Task 12 Time of Day and Vehicle Occupancy

Scope

Following an initial description of the model specification, the sequence of tasks is:

- Task 12.1 The Base Year Time Period Factors
- Task 12.2 Macro Time Period Choice
- Task 12.3 Generalised Cost Aggregation
- Task 12.4 Occupancy Factors
- Task 12.5 Time of Day Choice and Occupancy Report

Definitions: Note that, in this report, the terms macro and micro time period choice are used instead of peak spreading and trip re-timing which are used with the current ART model and in previous ATM2 reporting. Macro time period choice relates to the choice between the 4 modelled time periods, while micro time period choice is concerned with the changes in the time profiles of traffic within the am and pm peaks.

Specification

Time of Day Choice and its Position in the Model Hierarchy

In principle, three separate cases can be considered. They are:

- no time period choice,
- time period choice below distribution/mode choice (DMS),
- time period choice above destination choice.

The first is not an option and, while the third option represents current thinking in some quarters (e.g. UK DfT), this raises a number of technical problems which have not yet been fully resolved. It is the second option which we propose to implement, but we develop the approach starting with the first option.

<u>The case of no time period choice</u>

Here we develop the distribution-mode split (DMS) model on an all-day basis, and thereafter apply fixed factors by time period and direction. The only question of significance is that of how to define the costs, given that they will generally be derived from period-specific assignments. There are a number of options depending on a) trip/tour considerations, and b) on the method of combining results from different time periods.

Assume that network costs from the assignment are defined on an O-D basis, separately for each time period t. Assume also (in the first place) that the set of (fixed) time period factors is on a **tour** basis, of the form π_{rs} where r is the outbound time period, and s the return (and $\sum_r \sum_{s \ge r} \pi_{rs} = 1$). We can allow for the possibility that these factors have some locational variation, but we generally drop any "ij" subscripts for simplicity. Likewise, it is assumed that the factors will vary by purpose p, but we suppress this argument as well.

Then the "fullest" specification we can imagine for the costs to be used within the DMS model is: $\overline{C}_{ij} = 0.5 * \sum_r \sum_{s \geq r} \pi_{rs}(C_{ijr} + C_{jis})$, where the factor of 0.5 is merely being used to convert back into single trip cost units.

On the assumption of fixed time period rates, this is probably the safest formula to use, but it is also the most "expensive", since it definitely requires assignment in each time period, plus some manipulation (the costs for the return trips need to be transposed to give the required quantity in P/A terms).

Note that if the tour proportions π_{rs} are not available, but instead only the (independent) outward and return proportions, the same kind of formula can still be used, merely substituting $\pi_{rs}(C_{ijr} + C_{jis})$ by $(\pi_{r*}C_{ijr} + \pi_{*s}C_{jis})$ in the previous formula.

[Further simplification is available by not using the proportions π_{rs} but merely assuming a representative period for each purpose (as in the LTS model) and basing it on the outbound costs only.]

The choice between these alternatives seems essentially one of convenience/ computational effort. The possibility of avoiding an assignment in the afternoon peak could be important for model turnaround: however, if the considerations are not very significant, then the full "tour" version (or its trip-based near equivalent) using the proportions over all time periods is probably the best measure for the costs.

The case of time period choice below DMS

In this case, the appropriate measure is strongly constrained by the nature of the time period choice process itself, and whatever is done, in principle it will be the **composite** cost[1] which needs to be passed to the DMS model.

The least controversial, but computationally most complex, is again a complete tour model, in which the joint probability of outward period r and return period s is modelled, essentially along standard "incremental" lines:

$$p_{rs|ij} = \frac{\pi_{rs} \exp(-0.5\lambda[\Delta C_{ijr} + \Delta C_{jis}])}{\sum_r \sum_{s \geq r} \pi_{rs} \exp(-0.5\lambda[\Delta C_{ijr} + \Delta C_{jis}])}$$

This could also be modelled as a choice of outward period, followed by choice of return period conditional on outward period. Alternatively, the combinations {rs} can be grouped in some way, and the choices (and hence the costs) restricted to these combinations.

Other possibilities are to model the outward and return periods quite independently, though this runs up against the possibility that a counter-intuitive shift could be predicted, in terms of **duration** at the

[1] In practice, for the range of changes expected, the average cost outlined earlier can be shown to be a reasonable approximation.

destination. Given the base proportions, however, this is unlikely to be a significant risk. If this approach is taken, then it is probably most appropriate to **add** the (incremental) composite costs from the two directions (correcting, as required, for the conversion between O-D and P/A), and to halve the result to convert back into trip cost units (though it is not completely clear whether this addition of independent composite costs has theoretical justification).

Note in passing, that it may be sensible to combine a fixed proportion approach to the "rest of the day" period (however defined) with time period choice **within** the busy period. Apart from the small added housekeeping, this does not raise any further issues of principle: the DMS matrices would first be factored to remove the rest of the day demand.

The essential question, then, is whether to go for a tour-based approach or the somewhat simpler trip-based. If the latter, there are other minor variants possible, such as (for example) confining the outward time period choice to the morning peak and interpeak, while keeping the afternoon peak proportion fixed, and comparably/conversely for the return time period choice.

Once again, the choice between the options rests largely on computational convenience, though given the need for base proportions (to drive the incremental choice models), this may impose constraints due to data availability, particularly if a tour-based approach is chosen.

Scope of Model

Four main processes are envisaged, the flow of data being illustrated in Figure 1:

- macro time period choice: the base year time period factors, separately by direction (outbound, return) from the household travel survey are adjusted to allow for differential changes in journey times/costs between the time periods in the forecasting scenario;
- time period factoring: the 24 hour P/A trip matrices by purpose and mode output by the distribution/mode choice models are factored into O/D matrices for the detailed model time periods using the resulting factors;
- occupancy factoring: the resulting matrices of car users are converted into vehicle matrices for assignment using occupancy factors; this process would be the gateway to the HOV processes discussed in **Error! Reference source not found.**;
- generalised cost aggregation: average 24 hour generalised costs are computed from the skims for the individual time periods, to be fed back to the distribution and mode choice models; these costs allow for the tour structure, averaging the changes in congestion and prices between the out and return trips.

Additionally, in the vehicle assignment procedures, it is intended that allowance would be made for changing profiles of traffic demand within the peak time periods in response to congestion (referred to as micro time period choice[2]). This affects the average journey times in the modelled peak time periods.

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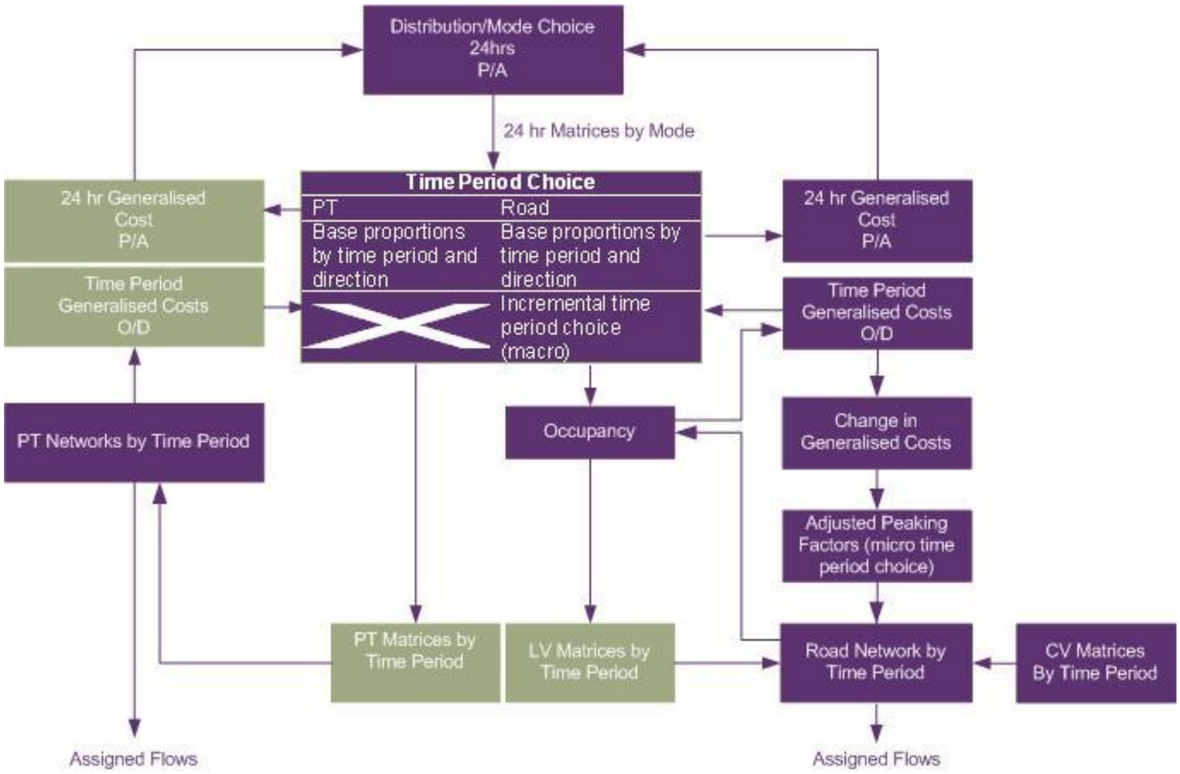
[2] In the road network developments for WTSM, the average delays/journey times for the peak periods was calculated based on assumed time profiles within these periods, designed to reflect the variations in times/delays in 15min periods within the full 2 hour time period, and the average of this based on the traffic profile over the period (the sharper the delay profile the higher the average delay). Reflecting methods used internationally, we will explore simple ways of relating the shape of

Additional points concerning the time period representation are:

- time period networks: up to 4 time periods will be considered – the am peak, pm peak, interpeak and offpeak[3]; for improved operational efficiency, interpeak generalised costs could be used, as an approximation, for the offpeak;
- the 24 hour active mode matrices will not be split by time period;
- the aforementioned processes do not apply to commercial vehicles, for which a simple set of time period factors will be assembled.

Finally, in the descriptions which follow we have deliberately opted for simpler more constrained options with a view to reducing computation costs and turnaround times. We will keep these decisions under review.

- **Figure 1 Structure of the Time Period Modelling**



the profile to the relationship between volume and capacity across the network such that, as congestion increases, the profile will flatten within the peak periods and dampen the delays.

[3] If implemented, this would be a free/flow network giving offpeak generalised costs; offpeak traffic would not normally be assigned.

Task 12.1 Base Year Time Period Factors

Scope

The time periods are: am peak, interpeak, pm peak and offpeak. The process takes the 24 hour P/A matrices for each purpose and mode and apportions them between the time periods, recognising the directionality of the travel in each time period (e.g. leaving home in the am peak to work and returning home in the evening peak). The resulting matrices are in O/D form, as required for assignment (so that the traffic flows are correct in each direction).

The process is designed to do the following. Take for example the HBW matrix:

- this is in P/A form, which means that the matrix cell ij contains the total number of HBW trips made in the day which are produced in zone i, the home zone, and attracted to zone j where the workplace is located;
- for a simplistic context, about half of these trips would appear on the road network in the am peak travelling from home to work from zone i to zone j;
- in the pm peak the other half of the trips would occur in the opposite direction from zone j to i, as people return home from work;
- the time period factoring process takes the 24 hour matrix and converts it into an O/D matrix for each time period which reflects these characteristics of the different time periods.

Inputs

Combined trip data base

Processing

A preliminary analysis is needed to determine the extent to which the data will support a geographic disaggregation (based on TAs, sectors or aggregations thereof) and the area classifications of interest.

Process the observed data (HTS and intercept surveys) to create the following O/D matrices for these aggregated areas - for each home-based trip purpose, and for car and public transport separately, using IJ to denote the TLA classification and m and p for mode and purpose[4]:

From home (fh) trips:	To home (th) trips
$T_{mp}(fh)^{24}_{IJ}$	$T_{mp}(th)^{24}_{IJ}$
$T_{mp}(fh)^{7-9}_{IJ}$	$T_{mp}(th)^{7-9}_{IJ}$
$T_{mp}(fh)^{9-16}_{IJ}$	$T_{mp}(th)^{9-16}_{IJ}$
$T_{mp}(fh)^{16-18}_{IJ}$	$T_{mp}(th)^{16-18}_{IJ}$

The time period factors are, then, the ratios of these matrices; e.g. for commuting trips by car in the am peak, we will have:

$$T(fh)^{7-9}_{IJ}/T(fh)^{24}_{IJ} \ \& \ T(th)^{7-9}_{IJ}/T(th)^{24}_{IJ}$$

[4] The process assumes that the 24 hour home based OD trip matrices are symmetrical, that is the ‘to home’ matrix is simply the transpose of the ‘from’ home matrix.

If we investigate a geographic breakdown of these factors (into say 3 geographic areas, as in the hypothetical example in Table 1) and we will have 9 values of these ratios for each IJ combination(a-i), plus the row (n-p), column (k-m) and overall (q) values. Allowing for sampling error we must decide whether any of the 9 cells or 6 row/column total values are significantly different from the average (q) to justify a geographic segmentation. An initial analysis of sampling error suggests that 500 observations (for an individual time period, geographical area, purpose and mode) is needed to identify significant differences).

- **Table 1 Breakdown of Time Period Factors by Geographic Area**

	Destination Area 'J'			
Origin Area' I'	N. Shore	Isthmus	Rest	Total
N. Shore	a	b	c	n
Isthmus	d	e	f	o
Rest	g	h	i	p
Total	k	l	m	q

For NHB trips, we expect to assume matrix symmetry over 24 hours (and origins = destinations in the trip ends). There is no th/fh distinction, but directionality in the time period matrices may be broadly achieved through destination area segmentation of the matrix factors.

For commercial vehicles, a set of average proportions by time period will be assembled from the classified traffic count data (refer Task 11.2).

This process will lead to a set of matrix factors ($MF^0{}_{mp}(d)^t{}_{IJ}$ where d is direction and t time period, m mode and p purpose) which can be applied to the 24 hour P/A matrices halved and transposed to give $T_{mp}(fh)^{24}{}_{ij}$ and $T_{mp}(th)^{24}{}_{ij}$ (referred to below as $T_{mp}(d)^{24}{}_{ij}$) to develop time period matrices, as follows.

$$T_{mp}{}^{t}{}_{ij} = \Sigma_d\, MF^0{}_{mp}(d)^t{}_{IJ} * T_{mp}(d)^{24}{}_{ij}$$

Outputs

The base year time period factors $MF^0{}_{mp}(d)^t{}_{IJ}$

Task 12.2 Macro Time Period Choice

Scope

In the future years, we are concerned that the time period factors for car trips should change to reflect impacts of changing congestion and road pricing strategies. In the description which follows, the approach is to assume that the time choice for each trip is independent of other trips on the tour but, as discussed earlier, the formulae need not be constrained in this way.

An incremental model will estimate the change in the peak proportions as a function of the change in the generalised cost differentials between the peak periods and the non-peak.

$$MF^1(d)^t_{pij} = \frac{MF^0(d)^t_{pIJ} * \exp\lambda_p.(GC^1(d)^t_{pij} - GC^0(d)^t_{pij})}{\Sigma_k[MF^0(d)^k_{pIJ} * \exp\lambda_p.(GC^1(d)^k_{pij} - GC^0(d)^k_{pij})]}$$

In this form, the superscripts 0 and 1 describe base and policy, λ_p is implicitly negative, the time period choices (k in the denominator) are, in two separate applications of this formula, (1) the am peak and interpeak and (2) the pm peak and interpeak. A more general version of this formula would relate not to 2 but to 3 or 4 time periods (as given in the introduction). It is important to note that the new proportions vary by matrix cell ij (reflecting the locationally-specific influences of pricing etc).

There is no possibility of estimating λ_p from the household survey data but, in principle, it should be larger than the distribution/mode choice model parameters for car trips for each trip purpose; this parameter will be set to give reasonable results and be consistent with the Sydney Harbour Tunnel experience and any other local evidence. The latter will include the profiles of historical count data which can be related to changes in roading capacity.

The set of matrix factors $MF^1(d)^t_{pij}$ replace the base year values $MF^0(d)^t_{pij}$, allowing for changes in time period choice due to congestion and pricing effects.

This task is concerned with collating information which can be used as the basis for setting $\lambda_{p.}$

Inputs

Time of day choice parameters from other models (e.g. current ART, WTSM)

Data related to Sydney Harbour Tunnel

Historical count data and records of associated changes in roading capacity

Any other local experience of time shift

Processing

Collate the above information

Process historic count data, analysing changes in profiles and relationship with changes in roading capacity

Research for any other local evidence and process as required

Outputs

Note with recommended value for λ_p

Task 12.3 Generalised Cost Aggregation

Scope

Reflecting the earlier conceptual discussion (see Figure 1), we propose to use average 24 hour costs as the input to the distribution and mode choice models, based on the characteristics of tours as follows.

Our highway networks will be for the am peak, pm peak and other times (interpeak and offpeak, individually or combined). To simplify, we use the 3 aggregated time periods.

The potential 9 tour combinations are given in

Table 2. The appropriate average generalised cost for trips in each of these tours is 0.5 * (C_{ijr} + C_{jis}) using the nomenclature in the introduction where r and s are the out and return time periods. In fact we expect to be able to compress the 9 tour types to say the 4 most significant aggregations (by way of illustration, the statistics for Wellington for these tours are given in Table 3):

- out in am peak, back in pm peak;
- out in am peak, back in non-peak period;
- out in non-peak period, back in pm peak;
- any other tour.

For a given trip purpose the appropriate average costs would depend on the distribution of tours; i.e. as before Σ_{rs} π^0_{rs} * 0.5 * (C_{ijr} + C_{jis}), where π^0_{rs} is the base year proportion of trips of each tour type. These average generalised costs are PA costs for the estimation based on appropriate purpose-specific weighted averages of the network OD cost components. These cost averages are also used in model estimation (Task 8.1).

In this form, the average costs are calculated using the base year weighting in the future scenarios. This is because the effects of the macro time shifts on the average costs are expected to be small compared with the price and congestion changes, and there is potentially considerable complication in modifying this for time shifts forecast in the macro time period choice model. We will however give further consideration to implementing the cost-averaging based on the predicted time period switching.

This procedure calculates average 24 hour costs for each mode and purpose, which are based on the round trip tour cost average, and thus allow for:

- peak charging, differentiated by time period and direction of travel,
- differential changes in level-of service by time period in the public and private transport networks.

▪ Table 2 Tour Descriptions

Time (r) of Outward Trip from Home	Time (s) of Return Trip to Home		
	am peak	interpeak/offpeak	Pm peak
am peak	1	2	3
interpeak/offpeak	4	5	6
Pm peak	7	8	9

▪ Table 3 WTSM Trip Tour Data

Purpose	The proportion of Trips by Tour Type 1)				Average Trip Charge Experienced (2)		
	am peak-pm peak	am peak-non-peak	non-peak - pm peak	non-peak periods	am peak trips	non-peak trips	pm peak trips
HBW	24%	43%	14%	19%	34	19	41
HBEd	5%	70%	3%	22%	27	19	41
HBShop	8%	27%	14%	51%	31	11	34
HBSoc	9%	21%	14%	55%	33	10	35
HBOth	10%	29%	10%	51%	32	11	38
NHBO	7%	39%	8%	46%	29	13	37
HBEb	14%	42%	10%	33%	31	16	40
NHBEb	7%	56%	3%	33%	28	16	42

(1) e.g. 24% of HBW trips are on an ‘am peak-pm peak period’ tour, which is a tour with am peak outbound trip and pm peak return

(2) Given a 50 unit charge inbound and outbound in both peak periods; e.g. the average charge paid by HBW trips in the am peak (allowing for the overall tour) is actually 34 units.

Inputs

Outputs of Tasks 2.6 and 2.11

Processing

Specify and parameterise cost aggregation process by purpose.

Outputs

Cost aggregation process specification

Task 12.4 Occupancy Factors

Scope

These factors convert car mode person trips for each trip purpose to equivalent numbers of vehicles for the traffic assignment. The approach adopted is similar to that used in the time period factor calculations and the factors are the average number of person trips per vehicle trip which are the ratio of total car driver and passenger trips to car driver trips (for each trip purpose). We may need to consider variations in occupancy rates by broad location and time period.

These factors can be checked against existing observed data (e.g. ARC occupancy surveys), though this would be across all purposes.

In order to derive the mean occupancy we shall need to make use of the distribution of passengers: this will be also useful for a possible extension to HOV analyses.

Inputs

HTS database

Observed occupancy data

Processing

Using the HTS data determine, for each purpose and modelled time period, the number of person trips per light vehicle (car + LCV), starting with the study area as a whole and then investigating for locational differences.

Compare the above with observed occupancy data

Outputs

Occupancy factors

Note

Task 12.5 Time of Day Choice and Occupancy Report

Write the Time of Day Choice and Occupancy report.