## Introduction

The rapid development of information technology, and an increasing emphasis on "knowledge workers" (Jones, 1996; Mueller, 2000) suggests the creation of a new culture in road safety where research will utilise a range of databases and surveys, which may be exploited or "mined" to provide simple, concise information to decision-makers.

This paper provides an inventory of databases for the city of Melbourne, Australia, which may be linked and analysed to inform road safety initiatives.

A national database of information about bicycle use and data resources on cycling matters has previously been developed (Wigan and Smith, 1996) to facilitate research into bicycle use and safety. Known as *ANBI* (Australian National Bicycle Information-base), this computer-based index covers both an information base and a reference collection.

In the road safety area, the more traditional bibliographic databases include *Transport & Road Update*, an ARRB Transport Research database which is amalgamated into the *Australian Transport Index*, along with *ATLIS*, the Australian Transport Literature Information System and *LASORS*, Literature Analysis System: Office of Road Safety (Beaumont, 2001). This paper refers to those transport-related or multidisciplinary databases which are not bibliographic, but are numeric or alphanumeric in nature. The emphasis here is not on one-off studies, but on information which is provided continually or at frequent intervals in a reasonably consistent manner to enable trends over time to be observed and monitored.

Morris (1983) has stated that the fragmentation, diversity and often the sheer lack of information produce the greatest challenge. The gaps in available transport information and statistics must also be clearly identified.

It is therefore the aim of this paper to be not only descriptive of those data sources relevant to road safety and their availability, but also to be prescriptive – to point out where gaps exist and how they might be filled.

This study is limited to the city of Melbourne in Victoria, Australia, which has an enviable reputation as the world's most livable city. The State of Victoria has been described as Australia's safest State (Comrie, 1999). In part, this is due to Victoria's Road Safety Strategy which is a multi-agency approach comprising a partnership of VicRoads, the Victoria Police and the Transport Accident Commission.

Through an integrated approach, it has been possible to reduce the incidence, severity and cost to the Victorian community of road fatalities from 776 in 1989 to 407 in 2000 (Transport Accident Commission, 2001). The methods used by the three agencies may be broadly described as enforcement, research, engineering, education, promotion and coordination. While this dramatic decline in fatalities could lead one to envisage a zero road toll in the next few decades, it is apparent that zero is not a target to be achieved by a certain date (Tingvall and Haworth, 1999). Rather, it is a change from an emphasis on current problems and possible ways of reducing these to being guided by what the optimum state of the road transport system should be.

This work was undertaken to ascertain the prospective role of databases in linking information from various sources to further determine some of the risk factors in road fatalities to reduce the road toll. This includes databases of the three agencies involved in Victoria's Road Safety Strategy – VicRoads, Victoria Police and Transport Accident Commission – as well as that of the Transport Research Centre at RMIT University in Melbourne, and other government and private agencies. While the focus in this paper is upon Melbourne, many similar databases are compiled elsewhere, and many of the issues raised and illustrated in this paper have wider applicability.

## Current road safety initiatives and issues

Before looking at databases and their potential role, it is useful to look at the current Road Safety Strategy in Victoria. Key challenges have been identified through analysis of current experience, road crash information and assumptions on our future environment. Blanket safety measures which have already been introduced to Victoria to reduce the road toll (VicRoads, 2000) include:

- Wearing of seat belts which became mandatory in 1970. Those people who do not wear seat belts are four times more likely to be killed in a crash, although data suggests that non-use of seatbelts is associated with other high risk behaviour.

- Random breath testing (RBT) allied with media publicity has helped reduce drink driving, but alcohol remains a major contributor to road death and injury. Despite recent improvements, 24% of drivers and riders killed have an illegal blood alcohol concentration (BAC). Legislation is underway to bring Victoria into line with other Australian States in setting the basic drink driving offence *at* rather than *above* 0.05 BAC, with a corresponding adjustment at 0.10 where there is mandatory loss of licence.

- Lower speed limits were introduced in residential areas of Victoria on 22 January 2001. The limit was lowered from 60 km/hr to 50 km/hr. Existing speed limits are being retained on some collector roads, arterial roads, main roads, highways and freeways. A 50km/hr limit was implemented in the adjoining state of New South Wales in April 1998, and over the 21 month period to December 1999 the cost saving to the community from avoided accidents has been estimated at $6.5 million (ARRB Transport Research, 2000).

Blanket measures such as these are regulatory in nature, and their enforcement is clearly an important element in determining their overall impact. There are, of course, elements of the strategy which rely on other methods besides regulation and enforcement. These include encouragement and education, as well as engineering solutions. Education through television advertising has been conducted by the

Transport Accident Commission to include some factual information about how accidents occur, in addition to showing the graphic accident and its aftermath. The effectiveness of the advertising campaigns has been vigorously debated. Campaigns have been analysed by Vulcan, Cameron, Mullan and Dyte (1996), reinvestigated by White, Walker, Glonek and Burns (2000) and further reinvestigated by Cameron and Newstead (2000). The most recent conclusion is that substantial reductions in road trauma in Victoria are associated with increased random breath testing using "booze buses" and a new speed camera program, each supported by TAC advertising.

Typically, advertising and education campaigns focus on high risk factors and on high risk groups of people. Some important findings relating to the road toll are:

- Fatigue is a factor in around 25% of crashes and in almost one third of rural single vehicle crashes. Most fatigue related crashes occur during normal sleeping hours.

- Drivers remain the largest single group of road user fatalities with young drivers over-represented. Older drivers also tend to be over-involved in crashes. The next 15 years will see a sixfold increase in numbers of licence holders aged over 65.

- Motorcyclists continue to be over-represented in state-wide statistics; they are about twenty times more likely to be killed than car drivers and passengers for a given amount of travel. Almost half those killed or injured are aged between 18-25 years.

- While half those seriously injured in bicycle crashes are adults, of all children killed and injured on the road, 25% are bicyclists.

- Pedestrians are one-third more likely to be killed in a road accident than other road users. Especially vulnerable are pedestrians aged between 4 and 14 years, those aged 60 and over and the intoxicated. In Melbourne they represent almost one in three road deaths.

- More people are more likely to be severely injured or killed in crashes involving heavy vehicles.

- Drugs and some medications are significant road safety problems. Both prescription and illegal drugs known to affect driving are found in almost 22% of drivers killed on Victorian roads. Drugs have been identified in postmortem examinations of a significant number of drivers judged to be culpable in crashes, with prescription and illegal drugs represented about equally.

- Generally, tests show that vehicles available to Australian consumers do not protect occupants as well as vehicles overseas.

Engineering solutions also contribute to play an important role in road safety. Although roads are of higher quality than ever before, road and surrounding features still contribute to one third of crashes. Accident Blackspot Programs involve a systematic process of identifying high risk sites, the factors contributing to crashes at those sites, and the development and implementation of cost-effective solutions which have been shown to provide significant benefits.

While different factors may individually contribute to the road toll, it is difficult to evaluate the individual issues because of the inter-relationship between many of them (Howard, 1999). Evaluation is, of course, a significant but far from trivial exercise and will assist in policy formulation. Many of these inter-relationships may be identified through a cross-tabulation of demographic variables and factors from different databases. The development of an evaluative framework presupposes that, at the very least, desirable performance measures are defined, and the requisite information is compiled for assessment. The choice of appropriate performance indicators for a road safety strategy is a topic in itself, and is not tackled explicitly in this paper. It is worth noting in passing, however, that this issue has been addressed elsewhere in relation to bicycle safety and planning strategies (Wigan and Smith, 1997).

## Databases and data sources

An array of databases and data sources which contain information relevant to road safety in Melbourne are summarised in Table 1. Key variables from these databases related to road safety are summarised in Table 2 in Appendix A, and the databases themselves are described in detail in Appendix B. These provide a starting point for a Melbourne road safety meta-database, and have been arbitrarily classified into three categories:

- Accident Information - sources of information about accidents and incidents
- Safety Measures – information on availability of protective measures and compliance with safety regulations (eg wearing of seatbelts, alcohol consumption, etc)
- Complementary databases - information on weather conditions, travel patterns and usage which may be cross-linked to the accident data to provide useful perspectives on road safety

There is clearly some overlap between these categories of information, eg the observational surveys also furnish information on usage, which has been used to deduce travel distance and exposure.

The Accident, Safety and Complementary databases have a number of variables in common, which may be cross-tabulated to provide a rich source of information, however the area of overlap is greater between the Accident and Complementary databases.

**Table 1 Databases and data sources relevant to road safety in Melbourne**

| Acronym | Database | Reference |
|---|---|---|
| | | |
| **Accident Information** | | |
| *ATSB | Australian Transport Safety Bureau | Australian Transport Safety Bureau (2000) |
| *MFD | ATSB Monthly Fatality Database | Australian Transport Safety Bureau (2000) |
| *SID | ATSB Serious Injury Database | Australian Transport Safety Bureau (2000) |
| *FF | ATSB Fatality File | Australian Transport Safety Bureau (2000) |
| **Crashstats* | Road Crash Statistics: Victoria | Crashstats (1998) |
| *INS | Insurance company | Brooks (2001) |
| *NCIS | National Coroners Information System | Lightfoot (2001) |
| NISU | National Injury Surveillance Unit | Harding (2001) |
| OBDM | Office of Births, Deaths and Marriages | Mattingsbrooke(2000) |
| *TAC | Transport Accident Commission | Healy and Thiele (2001) |
| | | |
| **Safety measures** | | |
| *LPIS | Licensed Premises Identification System | Thiele and van Niel (1999) |
| *OBS | Observational surveys | Intstat Australia Pty Ltd (1987); Drummond and Healy (1986); Diamantopoulou et al (1996) |
| | | |
| **Complementary databases** | | |
| *BoM | Bureau of Meteorology | Puri (2000) |
| e-tag | CityLink e-tag information | Ogden (1999) |
| *IRDB2000 | Integrated Regional Database | Australian Bureau of Statistics (2000) |
| *NVS | National Visitor Survey | Barry, Battye, Dale and Owen (1999) |
| *VATS | Victorian Activity and Travel Survey | Transport Research Centre (2000) |

* Variables from these databases are listed in Table 2 in Appendix A

The Accident databases described in Appendices A and B are those of the Australian Transport Safety Bureau (ATSB), *Crashstats*, insurance company data (INS), National Coroners Information System (NCIS) and the Transport Accident Commission (TAC). Variables which they have in common are:

- age
- gender
- mode of travel
- date of accident

A test study has been undertaken by Rosman (1996) in which similar variables were used to match police records to hospital records for the purpose of widening the scope of data available for research and policy evaluation. Rosman used the hospital admission and police records from the Western Australian Road Injury Database using special purpose software and comprehensive manual checking. This set of linked records were considered to be a "gold standard" which could be used to measure the quantity and quality of links produced using fewer identifying characteristics. Results showed that about 90% of links could be identified when a phonetic code of the family name of the casualty was used with age, sex, road user type and crash date. However, only about 50% of the original links were found if linking was performed without using names or phonetic name codes. The ATSB Fatality File may also be compared with data from the National Coroners Information System. Safety information such as whether a seat belt is worn is not included in the NCIS.

The Safety Measures databases Licensed Premises Information System (LPIS) and the Observational Surveys (OBS) have in common:

- gender
- licence type
- intercept time and date

Of the Complementary databases, namely Integrated Regional Database (IRDB), National Visitor Survey (NVS) and Victorian Activity and Travel Survey (VATS), the variables they have in common are:

- gender
- family structure
- household address

Each of these databases is available commercially for a fee.

The variables contained within the databases have been categorised as follows:

- Personal/household information – key data are age, gender, employment status, occupation, household address, years of driving experience

- Physical external environment – key data are mainly from ATSB accident data and the complementary data provided by the Bureau of Meteorology. The speed limits are covered in several of the databases. Information relevant to safety near schools may be attained from ATSB accident data and an analysis of school children's travel patterns from VATS

- Trip information – key data are mode of travel, purpose of trip, and activities

- Temporal information – each of the databases collects information on on a continuous basis thereby providing a monitoring capability through the use of longitudinal data

- Vehicle data – the key comprehensive item is vehicle type

- Incident/event details – key data include alcohol consumption, blood alcohol readings, and the prevalence of seat belt wearing

**Integration of Accident and Complementary Data**

A key area in which accident and complementary databases can be combined is in the estimation of accident risk. Accident or crash risk estimates are determined by dividing the number of crashes by the exposure, often defined as "the opportunity to have a crash". Exposure can be measured in numerous ways. Common measures include the distance travelled on the road, the number of trips of travel, the number of driver licence holders, the number of registered vehicles, fuel consumption or the number of people in the population (Diamantopoulou, Skalova, Dyte and Cameron, 1996).

Examples of recent work integrating complementary data with accident information, eg *Crashstats* for Accident Risk analysis include Observational Surveys, the VATS database and Geographic Information Systems analysis, each of which are outlined below.

Accident Risk Analysis using Observational Surveys

While the *Crashstats* data allows statements to be made relating to the "numbers" of casualty accidents affecting different road user groups, it does not give the on-road frequency (exposure) of particular attributes per kilometres travelled. Such attributes include different types of vehicles, drivers and passengers, within defined location areas and defined time periods. Exposure surveys enable an estimate of the exposure to accidents of different road user groups. Exposure surveys have been conducted in Melbourne in 1984,1985,1986 and 1988 and extended to country Victoria in 1994. The method used is that described by Drummond and Healy (1986). In all cases, exposure is defined as the distance travelled (in kilometres) over one week in "non-holiday" times for a defined network of arterial roads.

A simple equation for accident risk for a particular road user group is:

$$R = C/D$$

Where C = accident report data, ie *Crashstats*
And D = distance travelled, ie exposure estimate

Key road user groups may include for example, young drivers at night, young adult females and elderly drivers. By identifying high-risk groups on the road, targeted countermeasures can be developed and implemented. Accident risk information is essential for accurately targeting groups of people for road safety campaigns or legislation.

The most recent survey in 1994 expanded the scope of the data collection beyond Melbourne Metropolitan arterial roads, with measures of exposure also being surveyed in major provincial towns and on selected rural highways and freeways. Efforts were made to obtain exposure information for motorcyclists and their passengers, as well as for occupants of cars and car derivatives using observational surveys (Arup Transportation Planning, 1995). No data was collected about actual trips, however, a number of factors were used to estimate distance travelled.

The dataset collected above was analysed by Diamantopoulou et al (1996) together with a file of accident report data originally collected by the Victoria Police during 1990-94, to obtain measures of accident risk for different groups.

A review of the 1994 Road Exposure Survey (Transport Research Centre, 2000a) has indicated that practical operational issues associated with carrying out large numbers of on-road surveys may be avoided through the use of the VATS database.

## Accident Risk Analysis using VATS

The use of VATS to obtain exposure data has been previously undertaken by Procko and Richardson (1997). Unlike the observational surveys described previously, VATS data is collected for individuals over a 24 hour period on a year round basis for all travel in all of Melbourne. Although Procko and Richardson focused on only two demographic variables - namely age and gender - the richness of the VATS data holds promise for more detailed and revealing analyses. For example, the VATS data contains information about trips made as a passenger, which may be compared with the fatality and injury numbers for passengers to obtain crash rates for passengers (who tend to be young or old and female). The VATS data also contains information about the type of vehicle used on each trip (in terms of make, model, age and engine size) which can be compared with the vehicle types involved in crashes. In addition, the trips are described in terms of time of day, day of week and week of year which allows analysis of seasonal variations in crash rates. By means of a GIS representation of each trip, the trips are also described in terms of the types of roads used and the geographic location of the trip, which will allow estimation of crash rates for different road types and different regions. The multitude of possible explanatory variables makes the combination of crash data and VATS data a potentially powerful means of developing greater understanding of the factors underlying the occurrence of road crashes. This, in turn, will lead to the development of better strategies to reduce the occurrence and consequences of road crashes.

The use of VATS to obtain exposure data for cyclists has been described by Elliot (1998). This has allowed a ranking of LGA's (Local Government Areas) for bicycle safety within Melbourne. Nevertheless, as Wigan and Smith (1997) have noted, the small sample size of continuous travel surveys (such as VATS) may place limits on the usefulness of this information for monitoring the usage of minority modes (such as cycling and walking). Now with six years of consistent VATS data available however, this limitation may be partly overcome by pooling data across two or more years.

Geographic Information Systems analysis

A GIS approach using VATS data has been described by Kam (1999). This study is a further illustration of the value of combining accident statistics with complementary data. The use of Geographic Information Systems holds considerable promise for specific preventative measures to be undertaken at a local level to reduce the road toll.

Specifically, the study undertaken by Kam proposes a Geographic Information System (GIS)-based approach to analyse demographic, spatial and temporal variations in crash rates. The concept on which the approach is based stems from the premise that accident occurrence has to be understood as the interaction of three sets of environmental factors:

- the internal car environment (the vehicle occupants)
- the external physical environment (the geographical location)
- the dynamic traffic environment (which will vary at different times of the day).

As each trip is unique with respect to the three sets of factors, the adoption of this concept suggests that crash risk has to be examined from the perspective of the individual trips. It thus differs from the conventional approach of using an aggregated quotient obtained by dividing the total crash involvement of a particular population group by the combined travel distance of that group.

The implementation of the concept invokes the use of GIS to link data from two different databases – accident reports and travel and activity survey – via their spatial attributes. The GIS algorithm on which the program is based centres on the demarcation of a travel corridor predicated on the travel route of a given trip. Crash records falling within the defined travel corridor and matching the characteristics of the trip and the person making it will be regarded as potential accident hazards to which the person making the trip will be exposed. To demonstrate the use of the proposed disaggregated approach, the crash rates of different population groups residing within the Melbourne Statistical Division was computed separately for weekday and weekend, and for day and night hours according to their age-sex characteristics, the day of travel, and the time of travel. The trip information used for the purpose comes from the Victorian Activity and Travel Survey (VATS) conducted by the Transport Research Centre at RMIT University, while the accident records are sourced from Crashstats, the accident database produced by VicRoads.

The results obtained were compared with those generated using the conventional approach. A plot of crash rate against age group contrasts sharply with that derived using the conventional aggregate approach, which shows the population at either end of the age spectrum, those below 21 and those above 70, having a higher crash rate than those in the middle. The variation of crash rate with respect to age as revealed by the GIS approach suggests that persons in their 20s are among the most vulnerable group in terms of crash risk. The new licensees or those under 21 and senior citizens above the age of 70 are not the most accident-prone, though their crash rates are also among the highest.

Because of the disparate results obtained by using the two approaches, this study raises some noteworthy features:

- That each trip is unique in terms of its exposure to crash risk
- That crash risk may be measured independently of the linearity assumption implicit in the conventional aggregated approach
- A dataset may be computed for each trip

Recent advances in GIS technology and travel survey techniques have greatly facilitated the linking of apparently incompatible databases through their spatial attributes. The proposed exposure concept of using individual trips as the unit of road crash analysis is seen as providing a useful starting point from which other more refined GIS-based methods may evolve.

Applicability to Australasia and overseas

Table 3 in Appendix C summarises recent Activity and Travel Surveys which have been conducted in Australasia. Many of these have features in common with VATS (Victorian Activity and Travel Survey), and have been reviewed by Morris, Kam, Sindt and Lau (1999). The New Zealand Travel Survey which was commissioned by the New Zealand Land Transport Safety Authority (1998) is the only household activity and travel survey in Australasia to provide information on alcohol consumption. Only VATS and the Sydney HTS (Household Travel Survey) are ongoing surveys which provide comprehensive information for time series analysis of travel for every day of the year.

Moreover, time series analyses of accident rates can be useful in assessing the impact of key road initiatives. An example of the value of this approach is shown by some overseas work undertaken by Noland (2000) who undertook a review of US databases on fatalities and injuries, and analysed these to examine the effects of various highway improvements. Results strongly refuted the hypothesis that engineering design improvements have been beneficial for reducing total fatalities and injuries. While controlling for other effects, it was found that demographic changes in age cohorts, increased seatbelt use, and increases in medical technology have accounted for a large share of overall reductions in fatalities. The results have major implications for the cost benefit analysis of highway projects, and for Federal planning regulations that require safety to be considered as a planning factor. Such findings suggest that counter-intuitive policies should not be disregarded when developing Road Safety initiatives.

## Gaps and Deficiencies

The reporting procedures of police at the scene of an accident may be a source of inaccurate data. Andreassen and Cusack (1996) have undertaken a pilot study of an Electronic Accident Report (EAR) on a hand-held computer as a replacement for the current paper report form to assess its likely effects on the accident reporting / recording process.

The introduction of an EAR on a hand-held computer utilising pen technology in the feasibility study found an acceptance by the police officers using it. The EAR used in the trial, while having a potential for much enhancement, was found easy to use and logical in presentation, produced a superior accident diagram to that on the existing paper report form, took no longer to fill in, and converted hand written entries to text, improving on the legibility of the hand writing.

Andreassen and Cusack have also found in their pilot study that the current definitions used in relation to injury and vehicles pertaining to the reporting of accidents in the ACT should be altered to align with national standards. All road vehicles and all levels of injury should be included. By national standards the proportion of casualty accidents in the ACT could be as high as 20 per cent.

To date, there has been no follow-up in implementing the recommendations of the above study (Anderson, 2001).

If a national database is to be developed, a key problem is the lack of consistency of definitions because of differences between the States in reporting procedures. One example, described by Lydon and Mabbott (2001), is concern about the recording, definitions and accuracy of serious injury data. Issues include the consistency of definitions used in different jurisdictions, the procedures used to apply these definitions and the accuracy of injury data that can be obtained from standard crash reporting methods.

Data on pedestrian road fatalities in Victoria shows a constant level of pedestrian deaths, which represents 20% of all fatalities. Trends such as the return to inner urban living, lifestyle changes which emphasise the health advantages of walking, the effects of the 0.05 campaign and the ageing population may have significantly increased pedestrian risk exposure. However, off-road pedestrian accidents, such as in driveways or on other private land are not included, and traffic counts and many surveys do not measure the level of pedestrian activity (Road Safety Committee, 1999). Even surveys such as VATS which explicitly attempt to measure all modes of travel, sometimes fall short due to limitations of sample size and reduced accuracy of reporting of short trips.

## Conclusion

This project into the use of databases to inform road safety initiatives in Melbourne has shown that there are many databases which may be usefully related to road safety. The databases may be categorised into three types of information - accident information, safety measures and complementary databases. These sources may be combined to create a rich array of information and perspectives to inform policy initiatives to provide a safer environment for Melburnians.

All of the databases provide an ongoing collection of information. The value of high quality consistent and ongoing information has previously been pointed out by Wigan and Smith (1997, page 11) who aptly point out that "to monitor, one must first measure".

Melbourne has proved to be an excellent case study since it is one of only two cities in Australasia to have an ongoing household activity and travel database. The richness of an ongoing survey allows a methodology to estimate the exposure to accident risk of different road user groups. By identifying those most at risk, it helps to shape appropriate marketing and education campaigns, and target those groups for whom particular countermeasures may be appropriate.

The potential for integrating or cross-linking databases is dependent upon the level of consistency and compatibility of definition of common elements, and currently there are some inconsistencies in definitions of variables.

There is still much work to be done to achieve a national road safety meta-database which may be used in policy formulation. One future strategy may be to introduce ongoing household activity and travel surveys in all capital cities in Australasia. For these to be comparable and useful for road safety issues, it would be necessary to ensure that the format of those questions relating to road safety are consistent.

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# Appendix A

## Table 2 Databases and data sources relevant to road safety in Melbourne

| Variables | ATSB | | | BoM | Crashstats | INS | IRDB | LPIS | NCIS | NVS | Observational Surveys | | TAC | VATS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MFD | SID | FF | | | | | | | | 1984,5,6,8 | 1994 | | |
| **Personal / household** | | | | | | | | | | | | | | |
| Name | | | | | | | | X | X | | | | X | |
| Age | X | X | X | | X | X | X | | X | | X | X | | |
| Date of Birth | | | | | | | | | X | | | | X | |
| Year of birth | | | | | | | | | | | | | | X |
| Gender | X | X | X | | X | X | X | X | X | X | X | X | X | X |
| Height | | | X | | | | | | | | | | | |
| Weight | | | X | | | | | | | | | | | |
| Disabilities | | | | | | | | | | X | | | | |
| Pre-existing injuries | | | | | | | | | | | | | X | |
| Prior conditions | | | | | | | | | | | | | X | |
| Country of birth | | | | | | | | | X | | | | | |
| Years in Australia | | | | | | | | | X | | | | | |
| Ethnicity | | | X | | | | | | | | | | | |
| Indigenous identification | | | | | | | | | X | | | | | |
| Interpreter needed | | | | | | | | | | | | | X | |
| Language spoken | | | | | | | | | | | | | | X |
| Current roles | | | | | | | | | | | | | | X |
| Education attained | | | | | | | X | | | | | | | |
| Employment status | | | X | | | | | | X | X | | | X | X |
| Hours worked | | | | | | | | | | | | | | X |
| Regular overtime | | | | | | | | | | | | | X | |
| Details of working week | | | | | | | | | | | | | X | |
| Income | | | | | | | X | | | X | | | | X |
| Social security payment | | | | | | | | | | | | | X | |

| Variables | ATSB | | | BoM | Crashstats | INS | IRDB | LPIS | NCIS | NVS | Observational Surveys | | TAC | VATS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MFD | SID | FF | | | | | | | | 1984,5,6,8 | 1994 | | |
| Industry of employer | | | | | | | X | | X | | | | | X |
| Occupation | | | | | | X | X | X | X | | | | | X |
| Family structure | | | | | | | X | | | X | | | | X |
| Household visitors | | | | | | | | | | | | | | X |
| Marital / relationship status | | | | | | | | | X | | | | | |
| Household address | | | | | | X | X | X | X | X | | | X | X |
| Postcode of residence | | | X | | | | | | | | | | X | |
| Dwelling type | | | | | | | X | | | | | | | X |
| Home ownership | | | | | | | X | | | | | | | X |
| Licence type | | X | X | | | | | X | | | X | X | | X |
| Years driving experience | | | X | | | | | | | | X | X | X | X |
| Vehicle ownership | | | | | | | | | | | X | | | X |
| Number of bicycles | | | | | | | | | | | | | | X |
| Number of motorcycles | | | | | | | | | | | | | | X |
| Number of vehicles | | | | | | | X | | | | | | | X |
| Internet access | | | | | | | | | | | | | | X |
| Internet use - purpose | | | | | | | | | | | | | | X |
| Internet use - amount | | | | | | | | | | | | | | X |
| **Physical External Environment** | | | | | | | | | | | | | | |
| Air pressure | | | | X | | | | | | | | | | |
| Atmospheric Conditions | | X | X | | X | | | | | | | | | |
| Cloud cover | | | | X | | | | | | | | | | |
| Humidity | | | | X | | | | | | | | | | |
| Light conditions | | | | | X | | | | | | | | | |
| Rainfall | | | | X | | | | | | | | X | | |
| Temperature | | | | X | | | | | | | | | | |

| Variables | ATSB | | | BoM | Crashstats | INS | IRDB | LPIS | NCIS | NVS | Observational Surveys | | TAC | VATS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MFD | SID | FF | | | | | | | | 1984,5,6,8 | 1994 | | |
| Wind | | | | X | | | | | | | | | | |
| Horizontal road alignment | | X | X | | | | | | | | | | | |
| Natural/street lighting | | X | | | | | | | | | | X | | |
| Number of lanes | | | X | | | | | | | | | | | |
| Road surface conditions | | X | X | | X | X | | | | | | | | |
| Road type | | | X | | | | | | | | | | | |
| Sealed/unsealed road | | X | | | | | | | | | | | | |
| Speed zone | X | X | X | | X | | | | | | | X | X | |
| Traffic control | | | X | | X | | | | | | | | | |
| Vertical road alignment | | | X | | | | | | | | | | | |
| Accident Address | | | X | | X | | | | | | | | | |
| Distance from home | | | X | | X | | | | | | | | | X |
| Intercept location | | | | | | | | X | | | | | | |
| Nearest intersection | | X | X | | | | | | | | | | | |
| LGA | | X | | | | | | | | | | | | X |
| State | X | X | X | | | | | | | | | | | X |
| Vicinity of educational institution | | | X | | | | | | | | | | | X |
| **Trip information** | | | | | | | | | | | | | | |
| Destination / Origin | | | | | | | | | | X | | | | X |
| Activities | | | | | | | | | X | X | | | | X |
| Purpose of trip | | | X | | | | | | | X | | | X | X |
| Journey to / from work | | | | | | | X | | | | | | X | X |
| Motor vehicle race | | | | | | | | | | | | | X | |
| Mode of travel | X | X | | | X | | | | X | X | | | X | X |
| Expenditure - travel | | | | | | | | | | X | | | | |
| Expenditure - other | | | | | | | | | | | | | | X |
| Number of people | | | | | | | | | | X | | | | X |

| Variables | ATSB | | | BoM | Crashstats | INS | IRDB | LPIS | NCIS | NVS | Observational Surveys | | TAC | VATS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MFD | SID | FF | | | | | | | | 1984,5,6,8 | 1994 | | |
| **Temporal Information** | | | | | | | | | | | | | | |
| Time of event | X | | X | X | X | | | | | | | | | X |
| Date of accident/travel | X | | X | | X | X | | | | X | | | X | X |
| Day of week | X | X | | | X | | | | | | | | | X |
| Month | X | X | | | | | | | | | | | | X |
| Year | X | X | | | | | | | | | | | | X |
| Intercept time | | | | | | | | X | | | X | X | | |
| Intercept date | | | | | | | | X | | | X | X | | |
| Time of death | | | X | | | | | | | | | | | |
| Date of death | | | X | | | | | | X | | | | | |
| **Vehicle data** | | | | | | | | | | | | | | |
| Engine capacity | | | | | | | X | | | | | | | |
| e-tag registration | | | | | | | | | | | | | | X |
| Fuel type | | | | | | | X | | | | | | | X |
| Licence plate displayed | | | | | | | | | | | | X | | |
| Number of cylinders | | | | | | | X | | | | | | | |
| Registration number | | | | | | | | | | | X | X | | |
| State of registration | | | X | | | | | | | | | | | |
| Vehicle colour | | | X | | | | X | | | | | | | |
| Vehicle description – comprehensive | | | | | | X | | | | | | | X | |
| Vehicle make | | | | | | | X | | | | X | X | | X |
| Vehicle model | | | | | | | X | | | | X | X | | X |
| Vehicle type | | X | X | | X | | X | X | | | X | X | | X |
| Year of manufacture | | | X | | | | | | | | | X | | |
| Bull bar | | | X | | | | | | | | | X | | |

| Variables | ATSB | | | BoM | Crashstats | INS | IRDB | LPIS | NCIS | NVS | Observational Surveys | | TAC | VATS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MFD | SID | FF | | | | | | | | 1984,5,6,8 | 1994 | | |
| Motorcycle conspicuous clothing | | | | | | | | | | | | X | | |
| Motorcycle protective clothing | | | | | | | | | | | | X | | |
| Motorcycle headlamp | | | | | | | | | | | | X | | |
| Motorcycle helmet | | | | | | | | | | | | X | | |
| **Incident / event details** | | | | | | | | | | | | | | |
| Accident / event classification | | X | X | | X | X | | | | | | | | |
| Accident group | | | | | X | | | | | | | | | |
| Accident severity | | X | X | | X | | | | | | | | | |
| Injury type | | X | X | | X | | | | | | | | | |
| Object hit | | | | | X | | | | | | | | X | |
| Position in vehicle | | | | | X | | | | | | | | X | |
| Thrown out of vehicle | | | | | | | | | | | | | X | |
| Type of crash | | X | | | | | | | | | | | | |
| Crime/offence involved | | | X | | | | | X | | | | | | |
| Alcohol consumption | | | | | | | | X | | | | | X | |
| Blood alcohol reading | | X | X | | | | | | X | | | | X | |
| Breath test details | | | | | | | | X | | | | | X | |
| Drug testing | | | X | | | | | | | | | | X | |
| Licensed premises details | | | | | | | | X | | | | | | |
| Ambulance time taken | | | X | | | | | | | | | | | |
| Cause of death | | | | | | | | | X | | | | | |
| Classification of death | | | | | | | | | X | | | | | |
| Air bag | | | X | | | | | | | | | | | |
| Helmet used | | | X | | | | | | | | | | | |

| Variables | ATSB | | | BoM | Crashstats | INS | IRDB | LPIS | NCIS | NVS | Observational Surveys | | TAC | VATS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MFD | SID | FF | | | | | | | | 1984,5,6,8 | 1994 | | |
| Seat belt type | | | | | | | | | | | | X | | |
| Seat belt worn | | X | X | | X | | | | | | | X | X | |
| Nursed occupants | | | | | | | | | | | | X | | |
| Number of family members | | | | | | | | | | | | | X | |
| Number of fatalities | | X | | | | | | | | | | | | |
| Number of occupants | | X | | | | | | | | | X | X | | |
| Number of pedestrians | | X | | | | | | | | | | | | |
| Number of persons involved | | X | | | | | | | | | | | | |
| Number of serious injuries | | X | | | | | | | | | | | | |
| Number of vehicles involved | X | X | | | | | | | | | | | X | |
| Number of articulated trucks | X | X | | | | | | | | | | | | |
| Number of buses | X | X | | | | | | | | | | | | |
| Number of rigid trucks | | X | | | | | | | | | | | | |
| Passenger age | | | | | | | | | | | | X | | |
| Passenger gender | | | | | | | | | | | | X | | X |
| Police attendance/report | | | X | | X | | | X | X | | | | X | |
| **Database Access** | | | | | | | | | | | | | | |
| Commercial/fee | | | | | | | X | | | X | | | | X |
| Not available | | | | | | | | | | | | | | |
| Open to public | | | | X | X | | | | | | | | | |
| Permission required | X | X | X | | | X | | X | X | | X | X | X | |

## Appendix B

### Accident information

All accident databases stem from the Victoria Police who attend collisions (Rao, 2001). There are two major databases:

- TAIS (Traffic Accident Information System) which stems from the Police 510 Report, and is electronically disseminated to VicRoads and the TAC (Transport Accident Commission)
- CMIS (Collision Management Information System) which is derived from TAIS, and is disseminated within the force.

ATSB – Australian Transport Safety Bureau databases

The Australian Transport Safety Bureau (ATSB) is responsible for the collection, analysis and reporting of national road trauma statistics. The data are obtained from:

Department of Transport, Tasmania
Department of Urban Services, ACT
NT Police Department
Queensland Transport
Roads and Traffic Authority, NSW
VicRoads
WA Police Service

Trends in road trauma, including the identification of vehicle standard matters and high risk road user groups, are analysed and reported in monthly, quarterly and annual statistical reports. Road safety policy is developed by ATSB in response to these emerging trends and this analysis is the basis for further research and public education activities.

ATSB currently maintains three separate databases:

- Monthly Fatality Database (MFD)
- Serious Injury Database (SID)
- ATSB Fatality File (FF)

The Monthly Fatality Database is based on information provided by State and Territory authorities within a few working days of the end of each month. It contains a limited number of variables relating to people killed on the road in that month. The primary purpose of the database is to provide a national monthly road toll which is reported in *Road Fatalities Australia Monthly Bulletin*.

It is also used to provide an annual statistical summary. For each crash, it records the State/Territory, date, time of day, day of week, speed limit at crash site and number of vehicles involved. For each person killed, information is recorded pertaining to sex, age and road user classification. Also recorded is whether or not a bus or articulated truck was involved. Use is also made of Australian Bureau of Statistics data on population, vehicle registrations and motor vehicle usage for deriving road fatality rates.

The Serious Injury Database is also based on information provided by State and Territory authorities relating to people killed or seriously injured in road crashes. The information is provided quarterly approximately six months after the close of the quarter. This database is more detailed than the Monthly Fatality Database and is used to analyse contributing factors to fatal and serious injury crashes. It is also used to monitor trends in serious injury crashes which are reported in *Road Injury Australia Quarterly Bulletin* and an annual statistical summary.

The annual summary of Australian serious road crashes is defined as those crashes resulting in hospital admission, but not fatality, of one or more persons. The data derive primarily from a serious crash database compiled using crash unit record data. In addition, road crash hospitalisation rates are presented using Australian Bureau of Statistics data on population and motor vehicle usage.

The ATSB Fatality File is compiled by the Australian Transport Safety Bureau from copies of reports into fatal crashes provided by coroners. This database is highly detailed and contains, for example, coding of injury type and severity to regions of the body based on autopsy findings. It is typically available about two years after the end of a collection year and is used for in-depth analysis of factors contributing to road crashes.

ATSB has an agreement with the States and Territories whereby they provide information on serious and fatal crashes using an agreed set of common codes. Data on fatal crashes are held from 1989 and for serious injury crashes from 1988. There are approximately 1,600 fatal road crashes and 17,000 serious injury road crashes annually.

In addition to collating coded data from States and Territories, ATSB also undertakes its own coding of fatal road crashes from coroners' investigations. This involves the collection of source documents, (much of which is graphic in content), coding and data management.

The ATSB databases collate information on a State and Territory basis, and provide information at the Local Government Area (LGA) level for serious injuries, and the accident address for fatal injuries. Melbourne data is divided into the 31 constituent Local Government Areas.

*CrashStats* – Road Crash Statistics: Victoria

In Victoria, procedures are in place for the comprehensive collection of crashes and casualty accident data. Relevant accident report data is collected by Victoria Police, either on-site, or afterwards if they do not attend the scene. The VicRoads Accident Database (*Crashstats*) has been developed using data from these accident report forms. Criteria by which to search for accidents range from accident locations to the type of vehicles involved and the characteristics of the people involved.

The *CrashStats CD* contains statistics of road traffic accidents which were reported to the police and which met the following conditions:

- That the accident occurred from the calendar year 1987 onwards
- That the accident resulted in:
  the death of any person within thirty days of the accident
  personal injury as identified by the police officers completing the accident report (for 1991 onwards only)
- That the accident occurred on any road, street, thoroughfare, footpath, railway level crossing, or any place open to the public
- That the accident involved one or more road vehicles which, at the time of the accident were in motion, including motor cars, station wagons, utilities, panel vans, motor cycles, trucks, buses, trams and railway vehicles, pedal cyclists and ridden animals

In total, there are 58 variables in the *CrashStats* database. Of these, 20 key variables which are related to road safety are listed on the *Crashstats* CD-rom. These are listed below:

- Age
- Atmospheric conditions – clear, raining, snowing, fog, smoke, dust, strong winds, not known
- Date of accident
- Day of week
- DCA – Definitions for Classifying Accidents – according to VicRoads diagrammatic chart
- DCA Group of the Accident – this is a broader categorisation of the above
- Distance from home – this value represents the distance between the road user's home post code and post code where the accident occurred
- Injury type to person – fatal injury (killed or died within 30 days), serious injury (sent to hospital, possibly admitted), other injury (typically requires medical treatment) or non injury
- Light conditions – day, dusk/dawn, dark street lights on, dark street lights off, dark no street lights, dark street lights unknown
- Object hit – pole, tree, fence/wall, embankment, guide post (including km post), traffic sign (no parking/no standing), guard rail, fire hydrant, building, other fixed (railway, furniture, culvert, telephone box, etc), not known, traffic signal (traffic

lights), bridge (off path), barrier (road closure), traffic island, bridge (on path), roadworks (dirt, sign, barrier, excavation), safety zone (eg tram safety zone), kerb (if protruding), tame animal (cats and dogs etc), cattle (includes steers, bulls, cows), sheep, horse (not ridden), other tame animals, kangaroo (includes wallabies), wombat, wild animal (includes birds), unknown animal

- Position in vehicle – centre-front, centre-rear, driver or rider, left-front, left-rear, not applicable, not known, other-rear, pillion passenger, motor-cycle side car passenger, right-rear
- Road surface conditions – dry, wet, muddy, snowy, icy, unknown
- Road user (mode of transport) – pedestrian, driver (of cars, trucks etc), passenger (car, truck, bicycle etc), motor cyclist, pillion passenger, bicyclist, other driver (horse, tram, train), other passenger, not known
- Seat belt wearing – seatbelt worn, seatbelt not worn, child restraint worn, child restraint not worn, seatbelt/restraint not fitted, crash helmet worn, crash helmet not worn, not appropriate, not known
- Severity – Derived from values for each person in accident – fatal accident, serious injury accident, other injury accident, non injury accident
- Gender – male, female, unknown
- Speed zone (limit) – 40, 50, 60, 70, 75, 80, 90, 100, 110 km/hr, other speed limit, camping grounds/off road, not known
- Time of accident – common practice is to "round off the time" to the nearest 5 minutes or even nearest hour
- Traffic control – no control, stop-go lights, flashing lights, out of order, ped lights, ped crossing, RX gates/booms, RX bells/lights, RX no control, roundabout, stop sign, giveway sign, school-flags, school-no flags, police, other, unknown
- Type of vehicle – car, station wagon, taxi, utility, panel van, semi-trailer, truck (excluding semi), bus/coach, mini bus (9-13) seats, motor cycle, moped, motor scooter, bicycle, horse (ridden or drawn) tram, train, other vehicle, not applicable, not known

In the last three months, VicRoads have developed RCIS (Road Crash Information System) which has many times the functionality of *Crashstats* (Chapman, 2001). It is a map-based query and reporting system which is currently available for internal use only.

Insurance companies

Information on accidents and traffic incidents is collected by insurance companies to provide an estimate of risk and determine insurance premiums for different categories of driver. Companies such as AAMI (Australian Associated Motor Insurers) and RACV (Royal Automobile Club of Victoria) collate data which is related to accidents as well as other losses such as theft. This data may be mined for information related to road safety. The insurance company for which the variables are listed in the table are not exhaustive. The database (INS) contains additional information pertaining to claim and incident details.

NCIS - National Coroners Information System

The Victorian Institute of Forensic Medicine is a body corporate with perpetual succession established by the Coroners Act 1985. The National Coroners Information System (NCIS) is based at the Coronial Services Centre, a purpose built facility which also houses the State Coroners Office. Its principal functions are to provide forensic pathology and related scientific services, clinical forensic medicine services, teaching and research.

For all road trauma fatalities, an autopsy is undertaken which includes blood testing for alcohol and drugs.

A database of Blood Alcohol Content is held by the NCIS, and the figures are provided on a contractual basis to TAC and VicRoads. Blood alcohol (ethanol) content readings are prepared as a flat file. For each person, the following variables are listed which are relevant to accidents:

- Age
- Date of Birth
- Gender
- Blood alcohol reading – measured in gm per 100ml of blood.

The legal blood alcohol limit is 0.05%. In 1999, of 252 fatally-injured drivers, 57 (i.e. 22.8%) had a blood alcohol reading > 0.05 and 8 (i.e. 3.2%) had a blood alcohol reading < 0.05.

NISU – National Injury Surveillance Unit

In the case of road injuries, hospital records are not always consistent with the police data recorded. One of the major reasons for this is the time lapse before hospital data is available. Data may not be available for over 18 months after the end of the relevant year, and this delay contrasts with the crash databases which use police data where considerable efforts are being made to improve their timeliness (Lydon and Mabbott, 2001).

The National Injury Surveillance Unit (NISU) is the collaborating unit of the Australian Institute of Health and Welfare (AIHW) in the subject area of injury. The mission of the AIHW is:

“To improve the health and well-being of Australians, by informing community discussion and decision making through national leadership in developing and providing health and welfare statistics and information”

NISU’s role is to fulfil the AIHW’s mission in the subject area of injury, by:

- Analysing and reporting on existing data
- Assessing needs and opportunities for new information sources and mechanisms, and for improvement of existing ones
- Developing new information sources and other relevant infrastructure
- Providing advice and other services to assist others who are engaged in injury control and related matters

The AIHW maintains a National Hospital Morbidity Database which is compiled from data supplied by the State and Territory authorities. It is a collection of electronic confidentialised summary records for admitted patients separated (by discharge or death) from public and private hospitals in Australia in the years 1993-94 to 1998-99. The total number of records for 1998-99 was 5.7 million.

The State of Victoria has the potential to participate in a national program which involves matching police records to hospital morbidity records. A test study undertaken by Rosman (1996) has given a matching rate of 90% when a phonetic code of the family name was used with age, sex, road user type and crash date. However, only about 50% of links were found if performed without using names or phonetic name codes.

Office of Births, Deaths and Marriages

When a hospital patient dies as a result of road trauma, this information is included on the death certificate. Details include surname, first name, date of birth, cause of death, next of kin (usually provided by police), complexion, height, weight, eye colour, hair colour, various body measurements and whether or not the person is an organ donor. A copy of the death certificate is kept at the Hospital Patient Records section for a period of seven years, after which it is destroyed. Death certificates with these details may only be obtained from the Office of Births, Deaths and Marriages by the next of kin, and the electronic database at that Office is confidential, with no linkage to other databases (Mattingsbrooke, 2000).

TAC – Transport Accident Commission data

The Transport Accident Commission (TAC) is a statutory corporation established under the Transport Accident Act 1986 to manage Victoria's transport accident personal injury scheme. One of its primary objectives is to reduce the incidence and cost of transport accidents. The TAC belongs to the people of Victoria as a state owned enterprise of the Victorian Government. It operates as a commercial insurer and is funded by both premiums and investment income generated on reserves.

The scheme provides medical and income benefits on a no-fault basis and allows access to common law in cases of serious injury. This responsibility is balanced with its financial accountability to the Victorian people. Benefits to accident victims are provided at a level appropriate to their degree of trauma and the Victorian community's ability to pay. Accident prevention has become a key element of the TAC's commercial strategy of running an effective and efficient insurance organisation. By targetting expenditure on accident prevention, the aim is to save lives, reduce injury – and also dollars.

The TAC maintains a database based on claim form details. A medical certificate detailing injuries resulting from a transport accident is required as part of the TAC form submission. The claim form lists 63 questions which are relevant to accident insurance. Of these, key variables related to road safety are listed below:

- Gender
- Age
- Other family members involved in accident
- Language other than English spoken requiring an interpreter
- Social Security payments received
- Police Report details
- Date of accident
- Mode of transport
- Position in vehicle
- Thrown out of vehicle
- Collision with fixed object
- Speed limit at accident location
- Vehicle details
- Length of time licence held
- Seatbelt
- Alcohol consumption in two hours before accident
- Breath or blood test
- Drug consumption (including medication)
- Accident on the way to or from work
- Accident while performing daily work
- Participation in, or preparation for motor vehicle race
- Any other vehicle involved
- Prior conditions or problems
- Pre-existing injury details
- Employment status
- Details of working week
- Regular overtime

**Safety measures**

LPIS – Licensed Premises Identification System

The Victorian Transport Accident Commission in conjunction with the Traffic Alcohol Section (TAS) of the Victoria Police has developed the Licensed Premises Identification System (LPIS).

LPIS is a data collection, analysis and reporting system which takes routine drink-driving enforcement data and converts it into automatic and ad-hoc reports (Thiele and van Niel, 1999). These reports can be used by police to plan targeted drink-driving detection and prevention campaigns in high risk locations. They are also useful in formulating strategies on the part of Victoria Police and the Liquor Licensing Commission for dealing with licensed premises that are identified as being a major source of high risk drivers.

This may be done by:

- Police targeting the immediate environs of licensed "problem" premises either covertly or overtly and/or
- Taking measures to ensure licensees of "problem" premises are made aware of their patrons' behaviour both at the premises and when they leave. This would ensure that licensees are made fully aware of their responsibilities to their patrons and to motivate licensees to change their business practices, where appropriate.

Key types of information input include:

- Intercept Location Data which relates to where the offender had been intercepted by the Police, including the date and time of interception, the street name, the suburb and postcode of interception, map references and the police sub-district.

- Person Details which provides details of the person who is breath-tested, including the person's full name and address, date of birth, gender and occupation. Driver licence and vehicle details are also collected and entered. The number of prior convictions for drink-drive offences is recorded. The system automatically increments this field if a driver is subsequently breath tested at a later date.

- Informant details which include name, rank and number of the member of the police force are among variables entered into the LPIS.

- Evidential Breath Test Details which include the location of the evidential breath test, police district, date and time of the test and the distance travelled since the person's last drink. The BAC result and details of the police member operating the breath analysis instrument are also recorded.

- Alcohol Consumption and Licensed Premises Details which records up to three types of drinks per person. The system also records the type of venue at which the offender had last been drinking and whether the premises were licensed or not. If the last alcohol consumed, prior to interception, was at a licensed premises then the name and address of that venue is entered into the system. Licensed premises data is cross-checked against the register of licensed premises supplied by the Liquor Licensing Commission to ensure data integrity and accuracy.

- Additional Information about the type of offence committed, if applicable, is also entered into the system.

Initial findings have proven to be extremely informative. It has been shown that more than 85% of drivers exceeding the prescribed concentration of alcohol were male, of which 40% were aged between 26 and 39. A further 10% were aged under 21. Tradesmen (20%), labourers (15%) and the unemployed (15%) represent the most frequent occupation classes of drink-drivers.

Hotels were the most common venue for drinkers (32%) followed by home (20%) and friends' houses (15%). Two in every three drink-drivers had consumed full strength beer with light consumed by just 6%. The vast majority of drink-drivers (74%) recorded levels between 0.051 g/100ml and 0.15 g/100ml.

The system has the capacity to examine the characteristics of repeat offenders by developing an individual profile of recidivist drivers, their drinking habits and the number of times they re-offend. Initial data has found one in every three drivers has recorded a prior drink-driving conviction. They tend to be those aged between 26-39 years. This result supports previous research into recidivist drink-driving undertaken by Moloney and Palaia (1997).

In terms of distance travelled from the last point of drinking to the location of interception, it was found that while most offenders had driven only a relatively short distance before being tested, 17% had driven in excess of 10 kilometres

Observational surveys

The Melbourne On Road Exposure Survey originally conducted by the Road Traffic Authority has provided useful data identifying a measure of exposure of cars and car derivatives and their occupants. The first exposure survey in the Metropolitan Area was conducted in 1984; subsequent surveys were conducted to update the results of the 1984 survey in 1985,1986 and 1988. In all cases, exposure was measured as the distance travelled (in kilometres) over one week in "non-holiday" times for a defined network of arterial roads.

VicRoads, as part of its commitment to monitoring road safety initiatives, commissioned Arup Transportation Planning (ATP) in association with Drummond Research Pty Ltd to undertake the design, implementation and reporting of The 1994 Road Exposure Survey.

The 1994 Road Exposure Survey is a roadside survey of trips in progress. The surveys were conducted during July and August, in –holiday periods, on arterial roads in the Melbourne metropolitan area and in provincial towns. Information that was collected included age and sex of driver and passengers, licensing information for the driver, information about the vehicle and details of seat belt usage.

## Complementary databases

BoM - Bureau of Meteorology database

Meteorological data and measurements are collected on an automatic continuous basis from ten observation sites around Melbourne. The standard meteorological data included on the real-time database are temperature, humidity, wind, cloud cover, air pressure and rainfall.

CityLink e-Tag information

Electronic tolling collects information about vehicle movements from point to point on the Melbourne toll road known as CityLink, which is owned by Transurban. An electronic tag (or e-tag) is read at points along the road in order to calculate the toll and record transactions onto a customer's account. A digital image is taken of the number plate, but the image is not recorded if the e-tag is read successfully. For users without an e-tag, the image of the numberplate is used, the image is temporarily stored so it can be matched with the number plate information that is provided when the Day Pass is bought.

VicRoads plans to use CityLink e-Tags as the basis of a system for monitoring Melbourne's traffic conditions. This system will merely record the time taken for a tag to move from one location to another, after which the data will be discarded. VicRoads will not require details about the e-Tag owner or the vehicle, and will not have access to this via Transurban's records (Ogden, 1999).

IRDB2000 - Integrated Regional Data Base (includes Cdata and Transtats)

IRDB2000 is an integrated regional database which was released in March, 2000. It is a CD-ROM product which provides the ability to access and analyse regional economic and social data from a wide range of ABS and non-ABS collections. It includes information from the Australian Bureau of Agriculture and Resource Economics, Australian Electoral Commission, Australian Taxation Office, Department of Employment, Workplace Relations and Small Business, Department of Health and Aged Care, Department of Family and Community Services, Environmental Resource Information Network, the Productivity Commission and Department of the Environment and Heritage.

The broad range of data available includes agriculture, building, business register, demography, tourism, retail, population census and transport information. Unlike previous other years, ie 1996, 1997, 1998, the platform has been changed to GSP (Geographical Statistical Platform). This was developed by ABS in conjunction with ESRI ( a company which deals with GIS, and develops software to user requirements).

The GSP allows the intuitive finding and retrieval of information. Geographic areas, data items and time points may be selected to build a query. Data may be viewed as tables, maps, graphs and reports. For those cases where data was collected on different geographic boundaries or on boundaries which have changed over time, the IRDB has built in concordances between some of the more commonly used boundary sets, and has an estimation feature to deal with changes in boundaries over time.

While IRDB covers all regions of Australia, it is also available at the State level to obtain data specific to Melbourne.

The Census of Population and Housing (Cdata) is the largest statistical collection undertaken by the Australian Bureau of Statistics (ABS). Its objective is to measure the number and key characteristics of people in Australia on Census night. This provides a reliable basis to estimate the population of each State, Territory and local government area primarily for electoral purposes and the distribution of government funds. The census also provides the characteristics of the Australian population and its housing to support the planning, administration and policy development activities of governments, business and other users.

In every Census since 1976, the mode of travel to work, or Journey-To-Work information has been gathered. This includes train, bus, tram, taxi, car, truck, motorcycle, bicycle and walking.

Transtats on GSP is currently available as 1998 data and will soon be released with the data for 1999. It is an electronic data resource which enables information on motor vehicles to be quickly and easily obtained. Information from the 1998 Motor Vehicle Census is combined with other ABS data collections, including New Motor Vehicle Registrations (NMVR).

The Transtats on GSP CD-ROM allows a focus on such aspects as vehicle type, make, model, year of manufacture, engine capacity, number of cylinders, and fuel types.

The Motor Vehicle Census Unit Record File (MVCURF) – “Transport Flat File” is the parent to Transtats, ie Transtats is the front end of this huge database. The data has been obtained from the Road Traffic Authority and is available for 1999. It contains 12 million records and is best used in conjunction with Access. The data from MVCURF may be mapped using MapInfo.

National Visitor Survey (NVS) / International Visitor Survey (IVS)

The National Visitor Survey is conducted by BTR (Bureau of Tourism Research). It is the major source of information on the characteristics and travel patterns of domestic tourists. It measures travel for all reasons, including holiday and leisure travel, business travel and travel to visit friends and/or relatives.

During 1999, interviews were conducted with 81,703 Australian residents aged 15 years and over. Interviews were undertaken continuously throughout the year, using computer assisted telephone interviewing. The NVS is an origin-based survey. Respondents were interviewed in their homes and details were collected about their recent travel. Details were obtained of all travel in Australia – travel involving nights away from home, as well as same day travel – and travel by Australians overseas.

The NVS is a replacement for the DTM (Domestic Tourism Monitor) which had been conducted since the late 1970's.

The NVS uses computer assisted telephone interviews (CATI) rather than the face-to-face methodology of the DTM. It uses two-stage simple random sampling to select the survey respondent, firstly selecting households based on phone numbers, then selecting a person within the household. Due to this random selection of households and individuals, the NVS sampling methodology is more efficient than that of the DTM.

Another factor contributing to more reliable data is the scheduling of NVS interviews. In contrast to the DTM for which interviews were conducted only on weekends, the NVS runs continuously, with interviews taking place on each weekday as well as weekends (made possible by the CATI methodology).

Other notable inclusions in the NVS are:

- Collection of data for day trips and outbound (overseas) trips as well as for overnight trips
- Regions visited on overnight and day trips
- Leisure activities undertaken on overnight and day trips
- Itemised expenditure for overnight, day and outbound trips
- More detailed demographic data for both travellers and non-travellers, such as life-cycle information
- Information on intentions with regard to travel to and from Sydney during the Sydney 2000 Olympics
- Information about people with long-term health conditions and the impact of these conditions on travel arrangements and ability to travel

For overnight trips, cross-tabulations of visitor profiles by trip characteristics can be produced, such as:

- Visitor profile by region visited
- Purpose of visit by region visited
- Number of nights by region visited
- Transport used by region visited
- Accommodation used by region visited
- Visitor profile by accommodation used
- Activities participated in by region visited
- Visitor profile by activities participated in

- Trip expenditure by item
- Visitor profile by expenditure

Similar cross-tabulations will be possible for day trips.

The NVS uses a shorter recall period than was employed in the DTM. In the DTM, respondents were asked about overnight trips they had returned from in the past 4 weeks, or for longer trips, in the past 8 weeks. For day trips, the DTM asked the respondent to recall the frequency of different types of trips they had taken in the previous 12 months.

In contrast, the NVS asks respondents for details of overnight trips that they have returned from in the past 4 weeks, and day trips they have taken in the past week. Respondents are also asked about overseas trips they have returned from in the past 3 months.

A disadvantage of the adoption of the new NVS is a potential break in the time series data for domestic travel, since the survey methodologies for the NVS and DTM are considerably different.

BTR also conduct an International Visitor Survey which provides information about travel within Australia by inbound visitors. The IVS and NVS collect data on tourism including expenditure, trips, origin and destination. Using this data, the Analysis and Forecasting Section undertakes research into niche markets and significant tourism related issues, and uses advanced modelling techniques to develop forecasts of domestic, inbound and outbound tourism activity.

The NVS is compatible with, and complements, the IVS. As such, data from the NVS and IVS can be combined to provide information on total visitation to areas within Australia.

Every variable included in the Report may be cross-tabulated by the BTR System. The 1999 Annual NVS Report and the 1999 Annual IVS Report are available at a cost of $85.00 each.

Raw survey data may be obtained from CDMOTA (CD Monitor Of Tourist Activity) product being developed. The cost of the product is $2650, and includes both NVS and IVS information. Currently, CDMOTA has 84/85-96/97 DTM and 98 and 99 NVS domestic data files, and 89/97, 97,98 and 99 international data files. The 1998 NVS data will be available by the end of the year.

VATS – Victorian Activity and Travel Survey

The Victorian Activity and Travel Survey (VATS) contains one of the most comprehensive and up-to-date information sources on individual travel and out-of-home activities in metropolitan Melbourne. VATS is an ongoing household-based, year-round survey conducted by the Transport Research Centre (TRC) at RMIT University. Now in its eighth year, VATS uses a self-administered, mail-out/mail-back questionnaire supplemented by a limited "non-response" interview on a sub-sample. To-date, six years of data have been released: VATS94, VATS95, VATS96, VATS97, VATS98, and VATS99. In combination, these six databases contain travel and activity information pertaining to over 32,500 households or about 75,000 individuals. VATS99 was released in September 2000 (Transport Research Centre, 2000b).

VATS data is available in essentially the same format from 1994 to 1999. The survey form was redesigned for the year 2000 (Morris, Sindt and Holmes, 2001).

From the time the VATS began in 1993 up to VATS 99, the VATS samples were selected from a household address file obtained from MITS, a billing company for Melbourne Water. To capture the many residential developments that have been occurring in the outer regions of Metropolitan Melbourne, as well as the inner city, a new address database was employed for VATS2000. This database was the address database (PAF) from the Australian Post Office (APO).

*Process:* The VATS survey process for 1994 to 1999 comprised six distinct stages: a pre-contact, first mailing and four reminders. The pre-contact is made a week prior to the mailing of the survey questionnaire. The selected addressees are sent a pre-contact letter together with an information brochure notifying them that they have been randomly selected to participate in the survey. In the first mailing, the survey questionnaire, comprising a Household and Person Form, six Travel Forms, and a completed example of a Travel Form, is mailed to the selected address together with a covering letter and a postage-paid return envelope. A week after the initial mail-out, the first reminder, in the form of a post-card, is sent, thanking respondents who have already returned the survey forms and reminding those who have not. A new travel date is assigned to addressees who still have not filled out the forms. The travel day (ie day of the week), however, remains unchanged. Following that, the second, third and final reminders are issued a week apart from each other. In the third reminder, a full set of the survey questionnaires, similar to the package issued during the first mailing, is also sent in addition to the reminding letter. In all these reminders, a new travel date is assigned to all addressees who have not responded.

*Survey Instrument and Key Variables:* The self-administered questionnaire used in VATS consists of a Household and Person Form and a Travel Form. The Household and Person Form is designed to obtain information pertaining to the household as a whole, as well as the socio-demographic characteristics of individual household members and visitors. At the household level, the kinds of information requested include the number of persons in the household, including visitors staying at the selected address on the night before the travel day, the type of dwelling, ownership status, and the characteristics of the vehicles owned by the household. At the individual level, personal details are sought, including year of birth, gender, relationship to the oldest person, country of birth, possession of driver's licence, employment and activity status, and occupation.

The Travel Form is designed to capture the key characteristics of each out-of-home stop made by all household members between 4:00 am on the assigned travel day and 4:00 am the next day. For each stop, the key characteristics sought cover a description of the stop destination, its full address, the stop purpose, the mode used, and the arrival time at the destination. Depending on the mode used other information is requested. For car trips information is collected on the details of the car used, including parking place, parking fee (where applicable), and walking time from parking place to destination; for public transport trips information is sought on the ticket type, ticket fare and ticket zone.

The stipulation of stop and other addresses on the Travel Form enables the trip origin and destination to be geocoded. This means that the VATS data can be either analysed in the conventional manner of using standard statistical packages or examined on a Geographic Information System platform. This latter feature is especially useful as it allows the data to be mapped and used for network and spatial modelling.

*Database Organisation:* The VATS databases are organised into eight separate files linked together by a unique household number:

- Household File
- Person File
- Vehicle File
- Stop File
- Trip File
- Journey-to-work File
- Journey-from-work File
- Chain File

The Household, Person, Vehicle and Stop Files are the "basic" data files while the Trip, Journey-to-work, Journey-from-work and Chain File are the "derived" data files. Information in the "basic" data files is sourced directly from the survey forms; those in the "derived" data files are generated from the "basic" data files.

The data available from VATS 94-99 relevant to road safety, includes for each household member:

- Age of driver
- Car licence / motorcycle licence / no licence
- Sex of driver
- Number of passengers
- Vehicle type
- Vehicle size
- Vehicle age
- Mind set/ Attitude and Essential/Optional (Trip Purpose)
- P-plate (may be estimated from data based on age of driver)

The data which will be available from VATS2000 for each household member includes some additional data related to type of licence and the length of time the licence has been held.

In addition, the origin and destination of each trip undertaken in a “snapshot” 24-hour period is obtained. The straight line distance between the coordinates of the origin and destination may be adjusted by a correction factor which has been found to be applicable for VATS in Melbourne, to enable the calculation of the distance travelled in kilometres for a journey in Melbourne.

The VATS data is positioned as a useful complement to the 1996 Census data as it provides detailed travel and activity information not available in the Census. This is particularly so in the areas of daytime population profiles, activity data and associated travel data, and Journey-to-Work data. Non Journey-to-Work travel comprises more than 80 per cent of travel in the Melbourne Statistical District (MSD).

*Redesign of VATS for the year 2000:* The original survey form has remained essentially unchanged since the survey was begun in 1994. In late 1999, a review of VATS was undertaken to allow for the following:

- For some survey questions the answers were not straightforward. Some simplification or clarification of the questions was required
- Major changes to Melbourne’s transportation system come about in 1999, namely CityLink and privatisation of the public transport system. Relevant questions needed to be added.
- Societal changes needed to be taken into account. This included changes in family structures, and trends relating to changes in mode of travel, and emerging technologies (e.g. e-commerce).

It was important however, for the survey to maintain consistent longitudinal data.

An underlying important objective of the redesign was to align the VATS databases with the next ABS Census to be held in 2001 (CDATA 2001). The new questionnaire design, which has been put into effect since 1 January 2000, will enable valid comparisons to be made with the Census, and will furnish additional information on societal changes and the use of new transport infrastructure. In particular, questions on internet usage which are present in VATS from the year 2000, and in the forthcoming census in August, 2001 will give an indication of the effect of e-commerce on household travel and indirectly on the road toll.

## Appendix C

### Table 3 Summary of Travel and Activity Surveys in Australasia which may be used to inform road safety initiatives

| City/Country | Survey Acronym | Survey Year | Household (Net) Sample Size | Responding households | Address Data Source | Survey Instrument | Response Rate |
|---|---|---|---|---|---|---|---|
| **Australia** | | | | | | | |
| Adelaide | MAHTS | 1999 | 9,000 | | SEO | PI | ~67% |
| Berwick | HAS | 1976 | | 100 | CRR | PI | |
| Brisbane | SEQHTS | 1992 | 7,992 | 5,813 | QEB | MMQ | 73% |
| Canberra | CQHIS | 1997 | | 1,791 | CCD | PI | |
| Melbourne | VATS* | 1994/9 | | 32,500 | MWR | MMQ | 45% |
| Perth (FORS) | HTS | 1986 | 2,915 | 2,038 | ABS | MMQ | 70% |
| Perth (KONTIV) | | 1986 | 2,727 | 2,035 | ABS | MMQ | 75% |
| Perth (special) | | 1986 | 695 | 564 | TD | MMQ | 81% |
| Sydney | HTS* | 1997/98 | | 3,500 | ABS | PI | 70% |
| | HIS | 1991 | 20,259 | 12,096 | ABS | PI | 63% |
| | HIS | 1981 | 25,000 | | | PI | |
| **New Zealand** | | | | | | | |
| Auckland | HIS | 1992 | 19,707 | 9,967 | TD | CATI | 51% |
| Christchurch | CTS | 1990/91 | 8,000 | 4,320 | TD | TI | 54% |
| New Zealand | NZTS | 1997/98 | | 7,000 | CCD | PI | |

**SURVEY ACRONYM**
CQHIS = Canberra and Queanbeyan Household Interview Survey
CTS = Christchurch Transport Study
HAS = Household Activity Survey
HIS = Home Interview Survey
HTS = Household Travel Survey
MAHTS = Metropolitan Adelaide Household Travel Survey
NZTS = New Zealand Travel Survey
SEQHTS = South-East Queensland Household Travel Survey
VATS = Victorian Activity and Travel Survey

**ADDRESS DATA SOURCE**
ABS = Australian Bureau of Statistics
CCD = Census Collector District
CRR = Council Rate Records
MWR = Melbourne Water Records
QEB = Queensland Electricity Board Returns
SEO = State Electoral Office
TD = Telephone Directory

**SURVEY INSTRUMENTS**
CATI = Computer Aided Telephone Interview
MMQ = Mail-out/Mail-back Questionnaire

PI = Personal Interview
TI = Telephone Interview

*Note: The Melbourne and Sydney surveys are rolling surveys.

## References

Anderson, R (2001) personal communication, Department of Urban Services, ACT Australia

Andreassen, D and Cusack, S (1996) The Electronic Accident Report *Research Report ARR284* ISBN 0/86910/702/1 June 1996

ARRB Transport Research (2000) 50 km/h Urban Speed Limit Evaluation Technical Report 00.068, *publisher NSW Roads and Traffic Authority* Sydney September 2000

Arup Transportation Planning (1995) *The 1994 Crash Exposure Survey prepared for VicRoads* April 1995

Australian Bureau of Statistics (2000) Integrated Regional Database IRDB2000, available through www.abs.gov.au

Australian Transport Safety Bureau (2000) Transport Safety Statistics Unit, available through www.atsb.gov.au

Barry, T, Battye, R, Dale, T and Owen, Y (1999) Travel by Australians 1998, Annual Results of the National Visitor Survey, *Bureau of Tourism Research* Australia

Beaumont, L (2001) personal communication, ARRB Transport Research, Melbourne Australia

Brooks, M (2001) personal communication, AAMI, Melbourne Australia

Cameron, M and Newstead, S (2000) Response by Monash University Accident Research Centre to “Re-investigation of the effectiveness of the Victorian Transport Accident Commission’s road safety campaigns” (White, Walker, Glonek and Burne, November 2000) *Report No 177* November 2000

Chapman, R (2001) personal communication, VicRoads, Kew Australia

Comrie, N (1999) Enhancing Road Safety & Traffic Enforcement Into The New Millennium *6th ITE International Conference* Melbourne 6-7 September 1999

Crashstats (1998) *Crashstats Road Crash Statistics: Victoria*, VicRoads, Kew Australia

Diamantopoulou, K, Skalova, M, Dyte, D and Cameron, M (1996) *Crash risks of road user groups in Victoria Report No 88* Monash University Accident Research Centre June 1996

Drummond, A E and Healy, D J (1986) *The risk of driver crash involvement per distance travelled in metropolitan Melbourne* 13th ARRB/5th REAAA

Elliot, N (1998) Past, Present & Future Uses of VATS *Proceedings of the Victorian Activity & Travel Survey VATS97 Forum* Melbourne Australia 27 November 1998

Harding, J (2001) personal communication, Australian Institute of Health and Welfare, Canberra, Australia

Healy, D J and Thiele, R (2001) personal communication, Transport Accident Commission, Melbourne, Victoria

Howard, E (1999) Road Safety into the 21st Century *6th ITE International Conference* Melbourne 6-7 September 1999

Instat Australia Pty Ltd (1987) Review of exposure data base from the survey of day-to-day travel in Australia 1985-86 *Report No CR68,* ISBN 0 642 51123 3

Jones, B (1997) *Sleepers Wake* ISBN 019 553 7564 4th edition Oxford University Press

Kam, B H (1999) *A GIS-based Analysis of demographic, spatial and temporal variations in crash rates*, Report submitted to Federal Office of Road Safety, Commonwealth Department of Transport and Regional Development *The Transport Research Centre RMIT University* July 1999

Lightfoot J (2001) personal communication, Victorian Institute of Forensic Medicine, www.vifp.monash.edu.au/ncis

Lydon, M and Mabbott, N (2001) personal communication, ARRB Transport Research, Melbourne Australia

Mattingsbrooke (2000) University of Melbourne, Australia

Moloney, M and Palaia, D (1997) A Study of Drink Driving and Recidivism in the State of Victoria, during the Fiscal Years 1992/93 – 1995/6 (Inclusive) *Proceedings of the 14th International Conference on Alcohol, Drugs and Traffic Safety,* pp 815-820, Annecy, France

Morris, Hon P, Minister for Transport (1983) Address given to the First Australian Transport Information and Statistics Conference, Canberra, 6 July 1983

Morris, J, Kam, B H, Sindt, A C and Lau, C (1999) Travel and Activity Scoping Study – Review of Travel and Activity Databases, Transport Research Centre, RMIT University Melbourne April 1999

Morris, J, Sindt, A C and Holmes, J (2001) *The redesign of VATS (Victorian Activity and Travel Survey) for the year 2000* , RMIT Business Working Paper Series, in preparation

Mueller, Lieutenant General DM, AO, Vice Chief of the Defence Force (2000) Address given to Leadership Victoria Dinner, Melbourne, 8 December 2000

New Zealand Land Transport Safety Authority (1998) www.ltsa.govt.nz/research/travel_survey

Noland, R B (2000) *Traffic Fatalities and injuries: are reductions the result of 'improvements' in highway design standards* Annual Meeting of the Transportation Research Board, 10 November 2000

Ogden, K (1999) Protecting your privacy *Royalauto* May 1999

Procko, J and Richardson, A J (1997) *The Use of Household Travel Survey Data to estimate crash rates by demographic groups,* Road Safety & Traffic Enforcement Conference, Melbourne, Australia. 20-21 August 1997

Puri, K (2000) personal communication, Bureau of Meteorology, Melbourne

Rao, U (2001) personal communication, Information Management, Victoria Police

Road Safety Committee (1999) *Walking Safely: Inquiry into the Incidence and Prevention of Pedestrian Accidents* Parliament of Victoria ISBN 0-7311-5274-3 June 1999

Rosman, D L (1996) *The feasibility of linking hospital and police road crash casualty records without names,* Accid Anal and Prev, Vol 28, No 2 pp 271-274

Thiele, R and van Niel, G (1999) LPIS: an information system to identify licensed premises that are major sources of drink drivers *6th ITE International Conference* Melbourne 6-7 September 1999

Tingvall, C and Haworth, N (1999) Vision Zero – an ethical approach to safety and mobility *6th ITE International Conference* Melbourne 6-7 September 1999

Transport Accident Commission (2001) *Road Safety Monthly Summary, February 2001 Issue,* Melbourne Australia

Transport Research Centre (2000a) *Victoria's On-Road Traffic Survey of Vehicles and Occupants: 2000/01* tender proposal

Transport Research Centre (2000b) *Victorian Activity and Travel Survey VATS99: The VATS Process* RMIT University Melbourne

VicRoads (2000) *Discussion Paper – Road Safety Strategy 2000-2005,* VicRoads Road Safety Department, Kew Australia

Vulcan, A P, Cameron, M H, Mullan, N and Dyte, D (1996) *Possibility of adapting some road safety measures successfully applied in Victoria to South Australia"* Report No 102, Monash University Accident Research Centre

White, M, Walker, J, Glonek, G and Burns, N (2000) *Re-investigation of the Effectiveness of the Victorian Transport Accident Commission's Road Safety Campaigns"* Report No 4/2000, Safety Strategy, Transport South Australia, November 2000

Wigan, M R and Smith, N C (1996) *Creating ANBI: the Australian National Bicycle Information Base* Paper presented at the Velo Australis "Bicycles; a global solution to local problems": International Bicycle Conference, Fremantle, Western Australia

Wigan, M R and Smith, N C (1997) *Performance Indicators and Metrics for a National Bicycle Strategy* Paper presented at the Transportation Research Board 76$^{th}$ Annual meeting, Washington DC, USA