Obtaining Travel Intensity Profiles from Household Travel Survey Data

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Innovative ways to examine the spatiotemporal variations in road traffic, by using data from the Victorian Activity and Travel Survey (VATS), are presented. The approach is shown to offer significant advantages over traditional methods of analysis, such as observational surveys or roadside traffic counts. By linking the complete vehicle travel paths reported in VATS with the detailed demographic data of the respondents, a comprehensive understanding of travel and driver behavior is developed. The general methodology described is shown to be applicable to any travel data obtained from household travel surveys, especially where the origins and destinations of the recorded trips have been geocoded and stored in a geographic information system.

Although traditional traffic measurement techniques such as observational surveys or roadside traffic counts are ideally suited to intersection analyses and the support of local area traffic management schemes, they can provide only limited data on the number and, at best, type of vehicles traveling through discrete areas. For a successful response to the growing environmental and social concerns about the impact vehicles are having on cities, consideration must be given to traffic flows across the entire road network, across the entire day.

This study sought to develop a spatiotemporal approach to the study of car travel patterns based on data from the Victorian Activity and Travel Survey (VATS). Use of such a household travel survey complements the counting-type approaches by recording detailed travel information for every trip made by a respondent on his or her survey day. Knowledge of the origins, destinations, and times of travel, linked to comprehensive vehicle and driver demographic data, provides a powerful analytical foundation for strategic transportation planning. Examples of policy areas in which such information is useful are:

- Measurements of exposure in road safety studies;
- Measurements of traffic concentrations in emissions modeling and monitoring;
- Measurements of the temporal changes in traffic volumes when defining clearway operating hours; and
- Overall measures of traffic movement in strategic road planning studies.

The focus of this study was developing a methodology for extracting and presenting the data in a format suitable for such studies. Although use of VATS data gives the study a Melbourne (Australia) focus, the general methodology described is shown to be applicable to any travel data obtained from household travel surveys, especially where the origins and destinations of the recorded trips have been geocoded and stored in a geographic information system (GIS) package. A further refinement of the analysis is possible because of specific questions asked on the VATS questionnaire.

SOURCE OF DATA

The data used in this study were obtained from VATS (*1*). VATS is a continuous survey that, since its beginning in 1993, has collected information from about 5,000 responding households every year (except 1994, in which a higher sampling rate elicited approximately 7,200 valid household responses). VATS data from 1994 were used.

The data collected were of all travel made by each person within each responding household. Whether a walk around the block or a car trip across the city, any travel made outside of the home was documented. Selected households completed the survey for one specified day of the year. Surveys were distributed for every day of the year. This continuity allows short-term variations in travel behavior (according to time of day, day of week, month of year) to be observed. All households were chosen from within the Melbourne Statistical Division (MSD), which contains the entire Melbourne metropolitan area.

Survey Methodology

The survey method used was that of a mail-out/mail-back self-completion questionnaire. The origins of this method stem from West Germany surveys of the early 1970s (*2,3*) and were refined over many years by Transport Research Center staff.

To maximize the response rate (approximately 55 percent for the 1994 data), the survey mail-out consisted of up to six stages. All households in the sample experienced the first two stages: the mailing of an initial contact letter notifying the household of their selection, followed by a survey pack sent to arrive 2 working days before the specified travel date. This pack contained the household and person form and individual booklets for each person to record travel. Depending on the cooperation of the household, up to four reminders were sent over a period of 4 weeks.

As a complement to the intensive mail-out process, other survey techniques were used to enhance the quality of reported data:

- Telephone interviews were used to clarify any information on completed surveys;
- Personal interviews of a sample of responding households were used to assess the quality of the reported data;

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- Nonresponse interviews of a sample of those households that have not responded after the fourth reminder were used to ascertain the reasons for not completing the survey and to obtain travel estimates for the nonrespondents.

Description of Data

The VATS data was stored in a relational database, consisting of five separate files: household, vehicle, person, stop, and trip. A complete list of the fields contained in each file is available from the authors. Of specific interest to this analysis was the trip data, containing geocoded information on the origin and destination of the trip, the mode of travel, and the time of travel (start time of trip, arrival time at destination, departure time) for any travel made by a VATS respondent.

For illustrative purposes, emphasis was placed on car travel, although the methods used were applicable across all modes.

Weighting of Data

The VATS sample was weighted up to represent the population by using figures from the 1991 Australian Census of Population and Housing. A person weight was applied to each respondent according to age, sex, and home location. Summing these weights for any specified region therefore provided the correct estimate and basic demographic breakdown of the entire population.

As people left their homes to travel, trip weights were applied to each respondent. Although basically the same as the person weights, these weights were adjusted further to account for some nonreporting of trips, as determined by the validation process. Summing the trip weights provided an estimate of the activity and travel behavior of the entire population.

Data Limitations

This study focused on the number of vehicles (or demand) for travel and the considerable applications derived therefrom, with no explicit relation to the amount of roadspace (supply) available. The provision of a GIS network with details on road type and capacity allowed for a more detailed exploration of road congestion and the associated problems.

VATS is a household travel and activity survey. Therefore, tourist and commercial vehicle flows are not represented in any of the following examples.

RESEARCH METHODOLOGY

Extraction and Initial Representation of Data

By using the 1994 VATS data, 21,500 records were extracted initially for use in this study. These were all the trips in which the mode of travel was listed as car driver. To focus on weekday travel, all weekend trips were removed, leaving a base sample of about 16,400 trips relating to the travel of approximately 4,100 different respondents.

As an initial estimation of travel activity, straight-line travel was assumed between origin and destination. To illustrate this method, the first 1,000 trips of the base sample are plotted in Figure 1. Although this provides some indication of where car trips were being made in the study area, two problems become immediately apparent.

First, the situation of Melbourne on Port Phillip Bay resulted in a substantial number of vehicles taking the damper water route to their destinations! So that these trips are not lost from any further analysis (obviously resulting in an underestimation of travel along the coast) it was necessary to shift these journeys back to land. This was accomplished by writing a small program that detects if the trips intersect the bay and, if so, looks for alternative fixed points on the land to pass the line through. Where possible, these fixed points were placed along main roads to reflect likely route choices.

The second problem encountered was that of visual clarity. In Figure 1, representation of the first 1,000 trips (6 percent) of the sample led to a confusing array of lines, with all detail lost in the suburban area. Therefore, to clearly portray such a large number of trips and achieve a level of detail applicable to a local area traffic analysis, a series of thematic maps was created.

Conversion of Initial Output to Thematic Map Display

Many typical sociodemographic thematic maps are based on key statistical boundaries with specific population interests, such as Local Government Areas (LGAs). In this instance, to accurately represent and compare vehicle movement across a region, small, homogeneous areas were required. Consequently, a grid of 1 km^2 regions was generated as the thematic map base.

For each grid square, the weights of the intersecting trip lines can be summed to determine a value of vehicles per square kilometer. The conversion of this figure to a more common value of vehicle kilometers per square kilometer requires a further summation of the lengths of trip lines within each square—impractical in this instance because of the necessary computer processing time. To overcome this problem, the vehicle kilometers associated with any specific grid square were determined by multiplying the trip weight of each

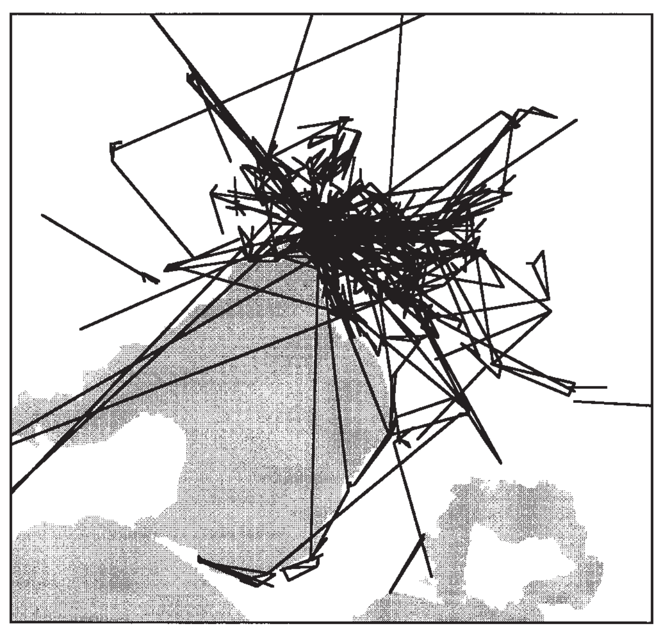

FIGURE 1 Initial representation of vehicle travel (first 1,000 trips).

line with a simple conversion factor—the average length of trip per grid square.

It would be difficult to give an accurate picture of vehicle intensity at a specific time, because this would require the placement of those vehicles traveling at that time at some specific distance along their route. For example, if a vehicle is undertaking a trip from 10:45 a.m. to 11:15 a.m., and one wishes to know where the vehicle is at 11:00 a.m., the assumption of constant speed would place the vehicle halfway along its route. However, depending on where the vehicle is traveling, along what roads, and at what time of day, travel speeds can vary enormously over a single journey. Combined with the assumption of straight-line travel, a proportional placement of vehicles could misrepresent substantially the location of the vehicles.

Accordingly, the temporal analysis concentrated on complete trips over hour intervals. For instance, to obtain a spatiotemporal display of vehicle intensity between 7:00 a.m. and 8:00 a.m., all trips starting (but not necessarily ending) in that time period were assigned to that time period.

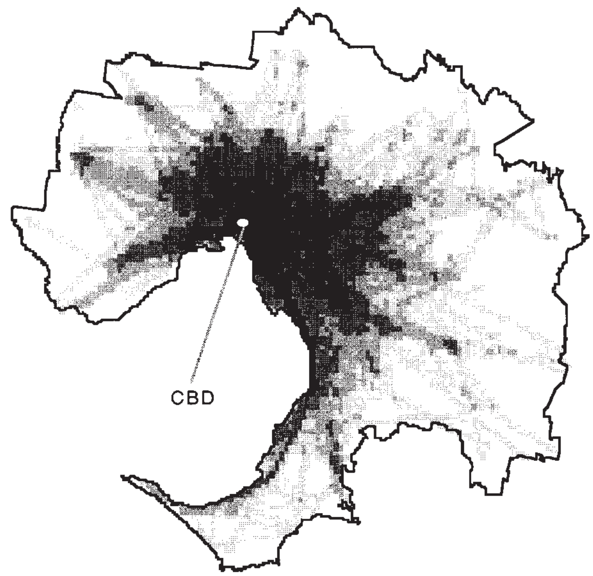

FIGURE 2 Daily vehicle kilometers per square kilometer (average weekday).

EXAMPLES OF SPATIOTEMPORAL OUTPUTS

Daily Traffic Intensities

The advantages of using grids in visualizing vehicle intensities are illustrated in Figure 2. The map represents all car travel across an average weekday and provides a clear definition of the high-intensity contour around the central city. Besides this central contour, the image is dominated by strong radial links through to the fringe suburbs of Melbourne, with vehicle intensity decreasing as the distance from the city center increases. The predominant activity is to the east of the central business district, and none of the western approaches carry the same intensity of vehicles.

Another powerful feature of this analysis is the simplicity with which the data can be disaggregated. For instance, because the times of travel are associated with each trip, it can be determined not only where the vehicles are but also when they are traveling. Maps of traffic intensity at different times of the day therefore can be produced, such as those in Figure 3.

The morning peak causes a high pocket of traffic intensity in the central city with a build up of traffic on the radial arterial roads, with the most pressure placed on the eastern corridors. The lunchtime flows, however, are spread more evenly across the suburbs, with far fewer regions recording high to very high traffic intensities.

Although VATS data were used in this study, the analysis described so far could be performed equally well with geocoded data from any household travel survey. This simple methodology therefore can be applied across different regions, allowing vehicle intensity comparisons to be made.

Increased Accuracy in Trip Representation

Associated with each vehicle trip record in the VATS data are the names of up to six main roads used to reach the destination. On the basis of knowledge of these roads, methods were developed at TRC that generate the likely travel path taken (*4*). By replacing the assumed straight-line travel with these more-probable paths, a much clearer view of travel in Melbourne can be produced

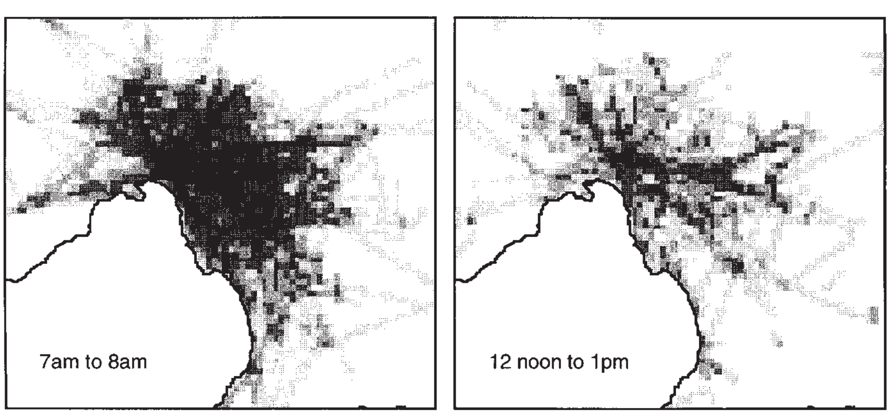

FIGURE 3 Car trip intensities for different times of day.

(Figure 4). This refined image of vehicle intensity was generated by applying the methodology described across a finer grid, 500 m^2.

The travel paths used in this analysis were restricted to intraregional trips (starting and ending in the MSD study area). This had little effect on the overall picture, except on the normally busy route to Geelong, outside the study region to the southwest of Melbourne. This explains the apparent lack of activity past Werribee on the Princes Freeway. Despite this, the result forms an impressive foundation for determining vehicle intensities across the entire metropolitan region.

Figure 4 allows the estimation of flows along key arterial roads and further illustrates the high demands placed on the city approaches. The South Eastern Freeway, in particular, records continuously high traffic flows up to 20 km outside of the city.

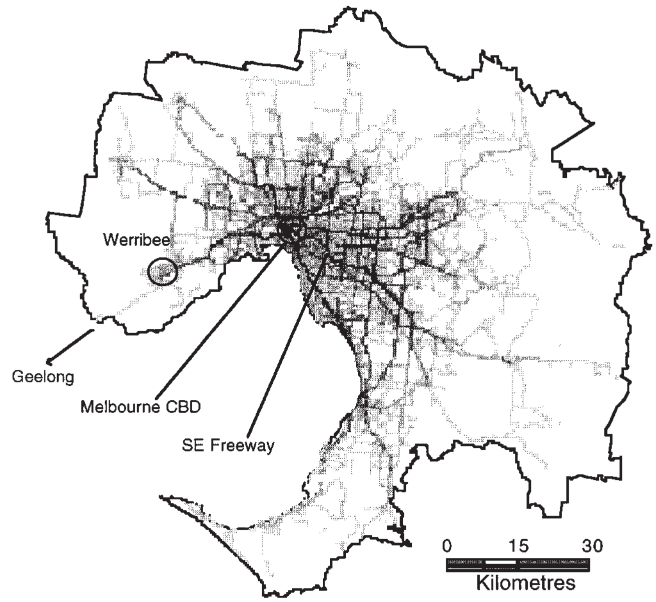

FIGURE 4 Refined map of vehicle intensities.

APPLICATIONS OF METHODOLOGY

Although the vehicle intensity analyses discussed are comprehensive in their spatial coverage, transport planning practitioners would be correct in stating that more accurate estimates per road link are obtainable through basic counting techniques. The advantage of the methodology outlined in this report is found in the deeper analytical potential, whereby traffic can be examined within a more holistic framework.

Specific Traffic Generation Sites

For any vehicle flows of interest, the origin and destination of travel can be extracted instantaneously. Therefore, within any region, congested flows can be traced to their constituent traffic sources, highlighting possible remedial, reduction, or diversion strategies. To illustrate this concept, a map of trip generation intensity (a count of the number of trips originating in each square-kilometer grid) is shown in Figure 5.

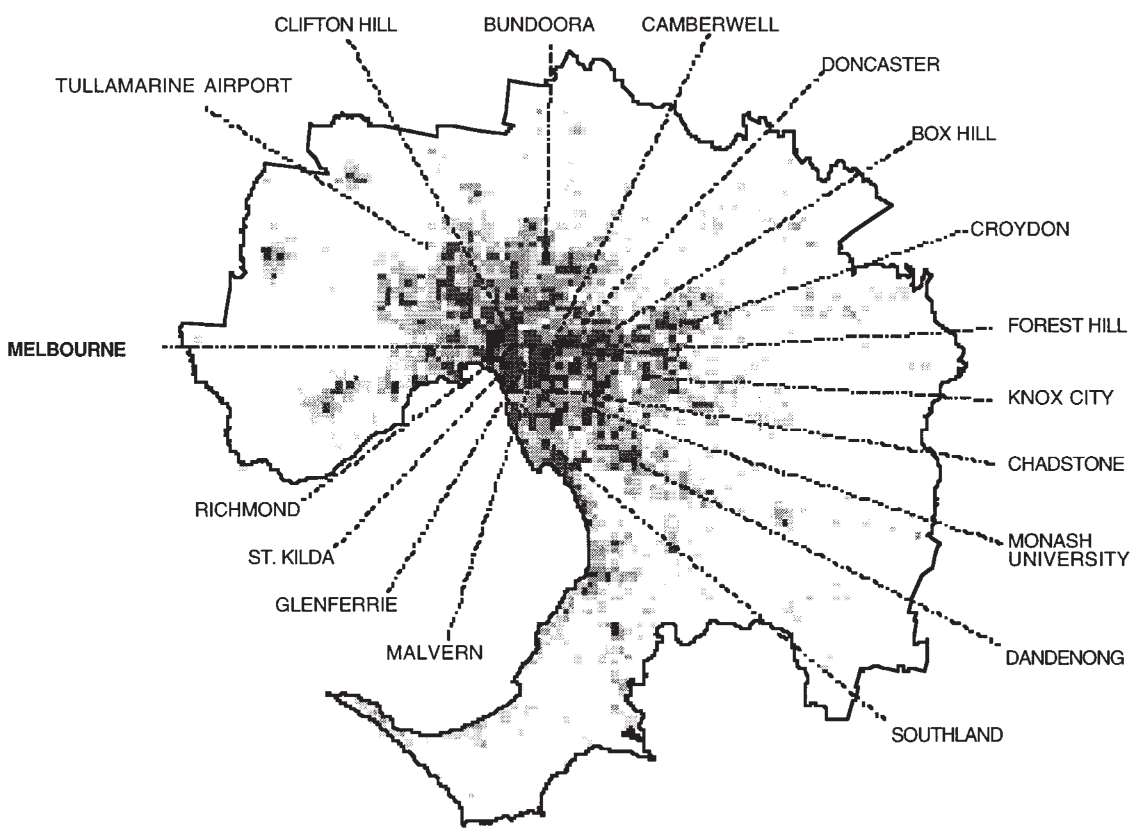

FIGURE 5 Locations of traffic generation sites on average weekday.

Although half of the high-generation grids are located around the CBD and inner Melbourne, the other half relate to precise sites around the metropolitan region. Most of these are regional shopping and commercial centers, although Tullamarine Airport and Monash University also feature as key trip generators.

The importance of Figure 2 (vehicle intensity contours) and Figure 5 (trip generation sites) in understanding personal travel behavior was emphasized by their inclusion in a strategic transport plan released by the Victorian government (*5*).

Traffic Intensity by Demographic Group

Although the previous examples concentrated on the counting of vehicles moving through various regions (perhaps best described as an innovative observational survey), the analysis method described also can produce more detailed outputs normally associated with an intercept survey. Just as different stop attributes (e.g., time of travel) were examined, driver demographics also may be examined.

By associating driver characteristics with any of the spatiotemporal traffic intensity representations, the differences in travel patterns between distinct demographic groups can be observed. For instance, Figure 6 shows the intensities of vehicle trips made by males under age 25, compared with the intensities of vehicle trips made by male car drivers over 65. Darker regions in both maps represents a high proportion of the group.

Figure 6 reveals the widespread travel of young male car drivers, with the group predominantly found to the north of the city and throughout the outer suburban region. The trend for older males is significantly different, particularly along the coast where very high proportions of the group are seen. Older males also can be found in a band through the eastern suburbs, and have only low representation in the northern and western regions.

This example is included not as a definitive representation of travel differences but instead to indicate the analysis potential. As the VATS sample size increases, travel behavior of specific demographic groups can be disaggregated by time of day and day of week. Such a detailed understanding of driver behavior is crucial to the development and enforcement of road safety campaigns.

Travel Profiles Across Geographic Regions

The use of a shaded grid map revealed site-specific car driver characteristics. Application of the same GIS methodology at an LGA level is shown to have important implications on how local traffic flows are perceived.

Because there are only 31 LGAs in the Melbourne metropolitan region, the limitations concerning processing time (encountered in analysis of the thousands of grid regions) were less of an issue. Hence, it was possible to calculate vehicle kilometers per square kilometer for each area at every hour of the day—the travel profile. At the same time, by knowing where the origin and destinations lie relative to an LGA, it can be determined whether the trips were traveling to or from the LGA, or whether they were internal or through trips.

Figure 7 shows the location of the six LGAs with the highest daily vehicle kilometers per square kilometer. The travel profiles relating these LGAs are presented in Figure 8.

As expected, traffic intensity peaks are experienced in the 7:00 a.m. to 8:00 a.m. and 5:00 p.m. to 6:00 p.m. periods, and the lunchtime volumes level out to a fairly constant intensity. Less expected is the magnitude of some of the traffic intensity curves for the more suburban areas (such as Whitehorse). It appears that the areas surrounding Melbourne actually carry more vehicles per square kilometer than does the central city itself, and even suburban centers such as Whitehorse have flows comparable to those in the central city region during the course of the day.

Types of Trip by LGA

Table 1 shows a breakdown of trip type for all LGAs in the study area. For travel between LGAs, Melbourne predictably attracts (and therefore generates) the most number of vehicle trips. By comparison, the LGA of Yarra attracts less than half the number of vehicle trips as Melbourne, and produces negligible internal trips, but still records the highest peak flows. This situation is attributable to the large volume of through traffic in Yarra.

Similarly, the combination of trip type will affect local area traffic management schemes. For instance, the Whitehorse LGA con-

FIGURE 6 Traffic intensities for male car drivers of different ages.

LGA Name	Vehicle kms per square km per day
Yarra	44791
Stonnington	39472
Melbourne	35473
Port Phillip	34310
Boroondara	30732
Whitehorse	26147

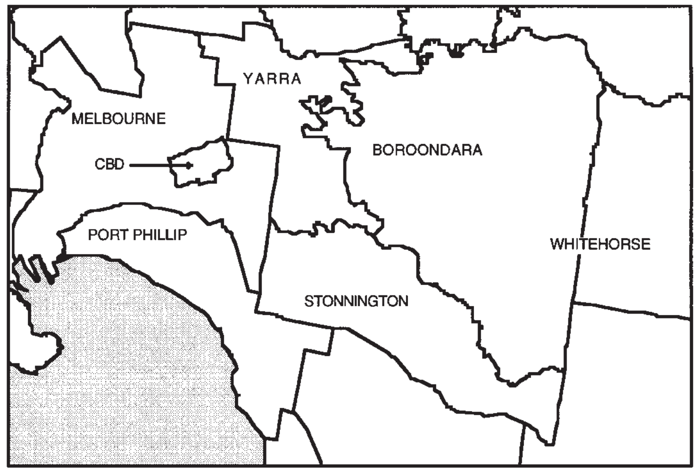

FIGURE 7 Six LGAs with highest daily vehicle intensities.

tains key east-west arterial roads recognized earlier as high vehicle intensity links, as well as activity and shopping centers. Planning therefore must balance competing travel needs; the ease of access to and from activity centers for distinct modes (private vehicles, commercial vehicles, public transport, and pedestrian movements) compared with a smooth flow of commuting traffic along the arterial corridors.

The interaction of through and local traffic in a region of high travel demand can place enormous demands on a local road supply, increase the risk of accidents, and generally reduce urban amenity. An understanding of the different types of trip contributing to overall traffic intensity therefore is an important precursor to planning for this traffic. Roadside traffic counts, although giving some idea of overall traffic intensity at a site, rarely provide much insight into the composition of trips contributing to that overall traffic intensity. The technique outlined, however, gives much useful information on this issue.

CONCLUSIONS

This study raised several points about how travel activity is measured and represented. By analyzing data from VATS, a household travel survey, it was shown that vehicle flows across the entire study area could be estimated.

Some traffic engineers may regard the innovative methodology used with some skepticism. It would be rightly argued, for instance, that the technology exists to collect very accurate traffic

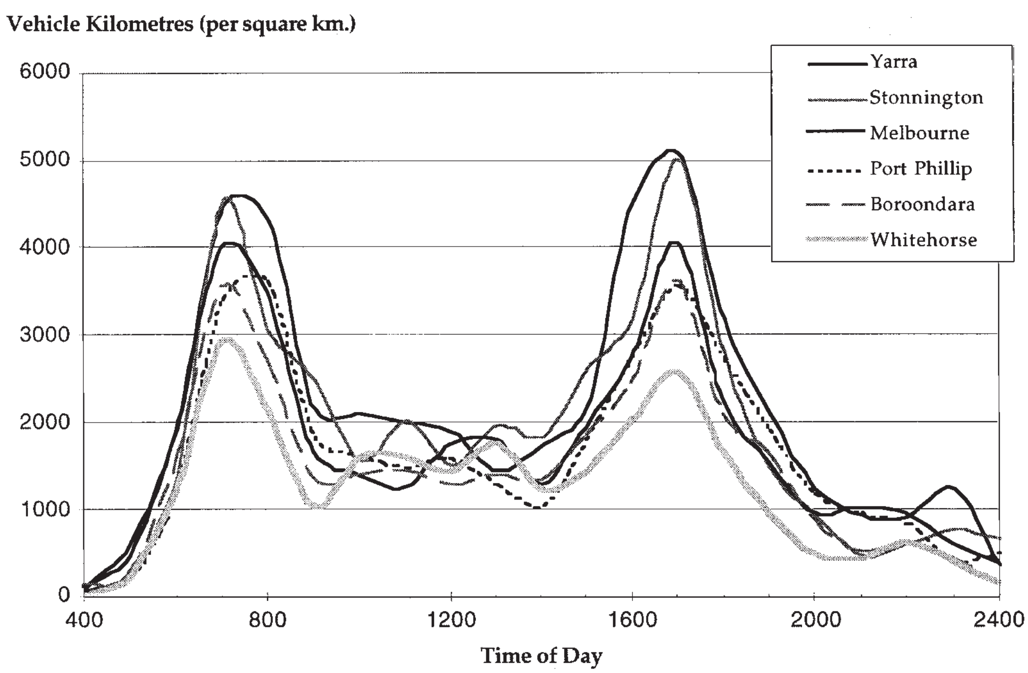

FIGURE 8 Temporal variations in LGA traffic intensities.

TABLE 1 Comparison of Trip Attraction and Generation for Local Government Areas (Car Driver Travel)

LGA Name	Internal trips	LGA Name	Origin in LGA *	LGA Name	Destination in LGA *	LGA Name	Passes through LGA
WHITEHORSE	187299	MELBOURNE	188867	MELBOURNE	191726	YARRA	240800
KINGSTON	163641	MONASH	140678	MONASH	141528	BOROONDARA	201248
YARRA RANGES	154869	BOROONDARA	129667	BOROONDARA	128630	STONNINGTON	177211
MONASH	133496	WHITEHORSE	124456	WHITEHORSE	124094	MELBOURNE	168256
BOROONDARA	131516	STONNINGTON	101744	STONNINGTON	103668	MORELAND	124376
MORN. PENINSULA	124339	PORT PHILLIP	101080	PORT PHILLIP	101963	MONASH	122800
KNOX	114947	KINGSTON	98513	KINGSTON	96912	WHITEHORSE	114605
MAROONDAH	112382	YARRA	95327	GTR. DANDENONG	96116	GLEN EIRA	114541
HUME	112346	GTR. DANDENONG	93683	YARRA	96053	DAREBIN	112666
BRIMBANK	103234	BANYULE	92308	BANYULE	89076	MANNINGHAM	91806
BANYULE	103116	KNOX	87596	KNOX	87829	MOONEE VALLEY	87498
GTR. DANDENONG	99458	MAROONDAH	83196	DAREBIN	84744	PORT PHILLIP	84203
FRANKSTON	94477	DAREBIN	81854	MAROONDAH	83399	MARIBYRNONG	81402
MOONEE VALLEY	92624	GLEN EIRA	75404	GLEN EIRA	75533	KINGSTON	79847
HOBSON BAY	90357	MORELAND	72706	MORELAND	73265	GTR. DANDENONG	76686
DAREBIN	73987	YARRA RANGES	71388	YARRA RANGES	70624	BANYULE	62178
CASEY	71637	MOONEE VALLEY	68855	HUME	70199	KNOX	48221
GLEN EIRA	70887	MANNINGHAM	67994	MANNINGHAM	67737	BRIMBANK	47125
BAYSIDE	68267	HUME	67968	MOONEE VALLEY	67194	MAROONDAH	45973
WHITTLESEA	66351	BRIMBANK	60405	BRIMBANK	57906	FRANKSTON	27593
STONNINGTON	63306	BAYSIDE	58307	BAYSIDE	56775	HOBSON BAY	27393
MORELAND	61058	HOBSON BAY	51188	HOBSON BAY	49634	BAYSIDE	23780
MANNINGHAM	56548	WHITTLESEA	50064	WHITTLESEA	48992	CASEY	22580
PORT PHILLIP	55333	CASEY	48414	CASEY	47590	NILLUMBIK	20300
WYNDHAM	54105	FRANKSTON	46116	FRANKSTON	47198	WYNDHAM	17222
YARRA	51273	MARIBYRNONG	43448	MARIBYRNONG	42094	YARRA RANGES	14835
MELBOURNE	49165	WYNDHAM	30707	WYNDHAM	32062	HUME	8546
MELTON	48962	NILLUMBIK	28981	NILLUMBIK	29063	WHITTLESEA	8122
CARDINIA	34840	MORN. PENINSULA	25613	MORN. PENINSULA	25315	MELTON	5632
NILLUMBIK	30129	CARDINIA	18204	CARDINIA	15021	CARDINIA	1722
MARIBYRNONG	26280	MELTON	12241	MELTON	12362	MORN. PENINSULA	0

* does not include internal trips

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data for any specified network link. This research was not intended to discard conventional traffic analysis techniques but instead to complement them.

For any defined traffic flow, at any time of the day, in any region, the methods described have been shown to be capable of providing a detailed description of traffic composition. Such a description could include information on the driver, vehicle, trip route, or trip type, as follows:

1. The provision of driver demographics allows analysis of the travel behavior of different groups of people. A common example concerns accident exposure, wherein drivers of specific demographic groups (e.g., young males) are targeted as part of road safety campaigns. By identifying and monitoring the spatiotemporal behavior of such groups, resources can be deployed more accurately. The driver exposure also forms an important commercial measurement, in terms of roadside marketing or facility placement.
2. The vehicle characteristics of traffic flows assist in pollution analyses and the monitoring of the on-road vehicle inventory in different regions. Because VATS links specific household vehicles to specific trips, it is possible to obtain detailed on-road vehicle fleet information from the VATS data.
3. The mapping of all vehicle routes provides an overview of network operation. Key destinations of travel can be mapped and linked to the origins and purposes of travel. Furthermore, the disaggregation of data to reveal the type of travel occurring in a region provides a simple, unambiguous, and tangible measurement of traffic composition. Therefore traffic hot spots need not be examined in isolation but rather in conjunction with the complete trip attributes, assisting local area traffic planning and specific local government transport strategies.

Although vehicle travel was used to illustrate the methodology, the same process can be used to analyze any mode of travel, from public transport patronage levels to nonmotorized transport behavior, such as pedestrian flows in the central business district.

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