The Study of Road Safety on Urban Motorways

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2016 Churchill Fellow

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Keywords

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Conclusions made, or opinions expressed, in this report are not the opinions of any entity other than the author. All comments and ideas reflect the views of the author and do not reflect the official policy or position of any other person, entity, organisation or employer. The views and approach are provided to stimulate critical thinking, to generate debate and consideration of alternative forms of analysis at a time when the rate of progress in road safety in Australia and internationally seems to have plateaued. These views are subject to rethinking and revision over time as new evidence presents itself and when context changes.

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This report presents the findings of 2016 Churchill Fellowship to study the topic of “Road Safety and Urban Motorways” which involved meetings with a wide range of road safety professionals from nine countries: France, Norway, Sweden, Netherlands, Belgium, Germany, Italy, Greece and Israel.

I am thankful to the Winston Churchill Memorial Trust for providing the opportunity to travel to Europe and meet with many organisations and experts, who willingly gave of their time and held open discussions on a wide array of topics involving many disciplines and perspectives.

I am also grateful to my employer VicRoads, who has supported me in my career and allowed me to undertake this opportunity. VicRoads resourced me to meet with more people whilst travelling overseas and gave me time to follow up the additional material gathered during the Churchill Fellowship to complete this report.

The Churchill Fellowship provided many highlights. Most importantly, the chance to develop relationships with key international specialists, including many who were subsequently engaged as a direct result of my personal visit to their organisation. These relationships will continue to deepen. The most useful ingredients were the openness and integrity which these specialists displayed while answering a wide range of questions and their willingness to share knowledge by providing broader observations on my subject.

The Churchill Fellowship proved to be both a professionally and personally rewarding experience providing the opportunity to see firsthand alternative ways of thinking. I am grateful that the Churchill Fellowship provided the means to step outside of my narrow perspectives to seek answers and insights from other disciplines with different perspectives and experiences to my own.

Any errors of interpretation or documentation are mine alone.

Dissemination of findings

I aim to disseminate my findings through:

- Publication of this report and subsequent refined reports;
- Presentations of relevant findings to the Australian road transport industry, national and international conferences, seminars and workshops;
- Inclusion of important findings in future road design and traffic engineering manuals and practice guidelines;
- Influencing key policy and program decision makers that new approaches are needed to further reduce the road toll;
- The inclusion of findings within National “Managed Motorway” training material.

Presentations delivered during the Churchill Fellowship

The following presentations were made by the author during meetings in all countries visited:

- Managed Motorways Overview (operations and control)
- Insights into Motorway Traffic Capacity and Traffic Theory
- Detailed Crash Analysis of Urban Motorway Serious Injury and Fatality Crashes
16 UNDERSTANDING THE MOTORWAY CRASH PROBLEM FROM TRAFFIC SCIENCE

Traffic flow on urban motorways at times is inherently unstable meaning that when the motorway begins to fill up to the traffic carrying capacity, the road efficiency can decrease suddenly (i.e. flows decrease in less than 1 min by as much as 20-50%) rapidly changing traffic conditions which can be inherently dangerous for motorists. It only takes a small disturbance in the flow to trigger a change in “Traffic State” which can occur even in what was traditionally considered to be quite low traffic flow and traffic densities (i.e. around LOS C <16 veh/km/ln). Many laypersons and unfortunately many traffic practitioners assume the more traffic you get onto the motorway the more vehicle traffic it carries. This is far from the accurate as when a motorway is overloaded the flow collapses and degrades into a car park with a commensurate increase in the crash risk which progressively degrades the motorway productivity.185

Historically the quality of traffic flow has not been linked by traffic road safety researchers or practitioners to the “chance of failure” where the failure creates an inherently dangerous “Traffic State” as shown by recent analyses linking crashes to “Traffic States”. Whilst some historical research shows that motorway crashes in congested conditions might not be as serious, (I. Potts, 2015) this is clearly not the case in Victoria186 where analysis of actual traffic conditions at the time of the crash has been undertaken. The research also shows that more vehicles and people are involved in urban motorway FSI crashes. A recent study shows both the pre-congestion and post congestion periods with moderate to high traffic volumes together with moderate (i.e. 70-85km/h) speed conditions and the initial stages of congestion (i.e. High LOS E and Low LOS F values) cause the most FSI crashes.

From research and published literature there also appears to be little acknowledgement amongst road safety experts that some of the Intelligent Transport Systems (ITS) and “Managed Motorway” initiatives are making solid inroads into reducing crashes i.e. Melbourne’s first “Managed Motorway” project on the Monash Freeway resulted in a 31% reduction serious injuries and fatalities when measured five years after opening (Gaffney J, Lam P, Somers A, Boddington K, Johnston D, 2015) refer Figure 57 Comparison of crash rates on Melbourne’s motorways btw 2011 and 2015.

It is now possible to show that the crash rates on motorways can be directly correlated to both the pre-congestion and congested traffic conditions, where there are higher distributions of vehicle speeds as the motorway approaches capacity and when queuing is about to begin or forming in at least one carriageway lane. Works by (Oh, 2000), (Alsaihi R, Dixit V, 2015) and (Marchesini P, Weijermars W, 2010) linking the crash likelihood to large speed differences between and within lanes. These are the conditions that “Managed Motorways” target. Another quotation from an important study by (Yeo H, Jang K, Skabardonis A, Kang S, 2014) relating crashes to “Traffic States” is as follows:

“Freeway traffic accidents are complicated events that are influenced by multiple factors including roadway geometry, drivers’ behaviour, traffic conditions and environmental factors. The influence of those factors on traffic crashes cannot be fully unveiled without detailed information not only on the crash itself but also on its surrounding circumstances.”

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185 Productivity of a motorway equals the product of speed x flow
186 This is only true when motorways are approaching gridlock or where average speeds are typically below 30km/h which is not the case when most congestion related crashes occur i.e. 40-60km/h. This highest FSI crash risk occurs when speeds are 70-85km/h.
In Australia it is important not to read in too much from other country’s reported capacity values as these values are often measured on more semi-rural type motorways (e.g. autobahns) and when compared to motorways in large congested Australian capital cities, these rural motorways generally have much larger distances between interchanges (e.g. 7-10 km interchange spacing) and much longer average trip lengths which reduces lane changing friction (i.e. “Lane Shear”) discussed above.

Sometimes these other motorways have lower capacities than which are measured on a 4 lane “Managed Motorway” facilities in Australia. Hence it does not follow that adopting such an operational regime (e.g. “car only” lanes) would translate to Australia and provide improved operational or safety benefits within the congested urban corridor context. This is because as origin-destination patterns influence average trips length, and the default speed limits are quite different in Australian capital cities, where motorways now take on much of the arterial road function as well. Road planners and designers have also contributed to this by allowing much closer spaced interchanges in an attempt to service more trips, all of which combine to cause quite different operating characteristics refer the Section 1.1.4 and 1.4 above.

16.4 Relationships between motorway efficiency and safety

The evidence is emerging that a well “Managed Motorway” is also a safe motorway. The level of additional safety provided by a “Managed Motorway” can no longer be ignored and there is potential for further improvements to road safety outcomes of congested urban motorways now that there is further understanding of the mechanisms involved in crash causation.

The relationship between efficient motorway operations and road safety has been ignored for too long and, hence this section is included to provide much-needed information so that the safety of future motorways are not compromised by decision makers, road designers or traffic operators. The following Figure 57 Comparison of crash rates on Melbourne’s motorways btw 2011 and 2015 reveals the measured benefits of “Managed Motorway” programs. The first two motorways (Monash Freeway and Princes Freeway West) are only deemed to be managed by the relevant VicRoads “Managed Motorway” criteria and these two motorways have a much lower crash rate being in the order of 25-30% lower.

![Figure 57 Comparison of crash rates on Melbourne’s motorways btw 2011 and 2015](image)

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195 refer as yet currently unpublished work Prof. Markos Papageorgiou.

16.7 The influence of motorway travel on casualty crashes

The following document from the Netherlands, Institute for Road Safety Research (SWOV, 2007) has indicated that although 40% of vehicle kilometres are travelled (VkT) on their motorways, a similar rate as in Australian capital cities, yet no more than 10% of all fatality crashes occur on them.\(^\text{197}\) By observation the Netherlands has quite different travel patterns to the Australian capital cities as most of their motorway travel although reasonably congested at some locations and at some times of the day could be considered to be more interurban travel (i.e. Utrecht to Den Haag or Amsterdam to Rotterdam) and would be more comparable to Australia motorways (e.g. Melbourne to Geelong or Sydney to Wollongong or Newcastle) and, hence comparisons or similarities will always depend on what contexts are compared.

By comparison in Melbourne urban motorway crashes comprise about 15% of all urban crashes and similar extent fatalities (refer Figure 63 Urban fatal crashes in Melbourne by arterial road and freeway), however the daily traffic volumes are much higher over the 24hr period than on motorways in the Netherlands, which by comparison still tend to have relatively short (i.e. only about 2 hrs) well-defined peaks comprising largely commuter travel.

The Dutch report also states “The reason for the annual increase in motor vehicle kilometres (of travel) not resulting in a proportional increase in fatal crashes lies largely in the fact that most of the increase goes to the relatively safe motorways”. This fact has most likely been replicated across Australia, as the urban motorway network has done much of the heavy lifting in terms of doubling the urban VKT from 20% to 40% in the past 20 years, whilst still maintaining only 7% of the urban road network’s length when measured in lane kilometres.

By comparison to the motorway network, the total travel on the arterial road network is relatively stable (refer Figure 62 Total travel on Melbourne’s urban freeway and arterial road network) between 2005 and 2014. Also as discussed in Section 7 Crash Risk a Function of “Events of Exposure”, such a strong disproportional increase in crashes would not be expected based AADT or number of encounters as shown in (Figure 11 Shape of relationship between relative exposure and accident rate) unless some new mechanism was involved or in the case of motorways are activated (i.e. density >LOS C).

\(^{197}\) Note. This figure was published 10 years ago i.e. is now dated because of the. “time trend bias”, 10 years later the VkT is now 50% and the crash rate would have expected to also have risen
In Melbourne, the total **fatality crashes** on freeways represent about 15% of all urban fatalities on arterial roads when averaged over the last 4 years (refer Figure 63 Urban fatal crashes in Melbourne by arterial road and freeway). The total **casualty crashes** represent a similar amount being 14% (refer Figure 64 Total casualty crashes on Melbourne’s arterial road network), averaged over the same period.

**Figure 62 Total travel on Melbourne’s urban freeway and arterial road network**

**Figure 63 Urban fatal crashes in Melbourne by arterial road and freeway**
The urban motorway fatality crash rate per 100M Vkt is 3.8 times safer (measured over the past 4 years) than the arterial road crash rate as the arterial road crash rate is 0.38 per 100mVkt compared to 0.11 per 100m Vkt for freeways (refer Figure 65 Freeway vs. arterial road crash rate per 100m Vkt).

A comparison of the Freeway vs Arterial road causality crash rate per 100m Vkt is shown in (Figure 66 Freeway vs. arterial road causality crash rate comparison per 100MVkt ). The arterial road is 25 times higher casualty rate per 100m VKT averaged over the last 4 years. **This makes the freeway approximately 25 times safer to drive from a casualty crash perspective and 4 times safer from a fatality crash perspective and hence the transference of travel, over recent decades (i.e. 100% growth in 15-20years) towards the freeway will have had a significant effect slowing or reducing the growth in fatalities**, a factor that has not been acknowledged or attributed by the road safety community in Australia. Thus the road system is changing in ways that explain crash reductions and changes over time, however, we must be looking specifically for this phenomena to find it. As quoted from Thomas Kuhn "You don’t see something until you have the right metaphor to let you perceive it".

**Figure 65 Freeway vs. arterial road crash rate per 100m Vkt**
It is surmised that if the last 10-15 years the extra growth in urban travel had of been shared more equitably between the motorway and arterial road networks (i.e. shared 50/50), over the past decade or so Victoria would have had 10 or more fatalities per year and more than 600 extra causality crashes per year. It could be concluded therefore that the disproportionate transference of travel towards the motorway network has reduced the urban annual toll each year in the order of 10% which supports the findings in the Netherlands discussed above. Hence another example of missing attribution in road safety analysis discussed in (Appendix C Nine Areas of Concern for Road Safety Science).

These findings in the Netherlands do not necessarily concur within much of the published Australian research and promotional material on mechanisms that reduce the road toll, however as stated above it is acknowledged by (The Netherlands - Institute for Road Safety Research, 2007) that their “main concern is once the motorway network is full and congestion continues to increase, is whether they as an organisation should be actively encouraging travel back towards the less safe arterial roads?” Is it possible that this is already occurring in Europe and in our Australian capital cities?

Unfortunately 10 years later, in 2017 this is highly likely to have already happening since 2007 and hence this in part explains why a number of leading countries in road safety including the Netherlands and Sweden are seeing a gradual rise in the road toll particularly on divided highways and motorways and on other roads including arterial roads networks as traffic growth spreads demand back to less safe roads. Hence it is likely in the near future, as urban motorway networks approach their defined capacity limits, that urban crash rates will again begin to rise.

16.7.1 Peak spreading currently masking the extent of the problem

Urban motorways in Australian cities currently only are able to maintain high levels of traffic growth by the mechanism of “peak spreading” and the extent that this is achievable will reduce each year due to limits of human activity (i.e. will enough people want to travel or work at 3 or 4 am?) and, the fact that the volumes in the middle of the day between the morning and afternoon peaks have little room for additional traffic growth. Hence in the very near future the morning peak and the