Task 7.6 Create Family Structure Model

Concepts

The car ownership and trip end models require family structure distributions for forecasting. The requirements are as follows.

Person Types

The basis of the trip end model is the population split into 7 person types for which we expect to be forecast for each zone by the planners (ie this is an input to the model).

Person types
P1: infant (<5)
P2: child (5-16?)
P3: young adult (17-25) unemployed
P4: young adult (17-25) employed by:
P5: adult (26-60) unemployed
P6: adult (26-60) employed
P7a: adult (>60) unemployed
P7b: adult (>60) employed

Household Types

The car ownership model uses a split of households by type, by zone.

Household types
H1: retired, 1 adult
H2: non-retired, 1 adult
H3: retired, 2 adults
H4: non-retired, 2 adults
H5: 3+ adults

For the trip end model, to define the car availability segmentation, we need a further classification of household types by car ownership for the captive/choice segmentation (for each zone). This will be estimated by the car ownership model.

Household types		Car availability
H1.1	0 cars	Captive
H1.2	1 car	Choice
H2.1	0 cars	Captive
H2.2	1 car	Choice
H3.1	0 cars	Captive
H3.2	1 car	Competition
H3.3	2+ cars	Choice
H4.1	0 cars	Captive
H4.2	1 car	Competition
H4.3	2+ cars	Choice
H5.1	0 cars	Captive
H5.2	1 car	Competition
H5.3	2 cars	Competition
H5.4	3+ cars	Choice

Household and Person Types Cross-Classification

Overall, for the trip end model, for each zone, we need a cross-classification of persons within household type, the latter segmented by car ownership level. This is obtained directly by combining the household car ownership forecasts with the Person type by Household type distribution.

Households by Type	**Person Types**							
and Car ownership	P1	P2	P3	P4	P5	P6	P7a	P7b
H1.1								
H1.2								
H2.1								
H2.2								
H3.1								
H3.2								
H3.3								
H4.1								
H4.2								
H4.3								
H5.1								
H5.2								
H5.3								
H5.4								

Method

The preferred method relies on a known cross-distribution of household and person types over the whole study area, derived from the household survey. This cross-distribution is re-weighted to reproduce the forecast aggregate demographic characteristics of each zone in the future years.

The planning data will provide for each zone the populations classified by person type and, separately, the number of households split onto 5 categories. Using the car ownership model we shall further disaggregate the number of households into the 14 categories.

The purpose of the family structure model is to develop the cross-classification of zonal population by person type and household category.

This process is referred to as a sample enumeration procedure. It can be solved using quadratic programming to estimate the proportions of each household type which in aggregate most nearly match the zonal distribution of persons by person type. However, in the case of Wellington where very large changes in family structure are not anticipated a more approximate approach was satisfactory.

The method, which follows work by MVA, is as follows.

From the household survey we can establish a matrix Nij of the average number of persons of type i in household category j as illustrated below.

The model we propose for forecasting the cross-classification of the population uses this matrix:

$$P'_{ij} = P'_i * N_{ij} * H'_j /(\Sigma_j N_{ij} * H'_j)$$

Where, for each zone:
P'_{ij} is a future population classified by person type i and household category j
P'_i is the population by type from the planning data
H'_j is the households by category from the planning data and car ownership model

Figure 1 The Population Proportions in each Person Type and Household Category

Household Category			Person Type						
					young adult		adult		
Adults	Status	Cars	infant	chld	unemployed	employed	unemployed	employed	retired
1 adult	retired	0	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	1.1%
"	"	1	0.2%	0.8%	0.0%	0.0%	0.0%	0.0%	4.6%
"	working	0	0.0%	0.1%	0.0%	0.2%	0.0%	0.3%	0.0%
"	"	1	0.3%	0.8%	0.0%	1.4%	0.0%	2.7%	0.0%
2 adults	retired	0	0.1%	0.4%	0.0%	0.0%	0.0%	0.0%	1.6%
"	"	1	0.1%	0.3%	0.0%	0.0%	0.0%	0.0%	8.2%
"	"	2	0.5%	2.3%	0.0%	0.0%	0.0%	0.0%	6.6%
"	working	0	0.4%	1.7%	0.4%	0.6%	0.9%	1.2%	0.0%
"	"	1	1.0%	4.4%	0.6%	1.8%	3.5%	5.8%	0.4%
"	"	2	0.7%	3.0%	1.2%	2.7%	4.4%	6.7%	0.0%
3 adults	-	0	0.1%	0.5%	0.1%	0.3%	0.3%	0.7%	0.4%
"	-	1	0.1%	0.5%	0.2%	0.3%	0.4%	2.5%	0.7%
"	-	2	0.3%	1.3%	0.3%	1.2%	1.1%	3.0%	1.8%
"	-	3	0.3%	1.6%	0.4%	0.9%	1.6%	2.2%	2.8%

Figure 2 The Matrix Nij - The Average Number of Persons of Each Type in Each Household Category

Household Category			Person Type							
					young adult		adult			Average
Adults	Status	Cars	infant	chld	unemployed	employed	unemployed	employed	retired	family size
1 adult	retired	0	0.03	0.12	0.00	0.00	0.00	0.00	1.00	1.15
"	"	1	0.06	0.26	0.00	0.00	0.00	0.00	1.00	1.32
"	working	0	0.09	0.36	0.00	0.38	0.00	0.62	0.00	1.45
"	"	1	0.08	0.23	0.00	0.35	0.00	0.65	0.00	1.30
2 adults	retired	0	0.15	0.75	0.00	0.00	0.00	0.00	2.00	2.90
"	"	1	0.03	0.12	0.00	0.00	0.00	0.00	2.00	2.15
"	"	2	0.25	1.00	0.00	0.00	0.00	0.00	2.00	3.25
"	working	0	0.32	1.29	0.25	0.40	0.60	0.75	0.00	3.61
"	"	1	0.21	0.82	0.10	0.30	0.60	0.95	0.05	3.03
"	"	2	0.11	0.45	0.18	0.35	0.60	0.87	0.00	2.56
3 adults	-	0	0.14	1.08	0.14	0.54	0.50	1.35	0.54	4.28
"	-	1	0.14	0.54	0.18	0.27	0.41	2.25	0.54	4.32
"	-	2	0.17	0.68	0.17	0.54	0.51	1.35	0.68	4.08
"	-	3	0.27	1.08	0.27	0.54	1.01	1.35	1.35	5.87

The forecast population distribution using this formula exactly reflects the planning forecast of persons by type and approximates the effects on the population cross-classification of changes in the household category distribution. It is likely to increase the proportion of the population in a person type/household category if either or both of the person type and household category are forecast to form a greater proportion of the future population.

In effect, the process adjusts the matrix Nij in forecasting. Although the forecast matrix would look very similar to the observed Nij, because it is a simplified procedure it does not fully preserve some of the logical constraints on Nij. For example the implicit average household size for 1 and 2 person households may be marginally different from 1 or 2. Given that it is our expectation that the population distribution will not change by a large magnitude in future in a city with slowly-changing population and high car ownership, we are of the view that this approximation is acceptable.

The alternative would be to use quadratic programming algorithms to search to a population distribution for each zone which met these logical household constraints. We are reluctant to adopt such an increase in complexity, particularly as the optimisation approach does not itself provide assurance that the outcomes are correct (only that they are compatible with the constraints).

Additional Requirements

The calibration of the trip production model has led to a requirement to allow for (i) growth in household income and (ii) the effects on adult trip rates of children in the household.

Household income has a uniform incremental effect on trip rates for all persons and requires no special calculations of family structure.

However, special consideration is required for the effects of children on adult trip rates.

The model indicates that the average HBO trip rate for a zone should be increased for the effects of children by:

$$\alpha * (P_1 + 2 * P_{2+})$$

where α is a the calibrated coefficient for children
P_1 is the proportion of adults in 1 child households
P_{2+} is the proportion of adults in households with 2 or more children

As illustrated by Figure 3, the proportions P_1 & P_{2+} are closely related to the average number of children/household in each zone, and we can use this relationship to estimate the additional adult trips generated by the presence of children in the household.

■ **Figure 3 The Variation in the Proportion of Adults with 1 or 2+ Children in their Household with the Average Number of Children per Household (by geographic sector)**