Road Safety Case Studies

M7 to M2 Pre-congestion Speed Management

Timothy Clark[1] and Sam Gray[2]

[1]*Transurban, Senior Transport Planner, Network Optimisation, Sydney Australia*
[2]*Transurban,Principal, Network Optimisation, Sydney Australia*

Corresponding Author: Timothy Clark, Level 9/1 Chiefly Square, Sydney, NSW 2000, ticlark@transurban.com 0431 239 737

This peer-reviewed paper was first submitted as an Extended Abstract and an Oral Presentation was recommended by two reviewers at the 2021 Australasian Road Safety Conference (ARSC2021) held online, 28-30 September 2021. The two Reviewers also recommended that the Extended Abstract be expanded into a 'Full Paper' and undergo further peer-review as a journal submission by three independent experts in the field. The Extended Abstract is published in the ARSC2021 Proceedings with a link guiding readers to this 'Full Paper' version which is being reproduced here with the kind permission of the authors and will only be available in this edition of the JRS.

Key Findings

A pre-congestion speed limit management trial showed:

- Reduction in observed crashes
- Delayed on-set of congestion
- More gradual breakdown in speed
- Reduced congestion footprint

The trial has since become part of the day to day management strategy with a second trial at an additional location along the M7 corridor, set to commence mid-2021.

Abstract

This paper explores the development and implementation of the M7 to M2 pre-congestion speed limit management trial conducted on workdays between 26th June 2018 and 31st December 2018. This trial was the first of its kind in NSW and was implemented using a live loop reporting system utilising key trigger values (specific loop metrics) to identify the opportune time to reduce speed limits prior to flow breakdown. Through measuring the rate at which speeds dropped during flow breakdown, the heatmap footprint of congestion, and the instance of congestion related crashes it was established the trial was able to have a calming effect on traffic flow and reduce the overall footprint of congestion.

Keywords

Speed Management

Glossary

Westlink M7 (M7)
Northwestern Roads Group (NRG)
Transurban (TU)
Variable Speed Limit Sign (VSLS)
Variable Message Signs (VMS)
Operations and Management Control System (OMCS)
Digital Video Management System (DVMS)
Data Analytics Tool (DAT)
Inteligent Transport Systems (ITS)
Closed Circut Television (CCTV)
Transport for New South Wales (TfNSW)
The Department of Transport, Victoris (DoT)

Introduction

NRG, owner and operator of the M7 had observed consistent morning flow breakdown at the M2 motorway interface near the Abbott Road merge. Eastbound flow breakdown typically occurred at 5:50am creating queuing

Received: 01/04/2021; **Received in revised form:** 25/06/2021; **Accepted:** 21/09/2021;

Available on-Line: 10/11/2021 https://doi.org/10.33492/JRS-D-21-00016

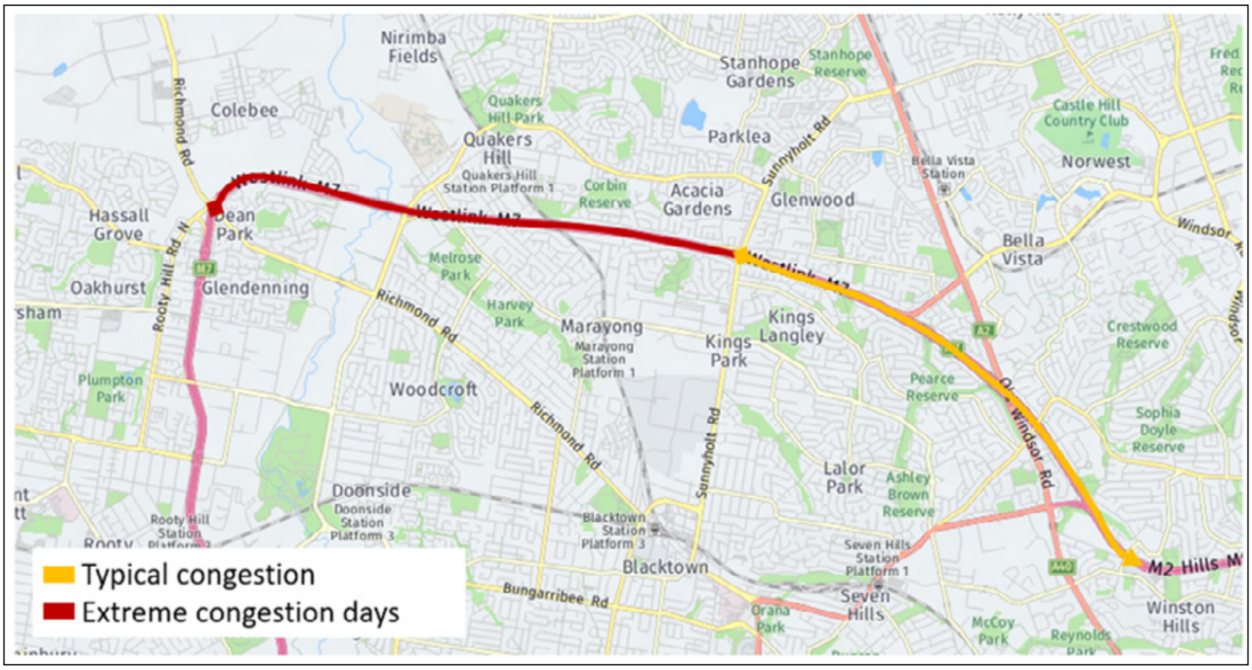

Figure 1 – Map of M7 observed congestion extents

that regularly extended back to Sunnyholt Road (5km), with extreme cases extending as far back as Richmond Rd (12km), see **Figure 1**.

Previously, under the original management plan, once flow breakdown had established the NRG operators would react to the prevailing conditions dropping the VSLS speed limits and provide advanced warning notification on the VMS in order to manage the risk of vehicles approaching the back of the queue.

Over the last 15 years, rather than 'react' to congestion, there has been a move to implemented 'proactive' speed management strategies in order to improve motorway flow, increase safety and delay the onset of flow breakdown. Recently in Australia, DoT in Victoria have completed a trial of 'proactive' VSLS speed limit control on the M80 in Melbourne and are now in the process of permanent implementation (iTnews, 2016). In NSW, the TfNSW operated M4 Smart Motorway uses variable speed limit signs to vary speed limits in response to heavy traffic and incidents to improve road safety, traffic flow and journey consistency (Roads and Maritime Services, 2017).

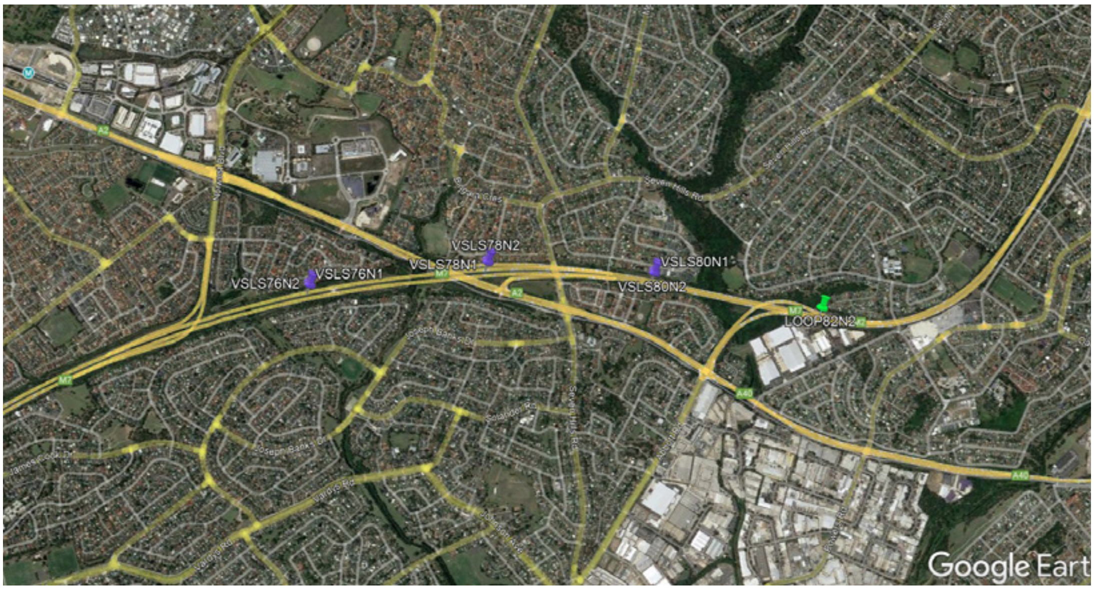

Figure 2. M7 Variable Speed Sign and Loop Locations

NRG under the guidance of TU recognised a key opportunity to leverage off this changing approach to speed limit management and conduct a trial of proactive speed limit control on a key section of the M7 within the existing functionality of the OMCS.

Methodology

The location of the study was identified by NRG, operators of the M7, as a region of the motorway that was experiencing repeated daily flow break down and identified as an opportunity to pilot a pre-emptive speed limit reduction trial. A trial scope was then outlined by NRG and TU in order to seek approval from TfNSW to alter the existing operation protocols related to speed limit changes on the M7. Previous protocols only permitted NRG from reducing speed limits on the M7 after congestion had already formed.

At the request of TfNSW in order to time the reduction in speed limit changes as to ensure optimal compliance, the dynamics of flow breakdown at the M7 M2 interface utilising loop data (LOOP82N1, see **Figure 2**) was analysed. This would ensure that the speed limit was reflective of current congestion conditions and would not be perceived as an arbitrary change. The analysis focused on data that could be analysed live using the M7 OMCS (see **Appendix**), with two key indicators, speed (measured) and count used to predict the onset of flow breakdown.

The trial was to run for 6 months with the aim to drop speeds limits approaching the M7 M2 interface approximately 10-12mins before flow breakdown occurred. Upon activation from within the M7 control room, speed limits would drop from 100km/h to 80km/h on the existing road side VSLS's (76N, 78N, 78M, 80N), shown in Figure 2. With the signs at 500m intervals this provided 2km of reduced speed approaching the point of congestion.

Speed limit drop trigger development

Figure 3 shows eastbound traffic volumes and speeds (30sec 2min rolling average) over the morning peak for each individual workday in March 2017 with the median value shown in bold (location of loops shown in **Figure 2**). Displaying volume and speed concurrently, the plot identifies the critical point where the onset of flow breakdown occurs. Demarcating the period "just before flow breakdown" and "after flow breakdown".

Before Flow Breakdown (March 2017)

At point A (**Figure 3**) around 5:30am approximately 10 minutes before flow breakdown, volumes above 9 veh/30s were steadily increasing at the merge. Concurrently driver speeds were below 92 km/h and continued to reduce. This marked the period where the merge was approaching capacity, but crucially just before flow breakdown. The minimal variation in all the individual working days showed this point occurred with consistent volumes and speed. The variation (standard deviation) between each of these values was 2 vehicles and 3.8km/h respectively, identifying the predictability of traffic just before flow breakdown period.

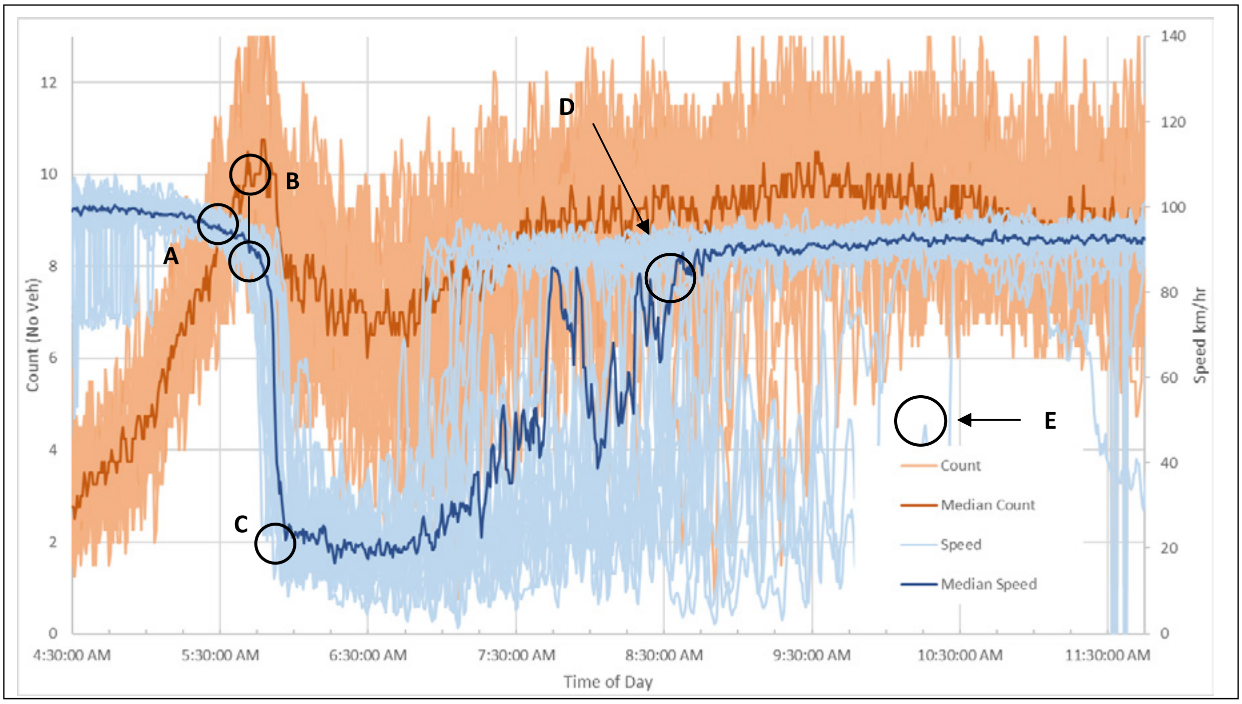

Figure 3. AM peak speeds & counts March 2017

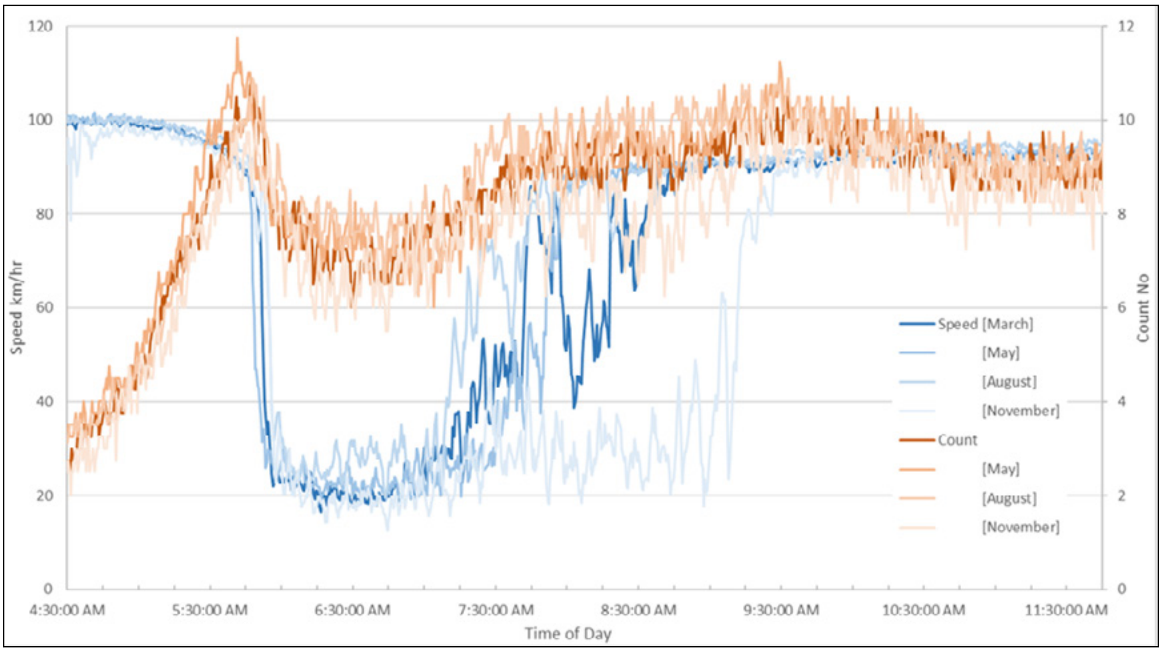

Figure 4. Speed Count Seasonality

At Flow Breakdown (March 2017)

Point B (**Figure 3)** at 5:43am, the increasing volumes were above 10.5 veh/30s reaching tipping point as speeds continued to drop. The capacity of the merge was reached and flow began to breakdown. At Point C (**Figure 3**), 5:53am, the combination of relatively high speeds and large volumes caused turbulence within the traffic stream resulting in emergency breaking and a sudden speed drop of over 60km/hr in 10 minutes to 24km/hr. Once flow break down has occurred, speeds do not typically recover for up to 3 hours, Point D, with some extreme daily cases not recovering until 10:15am, Point E (**Figure 3**).

Seasonality

Figure 4 shows the median values of workdays in March, May, August and November. The first 1hr of flow breakdown (5:50am-6:50am) occurred without seasonal differences. Furthermore, it is only the recovery period that exhibits any seasonal variability, likely as a result of decreasing demands at the end of the peak, however this was not the focus of the trial.

Applying Speed Limit Drop Triggers

To ensure the daily appropriateness of the speed limit drop activation in conjunction with M7 DAT alert capability (see **Appendix**), the trial used a two-step alert based activation of the speed limit drop. The first step, 'Alert One' warned

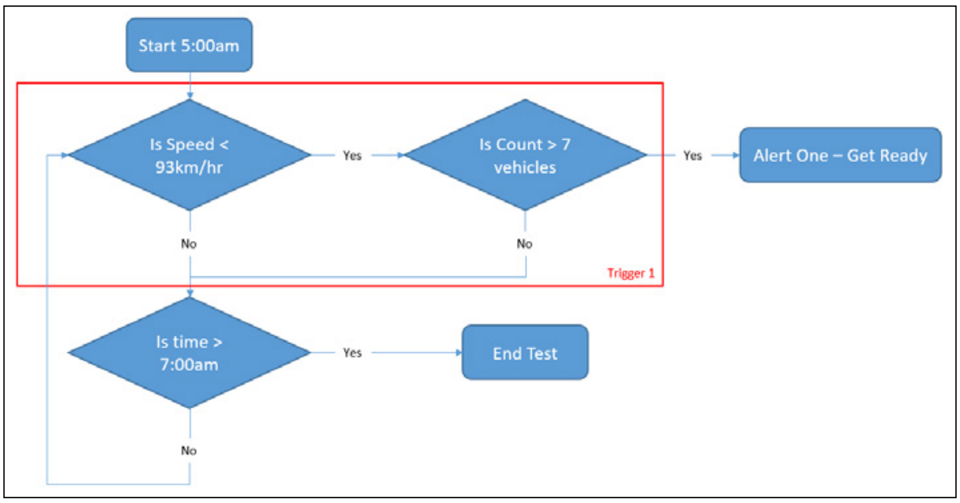

Figure 5. Alert One flow diagram

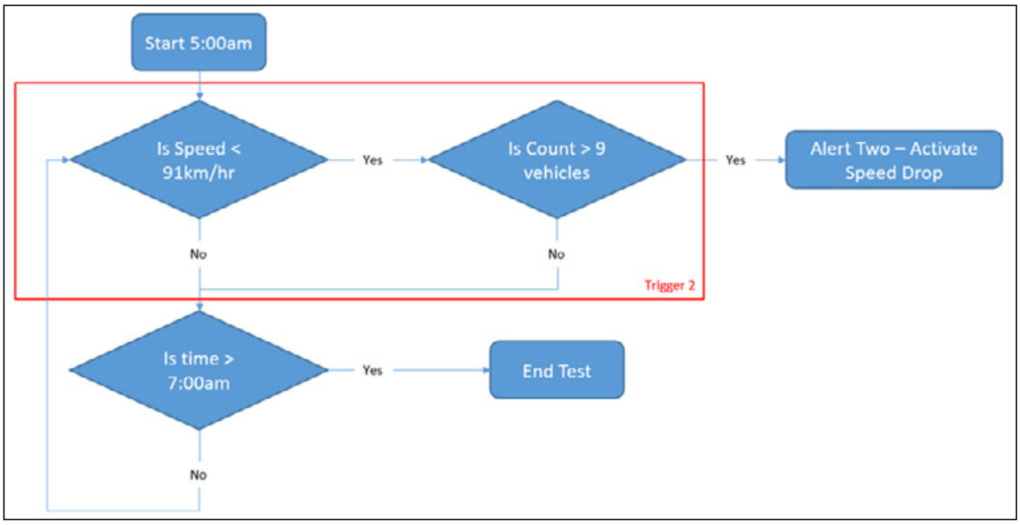

Figure 6. Alert Two flow diagram

the M7 control room that conditions were beginning to deteriorate, while 'Alert Two' confirmed flow breakdown indicating to the control room to activate the VSLS speed limit drop.

Alert One – Warning

As conditions near the M7 M2 interface deteriorated rapidly, Alert One provided a warning that mainline traffic conditions were becoming heavier, drawing the situation to the attention of the control room operators. For the trial, an activation window of 5:00am to 7:00am on workdays was used as the process involved manual activation of the speed limit drop. The activation window would therefore remove the risk of unnecessary distraction outside of this timeframe.

Loop data from 81 individual workdays from 2017 was fed into an excel model where the most appropriate trigger values of volume and speed for Alert One were identified. The activation of Alert One is show in the flow diagram in **Figure** 5.

Alert Two - Confirmation

Alert two confirmed to the M7 control room that flow breakdown was imminent and activation of the speed limit drop would occur. As with Alert One, loop data from 81 individual workdays from 2017 was fed into an excel model where the most appropriate trigger values of volume and speed for Alert Two were identified. The activation of Alert Two is show in the flow diagram in **Figure 6**.

Results

Safety

Crash statistics were collected for the 6 months during the trial between Quakers Hill Parkway and the M2 between 5:30am and 7:00am. These crash statistics were then compared against the 6 months preceding the trial and to further historical values.

- Before the trial (between 26 June 2017 and 31 December 2017) there were 5 crashes along the eastbound corridor. 100% of these were 'nose to tail' or typical congestion related crashes, with 60% involving 3 or more vehicles.

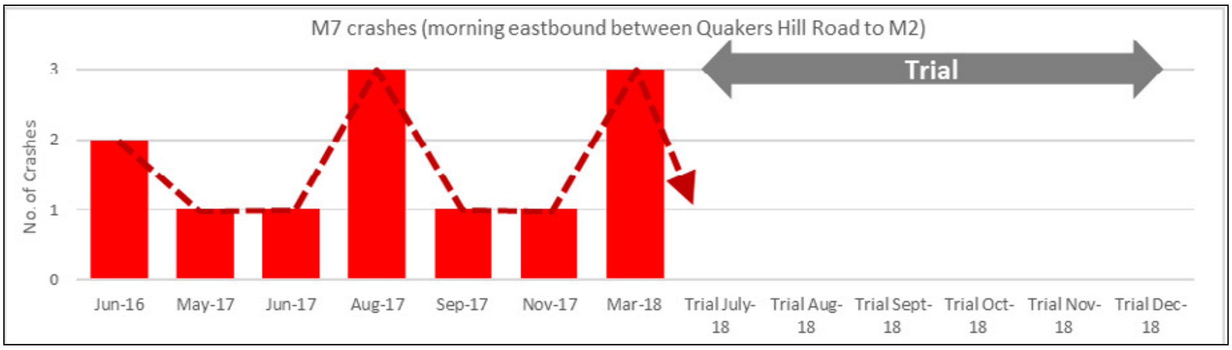

Figure 7. M7 crash performance before and during trial

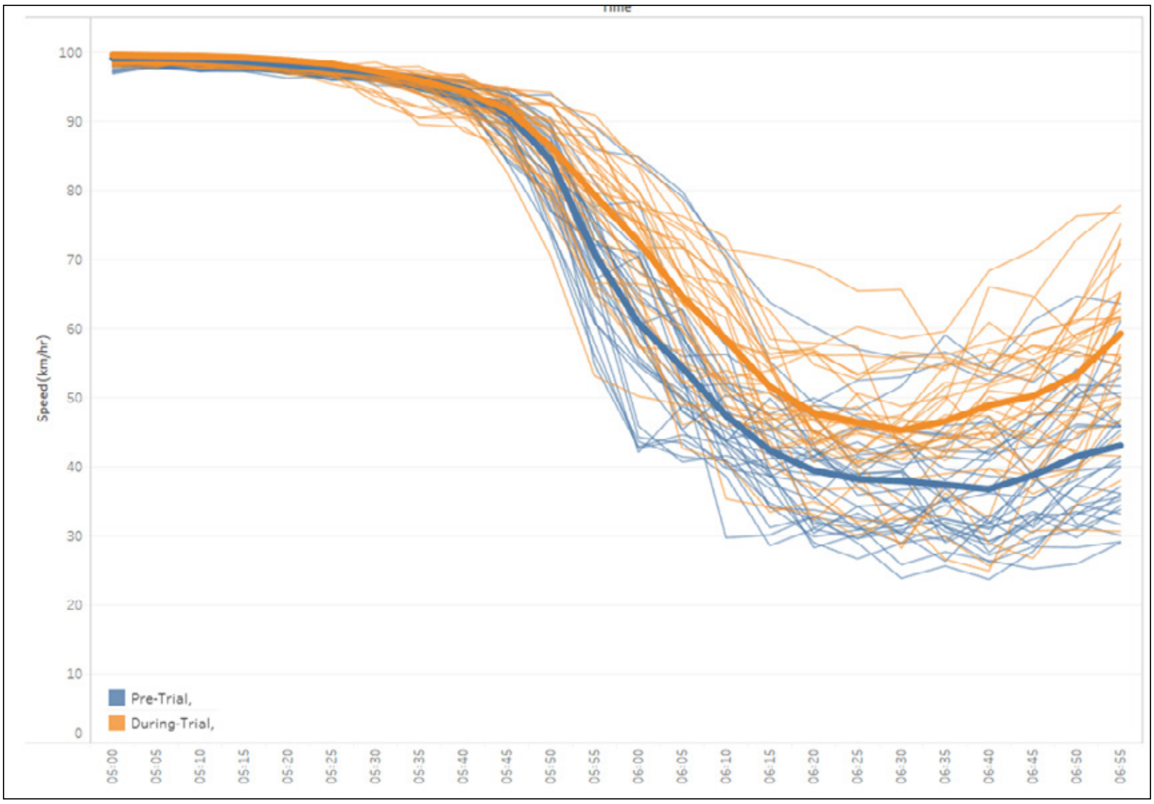

Figure 8. Eastbound speed profiles near M2 interface representative days

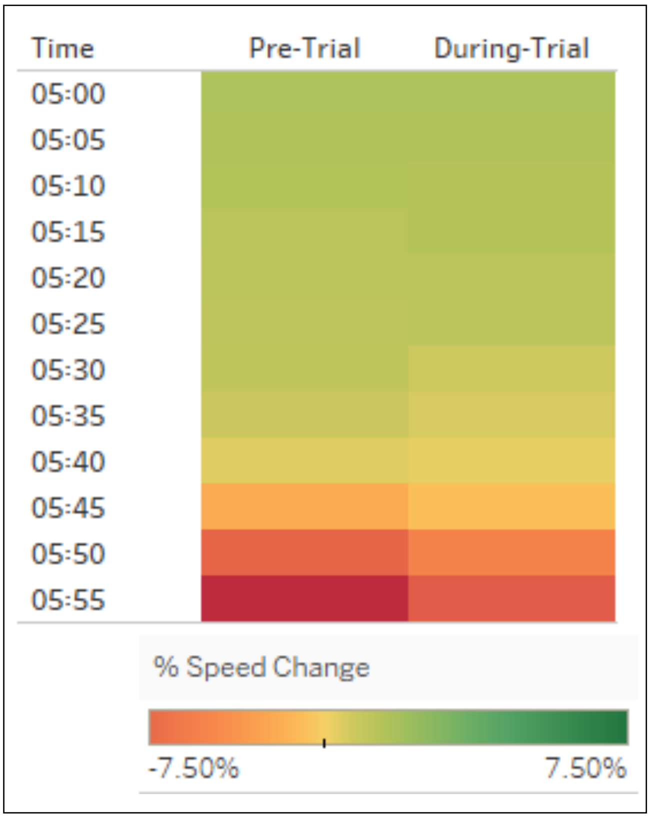

Figure 9. Comparison of 'rolling rate of speed change' March 17 (Pre-Trial) versus August 17 (During-Trial)

- During the trial (between 26 June 2018 and 31 December 2018) there were no crashes observed.

The analysis compared over 350,000 trips before the trial with 350,000 trips during the trial. As such there is good confidence in the exposure and relevance of the trial's benefit. Additionally, analysis revealed the 5 crashes before were not linked to rain events and were not linked to day light savings effects (the same yearly period).

A longer historical crash trend is shown in **Figure 7,** where 12 'nose to tail' congestion related crashes eastbound on the M7 corridor between Quakers Hill Road and M2 between 5:30am and 7:00am were identified, further illustrating the instance of congestion related crashes around this part of the network.

Impact to Traffic Flow

The traffic flow analysis focused on the same traffic loop (LOOP81N1) located at the source of congestion with the M2 interface. **Figure 8** compares all workdays in March 2017 (pre-trial) with all workdays in August 2017 (during trial) between the hours of 5:00am and 7:00am with the average speed profile shown in bold.

The comparison indicates the positive impact the pre-emptive speed limit reduction has had on traffic speeds with a more gradual reduction in speed decline, a key indicator of success, as was agreed to by TfNSW. Consistently higher speeds between 5:45am and 6:30am

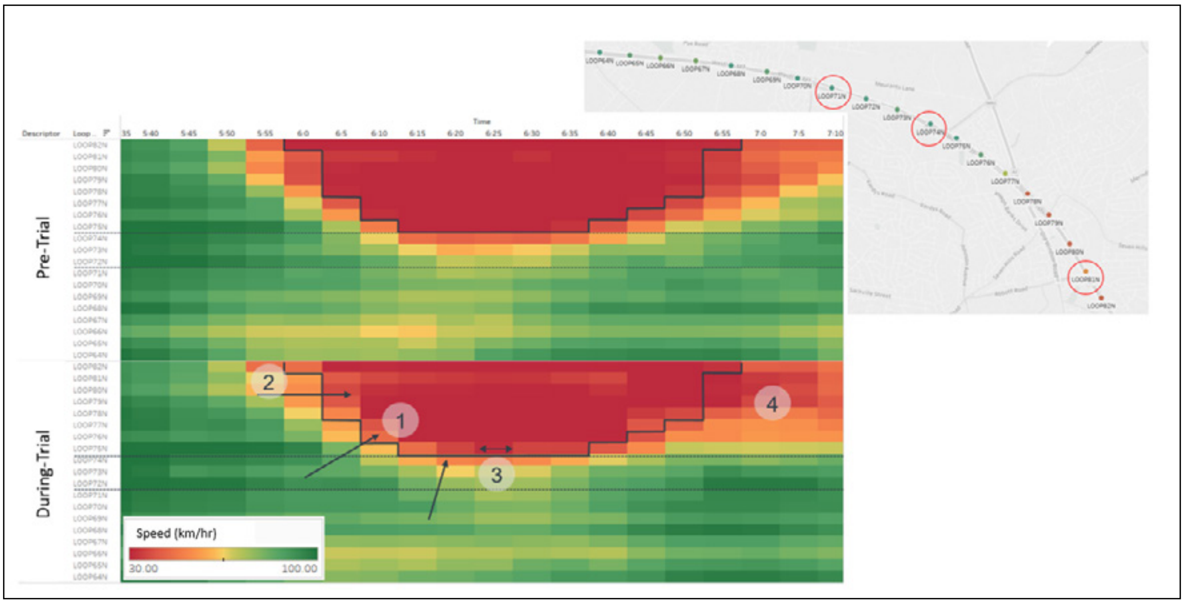

Figure 10. Speed comparison highlighting congestion footprint, back of queue, duration, and speed transition

have also been observed with the average indicating the greatest speed differential of 10km/hr occurring at 6:00am.

Figure 9 further illustrates the slowed rate of change with less intense speed reductions occurring during the trial and over a longer period, 25min compared to 15min. It is theorised that this may lead to a safer transition into congestion through a reduction in breaking intensity and could be the result of reduced number of crashes.

To analyse the extent of congestion, a speed heatmap (**Figure 10** March vs August) was developed. A black line was drawn around the core of the shock wave (where sub 30km/hr speeds were experienced) on the pre-trial heatmap. This line was then superimposed on the 'during trial' heatmap and the following observations were made:

1. Observed delayed on-set of congestion.
2. Smoother transition into flow breakdown with a more gradual decline in speed.
3. Reduced length and duration of back of queue, a reduction of 15min sub 30km/hr speeds (20min down to 5min).
4. There was some additional turbulence experienced towards the end of the peak. Further analysis indicated this to be caused by increased traffic growth (around 2%) in the later part of the peak.

Discussion

It was difficult to deduce much from the analysis of crash data given the limited sample size however zero observed incidents was promising. Prior to the trial it was hoped that better use of emerging near miss data would be utilised, however this was unavailable at the time. It is hoped, given a potential future trial recently available, near miss data will lead to more fruitful analysis.

What is understood from the analysis however, is that reducing the speed limit to match the prevailing road conditions slightly ahead of time has shown to have a calming effect on traffic. This is observed through the consistently extended period to which it takes speeds to drop from free flow conditions to congested, with higher speeds observed through much of the early peak. This has shown to potentially reduce congestion impacts both in extent and duration and it is theorised that this calming effect may lead to a reduction in harsh breaking and associated safety benefits.

Conclusions

The trial was conducted on workdays between 26 June 2018 and 31 December 2018. It has:

- Shown reduced crashes from 5 to 0 over the common time period.
- Smoothed traffic flow.
- Delayed the onset of congestion.
- Reduced shockwave intensity and congestion length.

Overall the low-cost safety benefits of the trial have resulted in the trial being incorporated permanently into business as usual operations with a second trial at a second location along the M7 currently being proposed.

Acknowledgements

I would like to thank our colleagues at Westlink M7 in particular Glen Archibald and Paul Hanna for their help though the M7 to M2 Pre-congestion Speed Management Trial.

References

iTnews (2016), The Melbourne road where speed limits are set by algorithm accessed from https://www.itnews.com.au/news/the-melbourne-road-where-speed-limits-are-set-by-algorithm-431137

Institute of Transport Studies Monash University (2013), Traffic Engineering and Management, Institute Of Transport Studies, Monash, Victoria

Transport For NSW (2017), Centre for Road Safety Speeding, accessed from http://roadsafety.transport.nsw.gov.au/speeding/index.html

VicRoads (2017), Managed Motorways Framework, VicRoads, Kew, Victoria,

Roads and Maritime Services (2017), Features of a Smart Motorway (November 2017)

Roads and Maritime Services (2017), M4 Smart Motorway Project accessed from https://roads-waterways.transport.nsw.gov.au/projects/m4/smart-motorway-features.html

Appendix – Key M7 OMCS capabilities

The current M7 ITS infrastructure includes; 220 variable speed limit signs; 58 variable message signs; 88 CCTV cameras; loop detection every 500m and on every ramp; and an OMCS including a DVMS.

Additionally M7 created a tailored, add-on DAT that is able to provide real time and historic traffic data using outputs from the OMCS. Within this tool, alert parameters are able to be configured for real time vehicle speeds and vehicle counts averages (across user defined multiples of 30s intervals) and then displayed to the M7 control room using a GUI dashboard.