Modelling trip timing behaviour and the influence of peak spreading

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Abstract

Peak period traffic congestion is a problem faced by many urban areas around the world as the supply of transport infrastructure struggles to keep pace with ever increasing transport demands from the community. As Australia's largest capital city, Sydney is no exception with a population of over 4 million generating approximately 15.5 million trips each weekday, much of which occurs during morning and afternoon peak periods. It is for this reason that planners often focus on peak time periods for network provisions and operational management. This can lead to an inefficient allocation of resources, which could be unsustainable for future transport network operations. Peak spreading may be seen as having two broad dimensions. The first may be described as 'passive' peak spreading, which is a natural increase in the duration of a peak period as travel demand tests the capacity of a facility so that the levels of peak travel activity persist for a longer period. The second dimension is 'active' peak spreading, in which individual travellers deliberately change their travel behaviour to avoid peak periods, or transport policies are enacted to encourage people to travel away from the peak periods. The concept of peak spreading thus introduces strategies and management techniques to manage the peak traffic demand as it allows for the spreading of peak period traffic flow profiles in congested areas. It is therefore important to represent the effects of such strategies in a modelling environment for evaluation. After a critical analysis of current international practice for representing trip timing behaviour in current travel demand models, this paper provides a summary of observed trip timing behaviour in Australian capital cities. It also focuses on the requirements for a travel time model with abilities in the representation of peak spreading strategies and management policies. The model development to date is outlined with suggestions for future research directions.
Keywords: peak spreading, trip timing, discrete choice model, travel behaviour.

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1 Introduction

Peak period traffic congestion is a problem faced by many urban areas around the world. During morning and evening peak periods the transport networks experience the greatest pressures as a significant proportion of all daily journeys are commenced during a short time period. Financially, it is estimated that traffic congestion costs Australia $12.8 billion annually whilst 10.5 million tonnes of CO_2 are emitted in Australia per year as a direct result of congestion. Communities therefore stand to benefit from reductions in peak period traffic congestion in urban transport networks.

The concept of peak spreading introduces strategies and management techniques to deal with peak traffic demand as travellers are encouraged away from travel during the peak to shoulder-peak times. To assist in the introduction of peak spreading strategies, transport planners require appropriate analysis tools for policy testing. This can be achieved within modelling environments that allow for an evaluation of peak spreading strategies before implementation within the transport system.

2 Defining peak spreading

A useful definition of the peak spreading phenomenon is provided by the DTLR [6] as they suggest that the term ‘peak spreading’ refers to a reduction in traffic proportions during the most congested part of the peak period, with corresponding increases during the peak shoulders. International evidence of peak spreading is summarised by Bolland and Ashmore [2] as they note research that identifies its occurrence in the UK, USA, Holland, New Zealand and Australia.

2.1 Passive and active peak spreading

To further refine the peak spreading definition it is possible to identify the broad dimensions of ‘passive’ and ‘active’ spreading. Passive peak spreading describes a natural increase in the duration of a peak period due to increased congestion in mid-peak periods, affecting traffic flows during the peak shoulders. The active element describes the actions of individuals to deliberately change their travel behaviour to avoid peak periods. Journeys are re-timed to avoiding unacceptable peak congestion conditions. Hounsell [8] identifies these components and suggests that they are likely that both occur simultaneously.

Active peak spreading thus involves a conscious decision by the traveller to avoid peak conditions and re-time their journey. The traveller must be able to recognise the peak period and potential benefits from retiming the journey. To participate in peak spreading they must also have some degree of flexibility in departure and/or arrival time.

It is therefore necessary to separately identify passive and active spreading during policy strategy evaluations. Adjustments to traffic demand profiles should only be reflected in the active peak spreading element. To invoke peak spreading behaviour, transport planners need to develop transport strategies and policies aimed influencing traveller behaviour. This requires testing the effects of such strategies in a modelling environment, requiring a trip-timing model framework within which peak spreading parameters can be introduced and tested.

Figure 1: Map of the Sydney metropolitan region and surrounds.

3 Travel behaviour in Sydney

The New South Wales state capital of Sydney is located on the eastern coast of Australia. With a population of over 4 million and average household size of 2.71 persons the travel demand of the city are catered for by an extensive transport network. Central Sydney has transport links extending largely to the North, South and Western regions and bounded by coastline to the East as illustrated in fig. 1. The harbour is a dominant feature of the city and introduces the need for bridge and tunnel crossings. A total of 21,080 km of road assists in accommodating 15.5 million trips each weekday, each of an average duration of 32 minutes.

The Sydney Household Travel Survey (HTS) provides a detailed source of information on the travel behaviour of residents within the Sydney Greater Metropolitan Area (GMA). It is a continuous survey started in 1997 and involves a face-to-face interview with household residents along with a 24-hour travel diary. In the following analysis the 2002 survey dataset is used. This survey "wave" results contain data from a responding sample of 9,680 households and collected data reports on characteristics of households and their residents including detailed information on trip making behaviour.

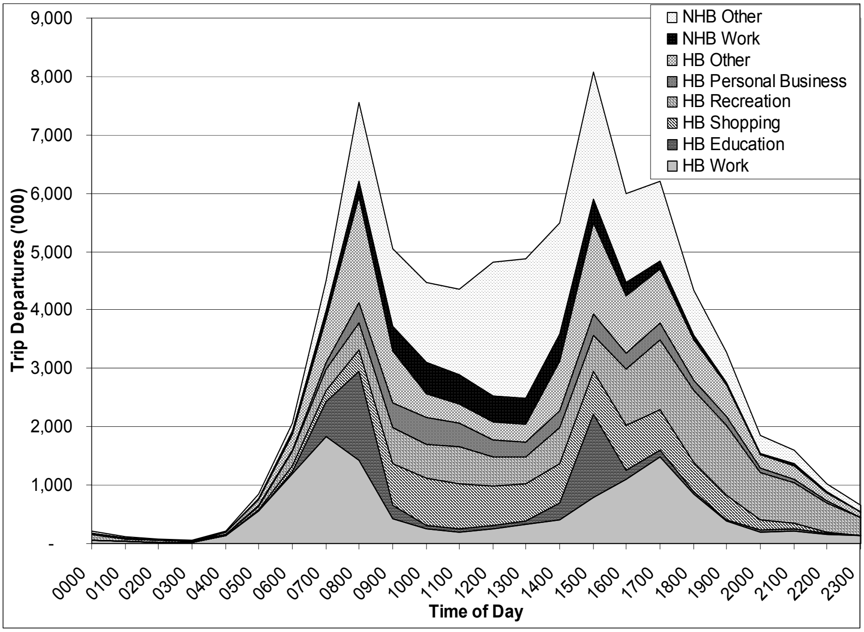

Figure 2: Trip departure times within the Sydney GMA.

Useful information relating to trip timing behaviour collected in the HTS includes start and finish work times, flexible work hour times, regular departure times and associated reason for departure time choice. Fig. 2 displays the departure timing for trips within the Sydney GMA across all persons and travel modes, stratified by trip purpose.

As illustrated in the fig. 2, pronounced peaks exist for the AM and PM periods. The AM peak has an obvious single ‘spike’ which occurs at approximately 8.00am with a large contribution of Home-Based (HB) work and education trips. At this time, the private motorised mode dominates with 72% of all trips. The PM has a peak occurs at 3.30pm with a significant number of HB education trips and also at 5:30pm with many HB work trips. The PM peak also has more HB recreational and shopping trips compared to the AM. During the PM peak approximately 69% of trips are performed by private motorised modes. During the interpeak period, Non-Home Based (NHB) trips contribute significantly along with the HB shopping purpose.

Information contained in the HTS database reveals that of those persons who reported the departure time from home to main job, approximately 13 percent reported “to avoid traffic delays” as a reason for departure timing choice. This provides evidence of active peak spreading behaviour of the Sydney travellers. The Sydney HTS contains respondent information essential to the development of any trip-timing model capable of representing peak spreading effects.

4 Modelling trip timing and peak spreading behaviour

Strategic transport modelling tools allow for the testing of broad policy strategies across large transport networks at a macro-level. The traditional four-stage modelling approach as detailed by Ortuzar and Willumsen [10] is a widely-used approach to strategic modelling that accommodates travel demand generation, distribution, mode allocation and network assignments. In recent years modelling of the trip timing decision has become increasingly more important with the need to model policy measures. It is now regarded as one of the more important behavioural modelling decisions after the route choice decision SACTRA [12].

Several techniques for including the trip timing decision within traditional four-stage modelling approaches are reported by Cambridge Systematics Inc. [3]. The techniques described are summarised in the following:

1. Temporally distributing daily link volumes after trip assignment,
2. Temporally distributing mode specific trip matrices between the mode choice and trip assignment stages,
3. Temporally distributing person trip matrices between trip distribution and mode choice and
4. Temporally distributing zonal trip end estimates between trip generation and trip distribution.

Also identified are several innovative approaches to trip timing modelling, including a link based, trip based and system-wide trip timing model approaches. All discussed approaches have varying levels of sophistication and modelling complexity. Selection is largely dependant upon desired output accuracy and input data available.

A range of successful modelling approaches for the incorporation and assessment of peak spreading behaviour are well summarised by DTLR [6]. These modelling methodologies demonstrate a range of approaches for peak spreading modelling with a range of complexity and usefulness in policy testing, range of data requirements and transferability between study areas:

1. Peak hour to peak period ratios with a relatively simple technique to adjust traffic demand profiles to reflect peak spreading,
2. Utilisation of historic peak period and peak hour traffic growth trends to achieve a similar demand profile adjustment to the previous method,
3. Development of a traffic network 'peakiness factor' as a simple function of average traffic speed and a calibrated coefficient using data from a range of sources,
4. Development of peak hour to peak period ratio based on a functional relationship that includes a V/C measurement from the network,
5. Proportionate models that estimate the proportion of travellers that choose to shift departure times, based on information from Stated Preference (SP) surveys,
6. Multi-period equilibrium models aim at modelling traffic flows in a range of time periods simultaneously whilst maintaining relative travel costs between limitations, once they exceed a pre-determined cost roof. Calibrated penalties representing drivers' reluctance to shift between time periods are introduced,
7. Discrete choice models of departure time choice that often use a logit modelling procedure where changes in travelling cost between time periods is used to govern the demand spread. These models are discussed further in following paragraphs of this paper.

Another modelling approach is a continuous time choice model that allocate a trip to a particular time period similar to discrete choice models, however as they operate in continuous time where only select times exist as opposed to defined time intervals. This technique has been applied to several model structures including HADES, UK DfT [13], METROPOLIS, De Palma and Marchal [5] and in the modelling of urban shopping trip departure timing, Bhat and Steed [1].

Discrete choice modelling is widely used in transportation modelling to represent the choice of one from a set of mutually exclusive alternatives. The multinomial logit model (eqn. (1)) provides a useful mechanism for employing discrete choice modelling.

$$P_{iq} = \frac{e^{V_{iq}}}{\sum_{j=1}^{J} e^{V_{jq}}} \tag{1}$$

In equation (1), P_{iq} is the probability that alternative i is chosen by individual q and V_{iq} is the deterministic component of the utility of alternative i for individual q. One complication of the multinomial logit model is the IID assumption Koppelman and Sethi [9]. It is possible to partially relax this with the use of a nested logit model which is essentially a set of hierarchical multinomial logit models linked by a set of conditional relationships. When applied to the departure time choice problem, the discrete choice model represents the travellers' choice of a departure time from a selection of time periods or 'slices'. In the nested logit model form, time periods may be grouped together in 'nests'. The allocation of travel demand to individual time slices allows for the inclusion of temporal management policies, providing the model with time-dependant policy assessment capabilities.

The extensive use of the discrete choice approach including multinomial and nested logit approaches is successfully applied to departure time choice modelling as demonstrated in [4, 7, 11, 14].

Within the discrete choice models, utilities are employed to characterise the departure time choices. Utility functions may be constructed to represent a range of information concerning the traveller, including external influences such as working arrangements, household structure, the journey and the transport system operation. A calibrated discrete choice operation may therefore be constructed with the use of a sample of household travel survey information such as the Sydney HTS and also combine stated preference survey information to allow analysis on policy strategy scenarios.

5 A trip timing model for Sydney

The approach adopted for representing the trip timing decision for Sydney journey makers is a nested logit discrete choice model with capabilities in representing policy strategies applied to the active peak spreading element. The modelling calibration shall largely be based on the Sydney HTS with further developments to include SP survey information. The modelling of trip timing decisions focuses on dominant trip purposes and modes during the peaks such as private vehicle travel, HB work, education and shopping trips. The temporal distribution will apply to existing demand information, this essentially being the mode-specific OD matrices prior to assignment processes. The resultant nested logit model has the following structure:

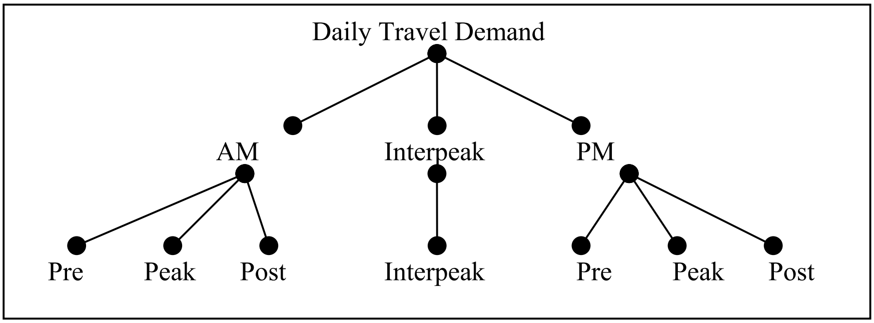

Figure 3: Suggested structure for nested logit trip timing model.

Further nesting within the AM and PM peak periods is possible with half-hour time slices allowing greater choice options for the travellers and greater flexibility for modelling policy options that focus on shorter time periods. Possible parameters for inclusion within the utility functions are household vehicle ownership, income, structure (eg. number of income earners, children), age, travel costs and desired arrival time to allow for flexitime inclusion possibilities.

The use of stated preference surveys will add another dimension to model calibration as respondents provide information relating to sensitivity to peak spreading policy options such as pricing regimes such as variable congestion tolls on roads and options relating to arrival time flexibility. Such SP information may also be included within the modelling structure broadening modelling capabilities.

6 Future research

As the development of the nested logit model progresses it is the aim of this research to further refine the modelling elements. This shall include building upon the base model structure and determination of select utility elements. In addition, the research shall endeavour to undertake SP surveys and incorporate respondent information into the modelling approach. The peak spreading evaluation model will be best suited within a wider modelling operational environment, such as the traditional four-stage model.

In addition to the Sydney HTS database, HTS data for other Australian capital cities such as Adelaide may provide similar data for model calibration. Comparative analysis between different cities shall be possible with the use of independent models.

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