, respectively.

5.7.3.5 SOCIAL TOURS

The zonal and disaggregate versions of the STOP/REPEAT frequency choice model for social tours are documented by Tables A8.5 and B8.5. Car availability (interacted with the traveller's sex) is the accessibility variable used for the disaggregate version, which also distinguishes age, employment status, and household size. The aggregate version uses only age.

5.7.3.6 RECREATION TOURS

Tables A8.6 and B8.6 show the zonal and aggregate version of the STOP/REPEAT frequency choice models for recreation tours. The disaggregate model includes measures of age, occupation, and car availability; the aggregate version contains measures of age and income.

5.7.3.7 MISCELLANEOUS TOURS

Tables A8.7 and B8.7 contain the disaggregate and zonal STOP/REPEAT frequency choice models for miscellaneous tours. The disaggregate version utilizes a logsum accessibility measure, an occupation indicator, two age variables, an education measure, and the number of children in the traveller's household (the presence of children indicates a need to "serve passengers"). The zonal version used two age variables and a sex indicator.

5.7.3.8 1/2+ MODELS OF EDUCATION TOURS FOR STUDENTS

The disaggregate and zonal version of this frequency choice model are shown in Tables A8.8 and B8.8. The disaggregate version's specification contains a logsum accessibility measure, a car availability accessibility measure, four indicators of educational level, an indicator of low income, and an indicator of residence within Rotterdam. The zonal version of the model has only a logsum variable and an age indicator for travellers below 12 years old.