Modelling the Choice of Second and Subsequent Trip Destinations as a Markov Process: Behavioural Implications

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Abstract: Modelling a sequence of destinations or activities as a Markov process implies a belief in constant transition probabilities, that circumstances and habits result in fairly stable proportions between the activities which follow a particular activity. In the case of private car touring, after predicting the initial visit as a choice based on relevant factors, the subsequent visits are modelled as a non-homogeneous Markov process, including both the probability of returning home and the high probability of staying another night. The complete model, calibrated to known aggregates, has been applied to the 22 major regional destinations in WA. Applying Markov probabilities to determine subsequent destinations means that choice of the first place to visit is critical in 'delivering' travellers to other places. Thus, enhancing one local attraction may boost visits to towns which can conveniently be included in the same tour. Although a logit model could be used to predict the first of a series of urban linked trips, that is not done in this preliminary application to people engaged in home duties or part-time work. Also, there is no natural time step, analogous to the overnight stays of tourists. Another significant dissimilarity is the high probability of leaving or returning home at any time of day. The applicability of Markov models depends on how much a policy or structural change is likely to alter the transition probabilities. The geographical basis of the car touring case means that enhancement of one destination is unlikely to substantially change the linkages underlying the probabilities but the urban case is more problematical.

Keywords: *Markov; Destination choice; Car touring; Urban trips*

1 INTRODUCTION

The subject of this exploratory paper is the extent to which Markov transition probabilities can be used to model the sequence of choices in linked trips. Markovian models have been used for travel adjustment or switching from day to day, e.g. Hazelton's (2002) traffic adjustment and Goulias's (1999) travel patterns, but there has been limited application to destination sequences.

A number of writers have noted the importance of the succession of destinations on extended trips or tours (Mings and McHugh, 1992; Oppermann, 1995; Eby and Molnar, 2002). Tourist destinations visited in sequence are complements, due as much to the spillover from one place to another as to the attractions at the later destinations. The initial visits can be predicted separately and then used as starting points.

Summarising the sequence of visits into a matrix of transition probabilities has the advantage, in the touring case, that such a Markov matrix includes the probability of staying another night. This turns visits into visitor nights, which are useful for planning.

Urban trip linkages are based on the specific purpose to be satisfied at each destination, so that the primary linkage is between activities.

2 PREDICTION OF CAR TOURIST VISITS TO INITIAL DESTINATIONS

2.1 Visitor attraction

The first module of the initial visits model is based on studies in the Southern Wheatbelt (Han, 1998) and the Pilbara (Taplin and Qiu, 1997). From the two results, the following generalised multiplier (ξ) was estimated to take account of the relatively greater attractiveness for tourists of smaller destinations:

$$\xi = \text{Exp}\{6.966 - 0.7347 * \text{Ln(Population)}\} + 1 \quad (1)$$

2.2 Destination choice

A multinomial logit (MNL) model, based on locality attractions, was estimated by McGinley from survey data to provide the primary predictor of destination choice. Ten attractions were found to be significant (Taplin, McGinley and Smith, 2002):

Fishing	Boating
Beach or River	Dolphins
Park, Forest, Bush Walking	Wildflowers
Museum or Historical Site	Wineries
Art Gallery or Craft Centre	
Animal/Wildlife Park/Fish Hatchery/Zoo	

2.3 Aggregate trip generation

Improvements in destination attributes can be expected to increase total trips within Western Australia - a generation effect. However, when the multinomial logit responds to an attribute enhancement at one destination it reduces the visitors to all others. To the extent that this reflects the limited total number of tourists, it is realistic but there should also be some generation effect. An added module is introduced to reflect such generation, at least to overcome inappropriate reductions at many destinations in response to enhancement of one of them.

2.4 Composite initial visits model

The three components are combined into the following initial destination model:

$$V_i = S_i(\xi_i P_0 P_i)^{\beta}\left(\frac{Km_{Per}}{H}\right)^{\gamma} \frac{Exp(\alpha_i + \sum_{q=1}^{10}\varphi_q A_{qi})}{\sum_{j=1}^{22} Exp(\alpha_j + \sum_{q=1}^{10}\varphi_q A_{qj})}\left(1 + G\varphi_q \delta A_{qj}\right) \quad (2)$$

where V_I is car visitors to destination i, S_i a scalar calibrated on current visitor number to i, P_o nominal origin population (1.7 million), P_i population of destination i, β the elasticity of demand for car trips with respect to the weighted population product (0.556), Km_{Per} distance from Perth, H an index of road condition (H = 1.0 for good sealed road), γ the elasticity of demand for car trips with respect to distance (-1.65), α_i the MNL alternative specific constant for destination i, φ_q the MNL attraction coefficient with respect to attribute q, A_{qi} the value of attribute q at destination i, and G is the general trip generation impact (0.05) across all destinations of an attribute change δA_{qj} at destination j.

3 PREDICTION OF SUBSEQUENT CAR TOUR DESTINATIONS

The main cross-effects between destinations occur when visits are made in sequence; the places are complements, due at least as much to the fact that they lie on a convenient route as to their individual attributes. The capacity of a basic destination choice to generate visits to other places is reminiscent of the Edgeworth-Pareto definition 'according to which two commodities are complementary if an increase in the quantity of one tends to increase the marginal utility of the other' (Vickrey, 1964, p.43).

Logit results give a poor representation of interactions between destinations and merely reflect the limited pool of tourists. They imply that a new attraction at one destination always decreases visitors elsewhere.

A preliminary approach was to estimate cross-destination elasticities from the correlations due to linked trips. These ad hoc elasticities reflected real interactions, but there was little or no theoretical foundation. Also, to avoid circularity, only some of the cross-destination elasticities could be used. Possibly, this difficulty could have been avoided by applying the elasticities in a second stage.

3.1 Representation as Markov transitions

Records of destination sequences were summarised in a matrix of transition probabilities from place to place. It reflects the direction of transition; the length of stay is reflected in the probability of staying another night. Table 1 shows a portion of the Markov matrix for the 22 major regional destinations in WA, which is presented in full in Appendix A.

Travel in the south of WA rarely overlaps with travel in the north. Thus, the highest probabilities of onward travel from the southern centres, in the top left of Table 1, are to other southern centres; similarly for northern centres (bottom right).

Table 1. Portion of 22-destination matrix of transition probabilities: WA car tourists

from: to:	Esp	Alb	Buss	Mar	Kalb	Shar	Exm
Esperance	**.664**	.116		.003		.003	
Albany	.031	**.669**	.003	.017			
Busselton	.007	.015	**.709**	.060	.007		
Margaret R		.028	.028	**.468**	.009		.009
Kalbarri					**.678**	.155	.004
Shark Bay		.004			.022	**.683**	.009
Exmouth						.020	**.800**

The probabilities of staying another night are on the diagonal of Table 1, in bold. The highest is for Exmouth; it is so distant from Perth that people tend to stay on when they have reached it.

4 RESULTS OF MARKOV PROJECTION OF CAR TOURIST VISITS

After 'predicting' first night visitors with Equn (2), the transition matrix is applied for 12 nights. This is a non-homogeneous Markov process, with visitors gradually leaving the 22 destinations. Only a few are left at the end of ten days (8 shown in Figures 1 and 2). Annual trips are projected as if starting on the same day, the destination totals being obtained by summing each destination over all trip days. These totals are calibrated to the known aggregates by varying the S_i in Equn (2).

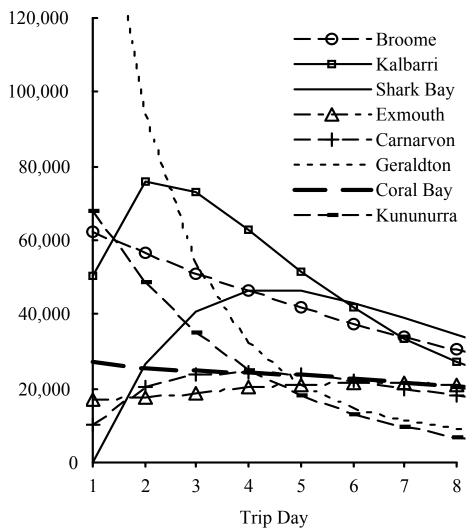

Figure 1. Markov projection of car tour party nights: northern WA destinations

4.1 Northern WA destinations

The main feature of Figure 1 is the difference between stops on the way and stops at desirable but more remote destinations. Geraldton is a stopping place on the way from Perth to destinations further north. Kununurra shows a similar pattern, as a major entry point from the eastern states. The numbers at the highly desirable destinations north of Geraldton, Kalbarri and Shark Bay, grow rapidly on days 2, 3 and 4 as Perth travellers proceed north.

4.2 Southern WA destinations

Southern car tour patterns in Figure 2 are similar to the north (Figure 1) but it is easier to make a circuit rather than the up-and-back pattern of the north. Albany is central to many circuits; a party stopping at any other place in the south is fairly likely to spend the next night at Albany and vice versa (column 4 and row 4 of Appendix A).

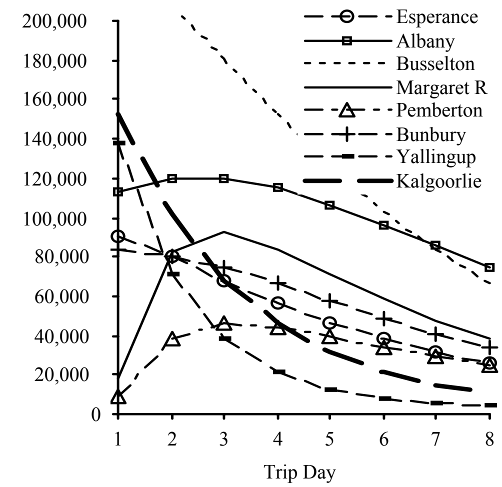

Figure 2. Markov projection of car tour party nights: southern WA destinations

4.3 Predicting impacts of change

Figure 3 gives an example of the model's capacity to project the impact of change. There is significant spillover from Kalbarri, where the hypothetical change is made, to other destinations.

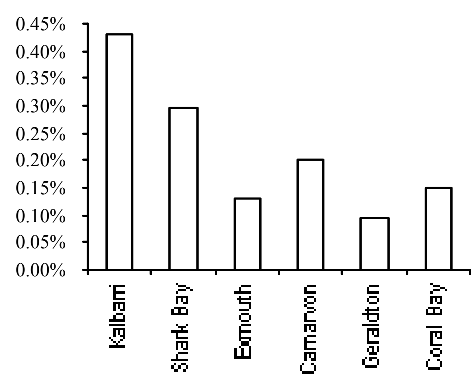

Figure 3. Response in the north to a 10% increase in art galleries or craft centres at Kalbarri

5 TRIPS BY CITY PEOPLE IN PART-TIME WORK OR HOME DUTIES

A Markov process is offered in this paper as a default model of linked trips in cities, against which the performance of others could be tested. Nested or multinomial logit (MNL) have been used in a number of studies, e.g. Bhat and Steed (2002), Cirillo and Axhausen (2002).

Only an initial Markov application is reported here, without any comparisons. People engaged in part-time work or home duties were chosen because there are relatively few constraints on their trips. However, taking children to school and picking them up ('escort') is heavily time constrained. The transition probabilities change considerably during the day and the trends shown in Figure 4 are the result of applying the separate matrices to the activity shares in the successive stages. The six matrices starting from 0800 are shown in Appendix B. Staying at home or going home is part of the transition matrix; each row sums to one when the 'home' destination is included.

Table 2. Average weekday transition probability: city people in part-time work or home duties ('home' column omitted)

from: to:	Work	Educ	Shop	Persnl	Esct	Leis
Work & related	**.534**		.033	.016	.046	.055
Education (self)	.045	**.500**	.091			.023
Shopping	.027		**.404**	.008	.014	.060
Personal business	.043		.151	**.323**	.032	.065
Escort (mainly children)	.049		.053	.016	**.355**	.041
Leisure	.023	.002	.050	.010	.019	**.486**
Home	.071	.014	.104	.030	.081	.133

Table 2 shows the average transition probabilities, the 'home' column being omitted. Each diagonal element, in bold, represents both those who did not make another trip in the next time period, staying at the previous activity, and a smaller number who made a trip to an activity of the same kind. This is in contrast to the touring case, where a diagonal element in Table 1 is the probability of staying another night. The averages in Table 2 do not represent probabilities at any particular time of day. Actual modelling is by time step, so that from 10.30 to 11.05, for example, there is a 30% probability that personal business will be followed by shopping (Appendix B).

As the urban data cover trips only, it has been necessary to impute the proportion of people at home. This has been set at 70% from 0500 to 0759, reducing to 20% who stay at home through the day. As the day progresses, many people return home and do not leave again, so that in the evening, the sum of those who have gone home and the assumed basic 20% rises to 71% in the early evening and 98% later.

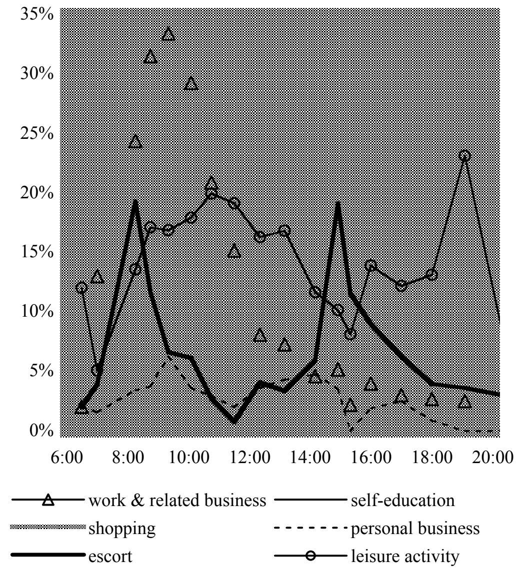

Figure 4. Activity proportions: city people in part-time work or home duties - separate transition probabilities for each period

6 BEHAVIOURAL IMPLICATIONS

The Markov process is a system without a memory, taking no explicit account of trips being usually in planned sequences. This means that real behaviour is not represented directly. Nevertheless, indirectly, the average distribution from one type of activity to others is the outcome of the planned sequences.

A general question is what does it mean to apply Markov probabilities. They are calculated from past transition frequencies and using them to project future outcomes implies a belief in their persistence. This seems sound for the car touring case because the transition probabilities are related directly to geographical location. In the urban case, persistence of probabilities tends to mean habits; not that everyone is unchanging but that those who change in one way are balanced by others changing the other way. There is no general argument for such population stability but there are reasons for believing in persistence of particular transition probabilities. For instance, there is a fairly high probability, in the group analysed, that taking children to school ('escort') will be followed by a trip to work (first two matrices in Appendix B). This is related to family circumstances and is not likely to change rapidly. Other types of studies have explored such activity linkages (e.g. Bhat, 1998).

The next issue is initial choice behaviour. A tourist trip is a fairly rare event and usually there is a major decision on where to go first, as represented by the initial visits model. This choice would often be made with an eye to subsequent destinations but these are related to the first choice through the Markov matrix. In contrast, the choice of first activity daily, in the urban case, is not a major decision. It is largely repetitive and it may be adequate to represent it by the normal activity shares.

The final issue to consider in this brief assessment is whether a policy or structural change is likely to alter the probabilities to the extent that the validity of any projection of the outcome is undermined. In the car touring case, this is unlikely because of the geographical basis. Enhancement of one destination is not going to change the linkages that underly the probability matrix.

The urban case is more problematical. If, for example, a Markov model were used to examine the impact of more people working at home then there would have to be some evaluation of how the changing proportions would alter the probabilities.

7 CONCLUSIONS

Whereas a series of linked trips between places or activities is usually planned as a whole sequence, a Markov model breaks this into a series of choices without regard for what has gone before. It is based on population (or sample) frequencies, not sequences, and its reliability depends on the stability of the proportions of activities that follow each other activity. Thus, the practical question is to what extent would the projected impact of a policy or structural change modify the transition probabilities. There is less uncertainty about projecting the impacts of change, in terms of stable transition probabilities, in the case of car touring than in the urban weekday travel case.

A consequence of applying Markov probabilities to determine all but the first car touring destination is that choice of the first place to visit is critical in 'delivering' travellers to other places. Thus, enhancing one local attraction may boost visits to towns which are nearby or can conveniently be included in a single tour.

The tourism model has already been applied to estimate the impact of suggested destination enhancements, as shown in Figure 3. A potential application of the urban model is to examine the impact of changing proportions of people working at home but this would need careful evaluation of the probability changes induced by the structural change.

8 ACKNOWLEDGEMENTS

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APPENDIX A

WA regional car trips: Average Markov night to night transition probabilities

from: to:	Bro	Esp	Alb	Buss	Man	Kalb	Shar	Exm	Mar	Car	Pem	Ger	Aug	Cor	Bun	Yal	Wal	Den	Dun	Dong	Kal	Kun
Broome	.883							.002		.002							.002					.004
Esperance		.664	.116				.003		.003									.003			.031	
Albany		.031	.669	.003	.003				.017		.037		.011		.023	.003	.014	.028				
Busselton		.007	.015	.709	.015	.007			.060		.015		.022		.015	.007		.007				
Mandurah			.016	.079	.619				.016				.016		.032				.016			
Kalbarri						.678	.155	.004		.026		.017		.009						.017		
Shark Bay			.004			.022	.683	.009		.089		.040		.036						.004		
Exmouth							.020	.800		.030				.030								
Margaret R			.028	.028		.009		.009	.468		.073		.083		.046							
Carnarvon	.008					.008	.024	.073		.581		.024		.073								
Pemberton			.131	.036	.012				.107		.381				.012		.048	.036	.024			
Geraldton						.126	.101	.006		.069		.522		.019								
Augusta			.032	.016					.048		.048		.597		.032		.032	.032				
Coral Bay	.009					.019	.019	.056		.028		.009	.009	.759								
Bunbury			.014	.034					.027		.027		.020		.622	.007	.007	.007	.007			
Yallingup			.038	.038					.115		.077					.462	.038					
Walpole			.111	.022							.044		.022				.556	.044				
Denmark			.136						.023		.045				.023		.068	.545				
Dunsborough			.028		.028				.167		.056		.028		.028	.028			.556			
Dongara						.300						.050								.350		
Kalgoorlie		.095	.008									.004									.646	
Kununurra	.017							.002														.714

APPENDIX B

Part-time work and home duties: Transition probability matrices, 0800 to noon: ('home' column omitted)

	0800-0830 start trip						0831-0900 start trip						0901-0943 start trip					
from: to:	Work	Edu	Shop	Pers	Esct	Leis	Work	Edu	Shop	Pers	Esct	Leis	Work	Edu	Shop	Pers	Esct	Leis
Work & related	1.00						1.00						.895		.053	.053		
Education (self)		1.00						.800						1.00				
Shopping			.600						1.00				.087		.304		.044	.044
Personal business				1.00			.200			.400	.400				.200	.800		
Escort	.188				.250		.158		.079	.053	.237	.026			.167		.458	.083
Leisure	.050					.750						.875	.050					.700
Home	.139	.041	.073	.025	.245	.130	.114	.034	.103	.046	.194	.160	.161	.025	.198	.074	.037	.161

	0945-1025 start trip						1030-1105 start trip						1106-1157 start trip					
from: to:	Work	Edu	Shop	Pers	Esct	Leis	Work	Edu	Shop	Pers	Esct	Leis	Work	Educ	Shop	Pers	Esct	Leis
Work & related	.810		.048			.048	.647		.059			.059	.600			.067		.067
Education (self)		.667						1.00						.333	.667			
Shopping	.037		.556			.074	.032		.387			.129	.056		.500			
Personal business			.091	.364		.091			.300	.100		.100	.200		.300	.200		
Escort					.857						.333						.125	
Leisure			.071			.607	.032		.065	.032		.742			.089			.588
Home	.086	.011	.140	.065	.022	.227	.036		.239	.072	.024	.108	.035	.012	.149		.012	.172