
This item was submitted to [Loughborough's Research Repository](#) by the author.
Items in Figshare are protected by copyright, with all rights reserved, unless otherwise indicated.

Driver's ability to absorb information from co-located signs along motorways

PLEASE CITE THE PUBLISHED VERSION

<http://www.trb.org/>

PUBLISHER

© the authors

VERSION

AM (Accepted Manuscript)

PUBLISHER STATEMENT

This work is made available according to the conditions of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) licence. Full details of this licence are available at:
<https://creativecommons.org/licenses/by-nc-nd/4.0/>

LICENCE

CC BY-NC-ND 4.0

REPOSITORY RECORD

Han, Clarissa, Peter Cairney, Ashleigh J. Filtness, Gregoire S. Larue, Amy Schramm, and Andry Rakotonirainy. 2019. "Driver's Ability to Absorb Information from Co-located Signs Along Motorways". figshare. <https://hdl.handle.net/2134/22164>.

1 **DRIVERS' ABILITY TO ABSORB INFORMATION FROM CO-LOCATED SIGNS**
2 **ALONG MOTORWAYS**

3
4
5 **Dr Clarissa Han, Corresponding Author**

6 ARRB Group
7 500 Burwood Highway, Vermont South, VIC 3133 Australia
8 Tel: 0061 3 98811695; Fax: 0061 3 98878104; Email: clarissa.yihan@arrb.com.au

9
10 **Dr Peter Cairney**

11 ARRB Group
12 500 Burwood Highway, Vermont South, VIC 3133 Australia
13 Tel: 0061 3 98811621; Fax: 0061 3 9887 9618; Email: peterc@arrb.com.au

14
15 **Dr Ashleigh Filtness**

16 Centre for Accident Research & Road Safety - Queensland
17 Queensland University of Technology
18 130 Victoria Park Road, QLD 4059 Australia
19 Tel: 0061 7 3138 7713; Fax: 0061 7 3138 0111; Email: ashleigh.filtness@qut.edu.au

20
21 **Dr Gregoire Larue**

22 Centre for Accident Research & Road Safety - Queensland
23 Queensland University of Technology
24 130 Victoria Park Road, QLD 4059 Australia
25 Tel: 0061 7 3138 4644; Fax: 0061 7 3138 0111; Email: g.larue@qut.edu.au

26
27 **Amy Schramm**

28 Centre for Accident Research & Road Safety - Queensland
29 Queensland University of Technology
30 130 Victoria Park Road, QLD 4059 Australia
31 Tel: 0061 7 3138 4944; Fax: 0061 7 3138 0111; Email: a.schramm@qut.edu.au

32
33 **Prof Andry Rakotonirainy**

34 Centre for Accident Research & Road Safety - Queensland
35 Queensland University of Technology
36 130 Victoria Park Road, QLD 4059 Australia
37 Tel: 0061 7 3138 4683; Fax: 61 7 3188 0111 Email: r.andry@qut.edu.au

38
39
40 Word count: 4,200 words text + 11 tables/figures x 250 words (each) = 6,950 words

41
42
43 Submission Date: 24 July 2015

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

ABSTRACT

The paper presents initial findings from an Austroads funded project *NT1782 Ability to Absorb Information through Electronic and Static Signs*. The paper aims to investigate how easily messages displayed on co-located signs can be absorbed, and if drivers can absorb messages and take appropriate action without any adverse impact on the safety and efficiency of driving. Co-location of three types of signs under motorway conditions was investigated: direction signs (DS), variable message signs (VMS) and variable speed limits/lane control signs (VSL/LCS). The authors reviewed global wide practices and research evidence on different types of sign co-locations. It was found that dual co-location of VSL/LCS, VMS and/or DS is a practical arrangement which has been widely practised overseas and in Australia. Triple co-location of VSL/LCS, VMS and DS is also practised overseas but is still new to the Australian driving community. The NT1782 project also employed an advanced driving simulator (ADS) to further investigate the possible impacts of sign co-location on drivers' responses in an emergency situation and there were no obviously adverse impacts have been identified from the ADS study. The authors consolidated all findings and concluded that although there is no clear evidence showing that triple co-location gives rise to riskier behaviour, this proposition should be viewed with caution. Further evaluation of triple co-location in a real-life setting is called for.

Keywords: sign co-location, direction signs, variable message signs, variable speed limit signs, lane control signs, advanced driving simulator, dual-colocation, triple co-location

1 INTRODUCTION

2 There are locations on the motorways where co-location of different types of signs on the same
3 gantry or post might be attractive to road agencies such as:

- 4 ▪ situations where a number of critical messages need to be conveyed over a short travel
5 distance, e.g. approaching an exit that is located part way around a left curve, just beyond a crest or
6 where batters make installation of roadside signs impracticable
- 7 ▪ situations where the available budget is limited and there is opportunity to make full use
8 of existing or proposed gantries
- 9 ▪ situations where there is a need to minimise redundant signs without omitting any
10 important information.

11 The ability of drivers to see, read and understand traffic signs has been extensively
12 investigated. However, co-location of a number of critical messages over a short distance has the
13 potential to exceed road users' capacity to absorb and act on them. The paper aims to review
14 current practice and guidelines on the sign co-locations and investigate the possible impacts of
15 sign co-location on the safety and efficiency of driving under motorway conditions. It is
16 anticipated that work on this will inform future policy in relation to the use of co-located electronic
17 and static signs along motorways in Australia. Co-location of three types of signs under motorway
18 conditions was investigated: direction signs (DS), variable message signs (VMS) and variable
19 speed limits/lane control signs (VSL/LCS).

20 The paper presents findings from the recent Austroads funded project *NT1782 Ability to*
21 *Absorb Information through Electronic and Static Signs* (Austroads 2015), it starts with a
22 comprehensive review of current standards, guidelines and practice. The paper then focuses on
23 identifying the evidence for and against sign co-locations based on existing research works.
24 Further discussion is also conducted to obtain more evaluation evidence and recommend possible
25 situations and solutions when considering co-locations of DS, VMS and VSL/LCS for motorways.

26 REVIEW OF CURRENT PRACTICE AND GUIDELINES

27 The authors reviewed both overseas and Australian practices, standards and guidelines on
28 co-location of dynamic and static signs. It was found that co-location of dynamic and static signs
29 are not considered by Australian standards (i.e. AS 1742 Set-2014, *Manual of uniform traffic*
30 *control devices* (Standards Australia 2014)) or US standards (i.e. *US Manual on Uniform Traffic*
31 *Control Devices* (FHWA 2012)). Sign separation with sufficient distances is recommended when
32 there is a need to convey two or more different messages in one location. Generally, speed limits
33 should not be used in conjunction with other guide signs. However, a lot of mismatches exist
34 between standards and current practices in terms of sign co-location. Co-location of dynamic and
35 static signs has been applied on both Australian and overseas motorways.

36 Amongst DS, VMS and VSL/LCS, there are five types of co-location formats of:

37 1. Dual co-location of VSL/LCS and VMS

38 European guidelines such as EasyWay (2012a and 2012b) provide harmonisation
39 deployment guidelines for VSL and VMS. The co-location of VMS and VSL in Copenhagen
40 (Figure 1) and co-location of VSL and VMS on the M42 in the UK (Figure 2) are given as
41 examples of good practice. It has also been applied in Australia (e.g. Figure 3) and recommended
42 by Austroads guidelines (Austroads 2009a). Highways Agency (2014) reported that co-location of

1 VSL/LCS and VMS applied in UK managed motorway projects have received positive feedback
2 from users.



3
4 Source: EasyWay (2012b).

5 **FIGURE 1 Co-located VMS and VSL in Motoring 3 around Copenhagen**

6
7



8
9 Source: Highways Agency (2014).

10 **FIGURE 2 Co-located VMS and VSL along the M42**



1
2 Source: Austroads (2015).

3 **FIGURE 3 Co-located VMS and VSL on Monash Freeway, Australia**

4 2. Dual co-location of VSL/LCS and DS

5 Dual co-location of VSL/LCS and DS is a common practice in US managed lane
6 applications (FHWA 2011) and European managed motorway applications (e.g. Highways Agency
7 2014, EasyWay 2012a). Figure 4 provides an example of a priced dynamic shoulder lane (PDSL)
8 in Minnesota. The PDSL allows eligible and toll-paying vehicles to use the inside shoulder during
9 the morning peak period only. Figure 5 shows a simple co-location of VSL and DS from a Dutch
10 motorway. Figure 6 shows a complicated co-location of VSL and DS from a Dutch motorway. The
11 sign in Figure 6 is also the most complicated hybrid sign in practice.

12 In Australia, dual co-location of VSL/LCS and DS is applied in many managed motorway
13 applications and has been considered by Austroads (2009a). Queensland *Traffic and road use*
14 *manual (TRUM)* provides detailed guidance regarding the co-location of VSL/LCS with both
15 lane-based direction signs and non-lane-based direction signs (TMR 2013). An example of
16 co-location of gantry mounted VSL and an advance direction sign in the case of a single exit in
17 TMR (2013) is shown in Figure 7. VicRoads *Managed Freeways Handbook* (VicRoads 2013)
18 indicates that co-location of DS and LUMS might be considered if geometric constraints prevent
19 sign separations. Figure 8 shows an example of co-located VSL and DS along Monash Freeway in
20 Melbourne.

21



1
2 Source: FHWA (2011).

3 **Figure 4 Lane control signal over I-35W PDSL (priced dynamic shoulder lane), Minnesota**

4



5
6 Source: Ungemah, Kuhn and Baker (2008).

7 **Figure 5 Example of simple co-location of VSL and DS in Rotterdam, Netherlands**

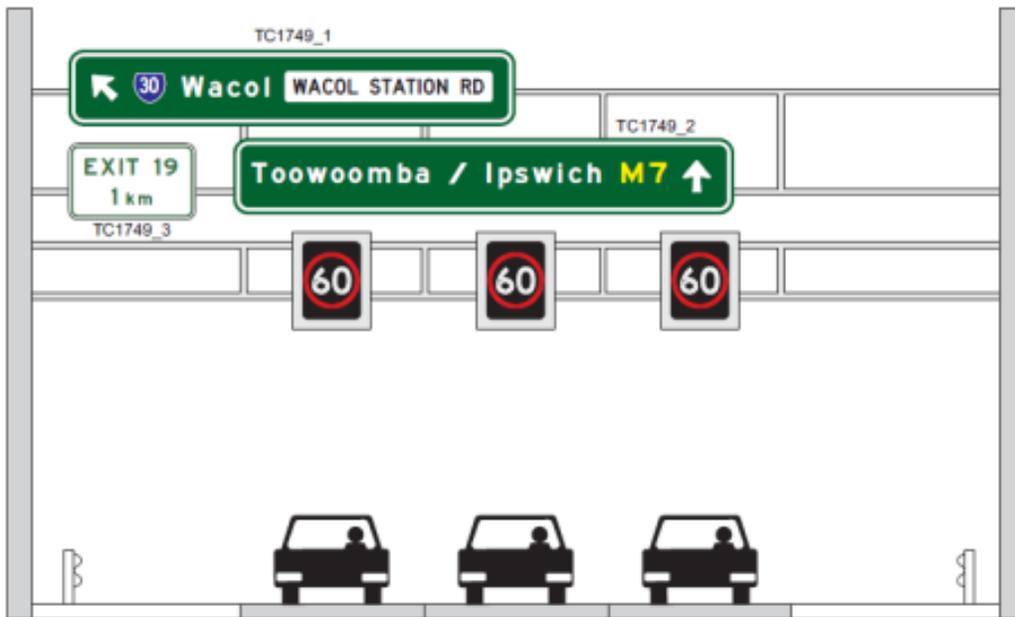
8



1
2 Source: Google Maps (2013), 'Rotterdam, Netherlands' map data, Google, California, USA.

3 **FIGURE 6** Example of complicated co-location of VSL and DS in Rotterdam, Netherlands

4



5
6 Source: TMR (2013).

7 **Figure 7** Co-location of gantry mounted VSL and advance direction signs in the case of a
8 **single exit**



1
2 Source: Austroads (2015).

3 **Figure 8 Co-location of VSL and DS on Monash Freeway, Australia**

4

5 3. Triple co-location of VSL/LCS, direction signs and VMS

6 This is the most complicated co-location of dynamic and static signs. It has been applied in the UK
7 M42 ATM pilot (e.g. Figure 9) and this project was acknowledged as world best practice by
8 European EasyWay guidelines (EasyWay 2012a, 2012b) and US guidelines (FHWA 2011).



9
10 Source: Grant (2007).

11 **FIGURE 9 Example of triple co-location of VMS, DS and VSL along the M42, UK**

12 In Australia, Department of Transport and Main Roads, Queensland (TMR) have
13 attempted to test dual and triple co-locations of lane use management systems (LUMS) with DS
14 and VMS on Queensland motorways. Larue et al. (2013) reported an advanced driving simulator

1 (ADS) study that aimed to investigate drivers' behavioural changes and comprehension resulting
 2 from the sign co-location proposed by TMR. Figure 10 shows an example of triple co-located
 3 signs that have been tested; however the testing results were inclusive. Further research evidence
 4 from Larue et al. (2013) is also discussed in Table 1 of the next section of the paper.



5
 6 Source: Larue et al. (2013).

7 **Figure 10 Triple co-location of VSL/LUMS, direction signs and VMS proposed by TMR**

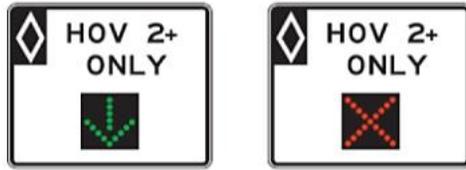
8

9 4. Co-location of VMS and direction signs

10 Co-location of VMS and direction signs is not commonly used or well-researched based on the
 11 findings from literature review.

12 5. Hybrid signs

13 A hybrid sign usually includes a dynamic message panel in a static sign that displays a graphic
 14 legend or a text message. The US MUTCD (FHWA 2012) cited hybrid signs as a special type of
 15 dynamic message sign used mainly in managed lane operations. Figure 10 provides some
 16 examples of different hybrid sign applications in the FHWA (2012). Hybrid sign is also supported
 17 by European EasyWay (2012b) and has been broadly applied in European countries, the US,
 18 Australia and New Zealand.



(a) Dynamic HOV lane control using graphic legends



(b) Dynamic HOV lane control using text messages



(c) Dynamic toll rates for priced managed lanes



(d) Comparative travel times

1
2 Source: FHWA (2012).

3 **Figure 10: Example of hybrid signs in the US MUTCD**

4
5 **EVIDENCE FOR AND AGAINST SIGN CO-LOCATION**

6 The authors also reviewed extensive existing research works including four laboratory
7 experiments, five driving simulator studies and two driver evaluations from both overseas and
8 Australian sources. Evidence relating to co-location of dynamic and static signs from these
9 researches has been identified. Table 1 brings this evidence together in order to assess the
10 arguments for and against co-location, and to identify any issues that remain to be resolved. The
11 evidence from standards and guidelines is also summarised in Table 1.

12

1 **TABLE 1 Evidence For and Against Co-location**

Information source	Evidence for co-location	Evidence against co-location
Standards and guidelines		
US MUTCD (FHWA 2012)	Approves co-location (hybrid signs) in limited circumstances – lane use, dynamic tolling and etc. Specifies limits for amount of information.	Overhead signs limited to essential signs. Regulatory signs including speed limits should not be used in conjunction with overhead sign installations; concern about amount of time available.
US Freeway Management and Operations Handbook (FHWA 2011)	Operational strategies, active traffic management, combination of operational and design actions to meet local and regional mobility objectives – VSL, LUMS, HOV and HOT – hybrid signs, gantry mounted.	
Highways Agency (UK) (see FHWA 2012)	VMS, VSL and direction signs co-located along M42.	
Netherlands (see FHWA 2012)	Speed and direction signs co-located, including complex signs with up to six layers of information.	
EasyWay (2012b) European project to harmonise VMS practice	Variety of combinations for VMS, pictographs, speed limits, direction arrows, route numbers.	
AS 1742.15 Direction signs, information signs and route numbering (Standards Australia 2014)		Generally only one type of sign per post; different types of message should be on separate posts. Only directly relevant auxiliary signs permitted with speed limits.
Freeway design parameters for fully managed operations (Austroads 2009a)	Co-location might be considered if geometric constraints prevent separation, driver ability to comprehend the information has been checked, and benefits outweigh disadvantages.	Preferable not to locate VSL/LCS on same gantry as static or other VMS.
TMR TRUM (2013)	Lane-based DS should be co-located with VSL/LCS; non-lane based DS may be co-located.	
Laboratory experiments		
Lerner et al. (2003)	A limited degree of co-location is allowed without causing driver information overload.	Driver information overload was likely to occur if a single sign displayed more than two destinations and/or more than two route symbols, or more than three sign panels in total.
Liu (2005)	Drivers adopted one of two scanning strategies, fixed or back-and-forth; the latter yielded better performance and suggests that drivers would be able to cope with multiple information in the one location.	

Information source	Evidence for co-location	Evidence against co-location
Cooper and Mitchell (2002)		Drivers could not always extract all the information on complex signs displayed for 2–3 s. Consistency and complexity of message affected the percentage of correct responses. Suggests possible limit for ability to extract information.
Edquist and Johnston (2008)	More than 3 traffic control devices in one scene or more than 5 in a 10 s drive increased ratings of clutter and time to detect changes in signs; this seems compatible with co-location of signs.	
Pyta and Cairney (2007)	The ‘exit closed’ message was conveyed most successfully on the co-location scenario, compared to the sequenced locations of direction signs and VSL/LCS.	
Driving simulators		
Liu, Sun and Rong (2011)	Highway guide and non-guide signs should not contain more than five pieces of information (e.g. five road names) – this is sufficient to permit co-location.	
Cooper and Mitchell (2002)	Tactical messages increased decision time by approx. 0.15 s, but strategic messages increased it by 0.45 s equivalent to adding three additional destinations. It suggests drivers can still cope with co-location provided number of directions is limited.	
Larue et al., (2013)	The CARRS-Q advanced driving simulator (ADS) was used to investigate the effects of different scenarios of dual co-location of VSL/LUMS and VMS and triple co-location of VSL/LUMS, direction signs and VMS. Changes in sign co-location and task complexity had little observed effects on vehicle dynamics variables.	Co-location increased gaze times beyond the 2 s ‘safe’ threshold for half the subjects, and resulted in some very long viewing times. BUT it is questionable whether the 2 s threshold applies in all driving conditions; it also depends on where the driver is looking.
Süsser (2004)	New multi-functional signs that flexibly combined direction arrows and flexible dynamic display panels were highly effective and well-received by drivers. They have been applied at important decision points on German motorways since 2004. They suggest that drivers are well able to cope with the level of complexity involved in co-location.	

Information source	Evidence for co-location	Evidence against co-location
Driver evaluations		
TTR (2007)	Investigated driver response to real-life motorway management system signing on M42; signs were generally well understood, and customer satisfaction levels were very high.	
Süsser (2004)	See above – drivers were highly satisfied with new signing system.	
Observation and analysis of on-road behaviour		
No studies found		

Note: Reader should refer to Austroads (2015) for further details of relevant literatures.

Studying the evidence in Table 1 suggests that the bulk of the evidence favours co-location, as follows:

- Standards, guidelines and practice

As discussed, the guidelines and standards which do not favour co-location appear to have been overtaken by developments in practice, where co-location is widely accepted.

- Driver evaluations

Driver evaluations have generally found high levels of satisfaction with new forms of complex signs.

- Experimental and simulator studies

These have generally found that drivers have been able to cope well with the amount of information likely to be presented on co-located signs and to be able to extract the required information from the sign array in time to make the required decisions. The three exceptions are:

- Cooper and Mitchell (2002), where subjects did not always manage to extract all the information from the array in the allocated time. Note however that this was based on the sign information being exposed for a limited time rather than being available over a number of seconds as it would be in real-life.

- Lerner et al. (2003) reported that driver information overload was likely to occur if a single sign displayed more than two destinations and/or more than two route symbols, or more than three sign panels in total.

- Larue et al. (2013) found that both dual and triple co-location of DS, VMS and/or VSL increased the time spent looking at the sign beyond the 2 s threshold identified by Klauer et al. (2006) in the Virginia 100-car naturalistic driving study, and in some cases this resulted in rather long viewing times.

UNSOLVED ISSUES RELATING TO CO-LOCATION

Current guidelines and most of the empirical work indicate that road users will be able to cope with co-location. The remaining issue is whether co-located signs require sufficiently long glance times to increase the risk of collisions. Two points should be considered in relation to this issue:

1. The issue is not 'can the driver extract the required information in the available viewing time?', but 'does extracting the information occupy the driver's attention for such a long

1 period (e.g. longer than 2s) that he/she is at risk of not taking in critical information from the road
2 directly in front of the vehicle?’

3 2. The extent to which looking away from the road immediately in front of the vehicle is
4 dangerous depends on what the driver is looking at instead. If the driver is looking at something
5 inside the vehicle, as is the case in many instances of distraction, then central vision (the most
6 central part of the visual field) is directed well away from the critical area in front of the vehicle
7 and the probability of detecting events in that area is very low. On the other hand, if the driver is
8 looking ahead to a gantry sign, the most sensitive part of the eye is only slightly displaced from the
9 critical area in front of the vehicle, and there is a good chance that events in that region, such as a
10 brake lights coming on, or another vehicle pushing into the lane, would register in peripheral
11 vision which would immediately trigger a direct glance in that direction. However, further
12 investigation and evidence would be required before a robust conclusion could be achieved.

13 The issues to which further research should be addressed are therefore these
14 – can drivers respond adequately to other events on the road while engaged in extracting
15 information from co-located signs, and can they respond as adequately to these events when signs
16 are co-located compared to when they are located separately? Here an extreme example of another
17 event on the road could be an emergency situation such as having a vehicle in front of the driver’s
18 vehicle brake suddenly as a traffic sign is approached.

19 **FUTHER RESEARCH EVIDENCE AND DISCUSSION ON THE IMPACT OF SIGN** 20 **CO-LOCATION UNDER EMERGENCY SITUATIONS**

21 To address the unsolved issues identified from the literature review, the NT1782 project also
22 employed the Centre for Accident Research and Road Safety (CARRS-Q) to further simulate
23 drivers’ ability to respond to an emergency event while extracting information from co-located
24 signs (Austroads 2015). The CARRS-Q ADS component extended the work of Larue et al. (2013)
25 by adapting the previously used simulation of a section of the Ipswich Motorway in Queensland,
26 Australia. Adaptations included an increase in traffic volume and the occurrence of an emergency
27 event towards the end of each scenario. Some further development of the ADS program was
28 conducted to incorporate the required sign arrangements. The simulator is capable of collecting a
29 wide range of driving performance measurements and driver eye movements.

30 The simulator study employed a repeated measures design in order to compare
31 participants’ behaviour and responses, three scenarios were developed and tested: no sign
32 co-location, with dual co-location and with triple co-location (Austroads 2015). Both normal
33 motorway driving and an emergency situation were considered. For each scenario participants
34 were instructed to drive to a given destination. Each scenario contained a lane closure and changes
35 in speed, indicated by the VSL/LCS sign. An emergency event occurred towards the end of each
36 scenario in conjunction with a change in VSL information. The emergency event was a vehicle in
37 front of the participant’s vehicle braking suddenly as a traffic sign was approached. After driving
38 each scenario participants completed the NASA TLX (task load index) (Hart and Staveland, 1988)
39 and after all three scenarios had been driven participants completed a survey asking their opinions
40 of triple co-located signs. Full study details can be found in Appendix A of Austroads (2015).

41 Some key findings and further discussions are summarised as follows:

42 1. Overall, participants responded safely to emergency situations while they were
43 extracting information from co-located signs. However, there was some evidence of slowed

1 response to the emergency situation for some individuals when triple co-located signs were
2 presented. Therefore although there is no clear evidence that triple co-location gives rise to higher
3 risk than dual co-location this proposition should be viewed with caution. Further evaluation of
4 triple co-location in a real-life setting should not be ruled out.

5 2. There was no difference in participant's general driving behaviour under normal
6 motorway driving conditions (no emergency).

7 3. Drivers appeared equally able to select the correct destination whether signs were
8 co-located or not. Complying with a posted speed limit change occurring in conjunction with an
9 emergency event was not affected by sign co-location.

10 4. The ADS study in Austroads (2015) found that in all three tested scenarios, the
11 maximum time spent looking at any one sign was less than this 2 s threshold. In contrast, Larue et
12 al. (2013) reported that both dual and triple co-location increased the time spent looking at the sign
13 beyond the 2 s threshold. This 2 s threshold was identified by Klauer et al. (2006) as being critical
14 for safe driving, and in some cases this could result in rather long viewing times. However, wince
15 neither simulator study identified any significant differences in the maximum eye gaze time
16 between dual and triple co-locations, it is probably safe to conclude that triple co-location did not
17 lead to higher risk of long eye gaze on one sign, when compared to dual co-location.

18 5. It appears that Australian drivers tend not to like the complicated triple co-located signs
19 based on the self-reported survey which suggested that there was perceived increase in information
20 load. Furthermore, the stressfulness item of the NASA-TLX was greater following the triple
21 co-location drive. However, the triple co-located signs are not currently in use in Australia and so
22 would have been completely new to most participants. Perhaps an information campaign aimed at
23 drivers would improve public acceptance and comprehension of the triple co-located signs.

24 **CONCLUSIONS AND RECOMMENDATIONS**

25 By consolidating all findings from the literature review, the analysis of evidence for and against
26 sign co-locations, and the recent ADS study (Austroads 2015) it is concluded that:

27 1. Although some standards and guidelines do not permit co-location of sign information,
28 these have been overtaken by current practice and more recent guidelines from other jurisdictions.
29 Particularly, dual co-location of VSL/LCS, VMS and/or DS is a practical arrangement which is
30 widely practised. Additionally, triple co-location of VSL/LCS, VMS and directional signs is
31 currently practised along UK motorways.

32 2. Experimental research suggests that dual co-location appears to present no difficulties
33 to drivers, either when VSL/LCS is presented along with a DS or with a VMS. It is suggested that
34 dual co-located signs should be provided along a route and/or throughout a network of routes in a
35 consistent manner in response to drivers' information needs.

36 3. Experimental research also suggest that with triple co-location of signs:

- 37 – most aspects of the driving task are not adversely affected
- 38 – in general, drivers responded adequately to an emergency situations in a simulator,
39 although there is some suggestion that for some individuals responses may be slower with
40 triple co-location.

41 4. The positive evidence from the review of current practice and guidelines and suggest
42 that, for the time being at least:

- 1 – triple co-located signs should be used only in situations where other arrangements for
2 displaying essential sign information are impractical
3 – drivers’ behaviour and reactions to the signs should be monitored closely in the period
4 following installation.

5 However, these findings should not rule out on-road trials with triple co-located signs.

6 5. The simulator study reported in Austroads (2015) found that Australian drivers did not
7 like the complicated triple co-located signs, although they were generally able to cope with the
8 information displayed on the sign. Over time, as drivers become more familiar with triple
9 co-located signs, drivers’ ability to absorb information and attend appropriately to the signs may
10 improve, and the degree of difficulty that they experience decrease.

11 Based on the overall findings from the paper the authors also suggest Austroads and
12 relevant stakeholders to consider the sign colocations in their future decision-making process such
13 as:

14 1. Austroads should inform Standards Australia of the above findings and suggest that
15 consideration be given to the inclusion of dual co-location of VSL/LCS, VMS and/or DS within
16 the Australian Standard AS 1742 *Manual of Uniform Traffic Control Devices* (Standards Australia
17 2014).

18 2. Austroads Traffic Management Working Group (TMWG) should consider
19 incorporating the above findings into the next revision of Austroads *Guide to Traffic Management*
20 – *Part 10* (Austroads 2009b) Section 4: Traffic signs and Section 5: Electronic signs.

21 3. Road agencies should conduct field trials of triple co-locations to further monitor and
22 evaluate drivers’ behaviour, comprehension and responses in real-life settings. Triple co-located
23 signs should only be considered in situations where other arrangements for displaying essential
24 sign information are impractical.

25

26 **ACKNOWLEDEMENT**

27 This paper is based on initial findings from an Austroads funded project *NTI782 Ability to Absorb*
28 *Information through Electronic and Static Signs*. The authors would like to acknowledge the
29 generous contribution from the project manager and reference group members including Kelvin
30 Marrett, Mana Tavahodi, Anna Clancy, Meredyth-Ann Williams, Jeremy Burdan, David
31 Jorgensen, Jon Douglas, Aftab Abro, Rifaat Shoukrallah, Dave Landmark, Maurice Burley, Joanne
32 Chang and Steve Clark.

1 **REFERENCES**

- 2
- 3 1. Austroads 2009a, *Freeway design parameters for fully managed operations*,
4 AP-R341-09, Austroads, Sydney, NSW.
- 5 2. Austroads 2009b, *Guide to traffic management: part 10: traffic control and*
6 *communications devices*, AGTM10-09, Austroads, Sydney, NSW.
- 7 3. Austroads 2015, *Ability to absorb information through electronic and static signs*,
8 AP R485-15, Austroads, Sydney, NSW.
- 9 4. Cooper, BR & Mitchell, J 2002, *Safety and effectiveness of the wider use of VMS:*
10 *final report*, report no. 526, TRL Ltd., Crowthorne, UK.
- 11 5. Department of Transport and Main Roads 2013, *Traffic and road use manual*
12 *(TRUM): technical notes 2.18: interim guidelines for the co-location of gantry*
13 *mounted variable speed limit signs with advance direction signs on motorways*,
14 TMR, Brisbane, QLD.
15 <http://www.tmr.qld.gov.au/Business-industry/Technical-standards-publications/Traffic-and-Road-Use-Management-manual/Traffic-and-Road-Use-Management-manual-under-dev.aspx>. Accessed 25 Feb., 2015.
- 16 6. EasyWay 2012a, *Variable speed limits deployment guidelines*, EasyWay, Spain.
17 <http://dg.easyway-its.eu/DGs2012>. Accessed 25 Feb., 2015.
- 18 7. EasyWay 2012b, *Variable message signs harmonisation*, principles of VMS
19 design: deployment guideline, VMS-DG01, EasyWay, Spain.
20 [http://www2.liikennevirasto.fi/ew/ew-vms-dg01_principlesofvmsdesign_01-02-00](http://www2.liikennevirasto.fi/ew/ew-vms-dg01_principlesofvmsdesign_01-02-00.pdf)
21 [.pdf](http://www2.liikennevirasto.fi/ew/ew-vms-dg01_principlesofvmsdesign_01-02-00.pdf). Accessed 25 Feb., 2015.
- 22 8. Edquist, J & Johnston, I 2008, 'Visual clutter in road environments: what it does,
23 and what to do about it', *Australasian road safety research policing education*
24 *conference*, 2008, Adelaide, South Australia, Department for Transport, Energy
25 and Infrastructure, Walkerville, SA, 6 pp.
- 26 9. Federal Highway Administration 2011, *Managed lane chapter for the freeway*
27 *management and operations handbook*, FHWA, Washington, DC, USA.
28 http://ops.fhwa.dot.gov/freewaymgmt/publications/frwy_mgmt_handbook/revisio
29 [n/jan2011/mgdlaneschp8/sec8.htm](http://ops.fhwa.dot.gov/freewaymgmt/publications/frwy_mgmt_handbook/revisio). Accessed 25 Feb., 2014.
- 30 10. Federal Highway Administration 2012, *Manual on uniform traffic control devices*
31 *(MUTCD)*, FHWA, Washington, DC, USA. <http://mutcd.fhwa.dot.gov/index.htm>.
32 Accessed 25 Jan 2015.
- 33 11. Grant, D 2007, Case study: M42 active traffic management (ATM), presentation,
34 Highways Agency, London, UK.
35 <Http://www.psrc.org/assets/537/ATMpresCaseStuday6.07.pdf>. Accessed 25 Feb.,
36 2015.
- 37 12. Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load
38 Index): Results of empirical and theoretical research. *Advances in psychology*, Vol
39 52, pp.139-183, Elsevier B.V., Amsterdam, Netherlands.
- 40 13. Highways Agency 2014, *Smart Motorways*, Highways Agency, London, UK.
41 <https://www.gov.uk/government/collections/smart-motorways>. Accessed 28 Feb.,
42 2015.
- 43 14. Klauer, SG, Dingus, TA, Neale, VL, Sudweeks, JD & Ramsey, DJ 2006, *The*
44 *impact of driver inattention on near-crash/crash risk: an analysis using the 100-car*
45

- 1 *Naturalistic Driving Study data*, report no. DOT HS 810 594, National Highway
2 Traffic Safety Administration, Washington DC, USA.
- 3 15. Lerner, ND, Llaneras, RE, McGee, HW, Taori, S & Alexander, G 2003, *Additional*
4 *investigations on driver information overload*, NCHRP report 488, Transportation
5 Research Board, Washington DC, USA.
- 6 16. Liu, YC 2005, 'A simulated study on the effects of information volume on traffic
7 signs, viewing strategies and sign familiarity upon driver's visual search
8 performance', *International Journal of Industrial Ergonomics*, vol. 35, no. 12, pp.
9 1147-58.
- 10 17. Liu, B, Sun, L & Rong, J 2011, 'Driver's visual cognition behaviors of traffic signs
11 based on eye movement parameters', *Journal of Transportation Systems*
12 *Engineering and Information Technology*, vol. 11, no. 4, pp. 22-7.
- 13 18. Pyta, V & Cairney, P 2007 '*Driver comprehension and response to the combined*
14 *direction and variable speed limit signs for the Gateway Motorway*', contract report
15 VC73823-1, ARRB Group, Vermont South, Vic.
- 16 19. Larue, G. Schramm A, Smith, S. S., Lewis, I & Rakotonirainy, A 2013, 'The
17 impact of co-locating regulatory and directional signs on driver performance',
18 *Transport Research Board 92nd Annual Meeting*, No13-3462, Transport Research
19 Board, Washington DC, USA.
- 20 20. Süsser, F 2004, 'New multi-functional display panels for network control on
21 German motorways', *European congress on intelligent transportation systems and*
22 *services*, 4th, 2004, Budapest, Hungary, Ertico, Brussels, Belgium, 6 pp.
- 23 21. Standards Australia 2014, AS 1742 set-2014, *Manual of uniform traffic control*
24 *devices*, Standards Australia, Sydney, NSW, Australia.
- 25 22. Transport and Travel Research 2007, '*Driver reaction to active traffic management: final*
26 *report*', prepared for Highways Agency, TTR, London, UK.
- 27