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# Technical Note

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| Subject | **Western Ring Route Variable Speed Limit Study – Stage 1** | | |

## Stage 1 – Establish the case for variable speed limits

## Executive summary

There have been a number of studies carried out on speed limits on State Highway (SH) 16. These have resulted in the highlighting of geometric, safety, capacity and congestion issues along the route.

To mitigate these deficiencies in the network it is recommended that variable speed limit signage be investigated further. The benefits of variable speed limit signs would be;

- Reduced weaving
- Increased capacity by optimising traffic flow
- A reduction in accidents
- Improved journey time reliability on the network
- Better network management response to incidents
- Reduced negative effects resulting from substandard shy lines
- Mitigation of the negative effects resulting from short ramp spacing
- $CO_2$ emission savings/benefits

We recommend that Stage 2 of the study (detailed on pages 9 and 10 of this Technical Note) be progressed.

### *Background*

With the opening of the Waterview Tunnel connection in 2017, connecting SH20 with SH16, and thus completing the NZ Transport Agency's wider Western Ring Route (WRR), an alternative route to Auckland's State Highway 1 will be available to motorists. The opening of this alternative route will significantly modify travel behaviour patterns in Auckland for short, medium and long distance trips in and around the region.

The changing character and geometric conditions of the WRR State Highway network prompted a study, undertaken by Aurecon in 2013, of the posted speed limit to determine what would be suitable for the safe and efficient operation of the network post construction. This study highlighted a number of deficiencies and inconsistencies in the network and proposed a static speed limit strategy for addressing these issues. Although considered to be outside of the scope of the study, the implementation of a variable speed limit for the area was mooted for further consideration of its suitability as a network management tool.

Following on from the 2013 work, the purpose of this current study will focus on the key characteristics of the network which steer towards a dynamic approach to speed and network management throughout the study area. This assessment will investigate how any such variable speed limit should be implemented so as to ensure uniform adherence. Findings from the 2013 assessment will be used to inform this study and help support the case for further investigation and possible implementation.

***Purpose of this technical note***

In order to assess the merits, or otherwise of the effectiveness of a variable speed limit (VSL) on SH16, principally between the Central Motorway Junction (CMJ) and Great North Road interchange, Aurecon is undertaking a three stage investigation using the framework developed in the NZ Transport Agency's business case approach. Using the business case as a template allows an early opportunity to influence the direction of the investment and can be used to seek early approval to undertake more detailed analysis and planning as part of a subsequent detailed business case.

This Technical Note forms Stage 1 of the study. The purpose is to establish the appropriateness of VSL in addressing the operational issues identified on this section of SH16. The aim of this stage of the study is to succinctly establish the problem facing users on this section of the highway network to evaluate whether variable speed limits would provide a suitable outcome. This study will focus on the suitability of variable speed limits for network management only. Other managed motorway tools such as enforcement and lane control signals will not be covered as part of this work.

***Previous assessment***

As part of the speed limit study undertaken by Aurecon in 2013 signed static speed limits of 80 and 100km/h were ultimately proposed throughout the study area. An excerpt from the completed report[1] is included below.

*"Based on the analysis conducted a number of aspects support a reduced speed limit in order to improve traffic performance and to reduce the severity of crashes. These savings could be claimed by reducing the speed limit on any section of road and are not overly specific to the studied section of SH16.*

*Based on the geometrics of the proposed motorway and the observed driver behaviour through similar sections most of the study length is suited to a 100km/h speed limit with the exception of Great North Road Interchange which, due to its reduced standard and added complexity, does warrant a reduced speed limit. This limit could be extended through to the St Lukes Interchange to incorporate the west facing ramps which create a reduced speed limit environment that is in context and therefore likely to have a higher level of compliance.*

*The debatable section however is from the CMJ through to St Lukes being a 2km length with little side friction and few geometric constraints. A reduced speed limit through this section would likely feel unwarranted which would result in a high level of non-compliance. It is noted that the minimum length of 100km/h speed limit is 2km and therefore this section of road would fit within those parameters to be posted differently from the Great North Road interchange and the CMJ.*

*To this extent it is proposed that the section of SH16 between the CMJ and that Great North Road Interchange be split into 3 sections as shown in Figure 4-1."*

[1] Posted Speed Limit Study, Aurecon, 4 December 2013

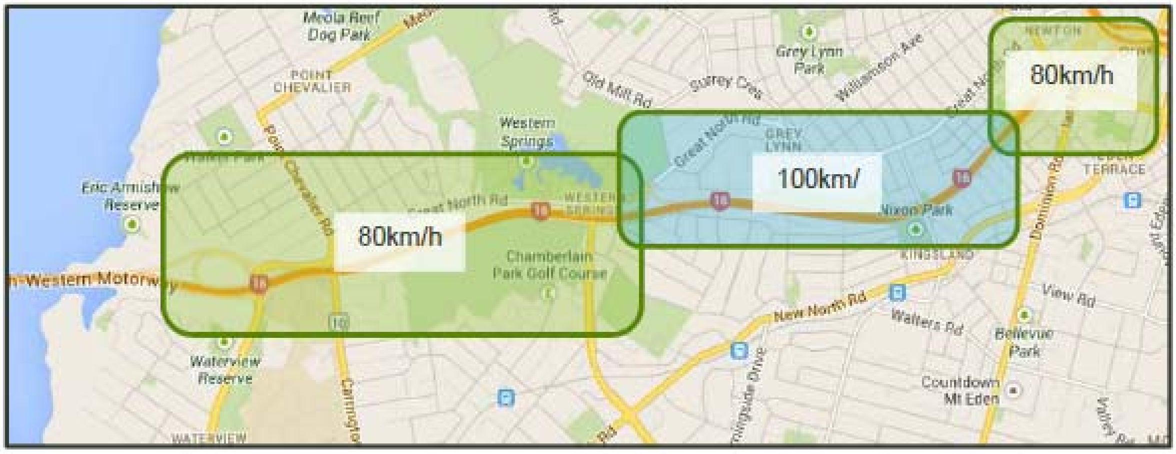



**Figure 1 – Proposed Static Speed Limits (Posted Speed Limit Study, Aurecon, 4 December 2014)**

However, the report also recognised that *"...during the congested and unbalanced situations a 60km/h speed limit may be more appropriate and therefore further consideration should be given to the implementation of a variable speed limit, or a peak time temporary speed limit"*

***Understanding the Problem – What is a suitable speed limit?***

As part of the Western Ring Route (WRR) Project the NZ Transport Agency are making significant alterations to the existing motorway network creating a new interchange at Waterview, forming a connection between SH16 and SH20, as well as a significant amount of upgrading work to existing interchanges on SH16 between St Lukes Road, to the east, through to Lincoln Road in the west. The Transport Agency are improving geometric conditions on the existing motorway to improve design standards and geometric consistency, however, the new infrastructure will add complexity to the driving environment but also increase traffic volumes and weaving movements on this section of the network.

In determining a suitable permanent speed limit to meet the character and changing geometric conditions of this section of SH16, previous work completed by Aurecon assessed certain key design and geometric criteria outlined in *Land Transport Rule 54001: Setting of Speed Limits*.

Accordingly, a number of criteria were assessed to determine a suitable permanent speed limit, including:

- Carriageway characteristics such as weaving, ramp spacing and lane allocation
- Crash data
- Speed data

***Carriageway Characteristics***

**<u>Weaving – St Lukes to Great North Road</u>**

It has been reported that during both peak and inter-peak periods heavy demand for the Great North Road off-ramp results in lane saturation in the outer most lane of the motorway approaching a demand of some 2,700vph; with 1,800vph being the desirable maximum and 2,000vph being the absolute maximum.

In addition to the heavy use of the outer lanes a significant amount of weaving is expected to occur between St Lukes and the Great North Road on-ramp. To illustrate this an indicative weaving diagram was created and is shown in Figure 1.

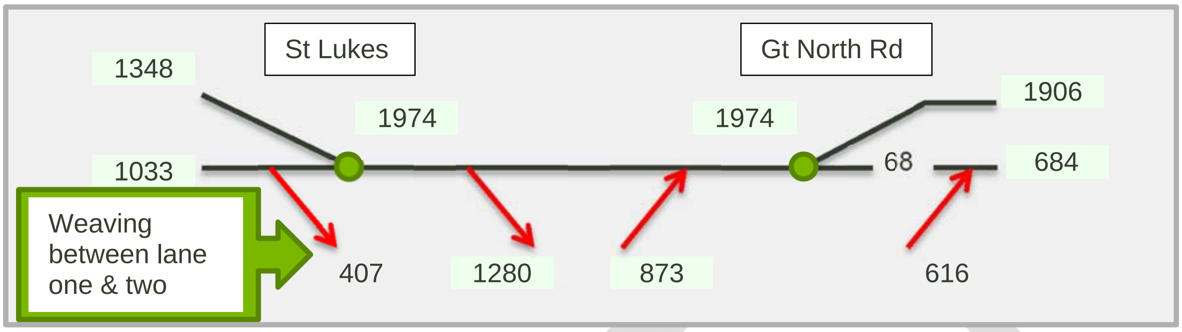



**Figure 1 – Future St Lukes to Great North Road Weaving Volumes (Per Hour)**

As can be seen in Figure 1 above there are a number of weaving issues predicted to occur as a result of conflicting user destinations. The primary conflict is expected to be the movements from the St Lukes Road westbound on-ramp weaving through traffic on SH16 wanting to take the Great North Road off-ramp.

A possible result of this interaction is if the Great North Road off-ramp becomes over capacity and stationary vehicles back onto the motorway, this would cause any users wanting to take the SH20 tunnel to stay away from the left most lane and then weave across under Carrington Road.

This environment is likely to result in road users experiencing slower speeds on the nearside (left) lanes compared to the offside lanes. This differential in speed is undesirable and leads to flow breakdown.

Based on the predicted weaving between St Lukes and Great North Road, two undesirable conditions are forecast to arise:

- Stationary vehicles in the left lane between St Lukes and Great North Road
- High levels of weaving on the substandard (based on intersection spacing and weaving demand) section of road under Carrington Road.

**Ramp Spacing**

An assessment of the proposed SH16 configuration, including ramp spacing, was analysed as part of the previous work undertaken by Aurecon in 2013. The following table lists the ramp spacing proposed on the North-western motorway heading away from the CBD (westbound).

Based on Austroads Traffic Management Part 6, successive on/off-ramps should be separated by a certain length depending on the number of lanes on the mainline. This separation gives due consideration of the turbulence associated with on/off-ramps and the additional weaving required on wider roads. Table 1 below lists the ideal separations and Table 2 (overleaf) lists the spacing's which exist on SH16 westbound within the study area. Those separations between on and off-ramps which fall short of the prescribed minimums within Austroads are highlighted in yellow.

| Number of Through Lanes | Ideal Minimum Ramp Spacing |
|---|---|
| 2 Lanes | 900m |
| 3 Lanes | 1,200m |
| 4 Lanes | 1,500m |

**Table 1 - Ideal Ramp Spacing (Austroads Traffic Management Part 6)**

For the proposed works on the North-Western Motorway (SH16) three sections between the CMJ and Royal Road will have sub-standard spacing. The two areas of most concern are the section between St Lukes and Great North Road and the section between the Patiki on-ramp and Te Atatu Interchange.

Neither of these sections has an auxiliary lane, however, the section between St Lukes and Great North Road has intentionally been designed to incorporate an auxiliary lane and only requires signage and line-marking changes to utilise this provision.

| North-Western Motorway - Westbound | | |
|---|---|---|
| On-Ramp | Off-Ramp | Separation (m) |
| Newton ( 4 lanes) | St Lukes | 1900 |
| St Lukes (4 lanes) | Great North | 750 (Substandard) |
| SH20 (5 lanes) | Rosebank | 1400 (Substandard) |
| Patiki (4 lanes) | Te Atatu | 1100 (Substandard) |
| Te Atatu (3 lanes) | Lincoln | 1400 |
| Lincoln (2 lanes) | Royal | 1750 |

**Table 2 - North-Western Motorway Ramp Spacing (Posted Speed Limit Study, Aurecon, 2013)**

***Crash Data***

Previous analysis of crash data for the St Lukes to Great North Road[2] section of SH16 revealed a prevalence of rear end and side swipe type crashes. These are generally caused by high volumes of peak time traffic, in conjunction with flow turbulence caused by closely spaced on and off ramps. This section of carriageway has a sub-standard geometry with the existing (at time of data capture) sight distance of 115m corresponding to a design speed of 65 km/h. As part of the WRR project, this will be upgraded to 85km/h, however, this section will be flanked with sections of carriageway designed to a higher geometric standard.

Previous reporting concluded that there are two section of road that have rear end and side swipe accident related issues that are not confined to peak hour congestion, namely from SH20 (Great North Road) through to St Lukes, and from St Lukes through Newton Gully toward the CMJ.

The above report went on to discuss the crash history on the Great North Road and their implication:

[2] Posted Speed Limit Study, Aurecon, 4 December 2013

*"For the Great North Road section, 13 (68%) of the westbound crashes occur on the approach to the Great North Road off-ramp as SH16 passes under Carrington Road. In the eastbound direction 4 (40%) of the crashes occur on the Great North Road on-ramp and further 4 (40%) within 400m of the end of the merge.*

*…this is one of the few sections of SH16 that is not being upgraded and retains the existing substandard geometry more suited for a 65km/h design speed.*

*In addition to the high crash rate and the substandard geometry this section is also expected to have high volumes of conflicting weaving movements in both the westbound and eastbound direction…*

*It is seen that a lower posted speed limit would go some way towards addressing the safety issues through this section by effectively increasing the weaving lengths provided for the various ramp merges and diverges in this area. In addition to this a lower speed limit would be more in context with the road geometry which is notably lower through the Great North Road interchange than on the adjoining sections."*

In the context of the proximity of this section to the Waterview tunnel, the risk and consequence of flow breakdown is more critical than elsewhere on the network.

Similarly, from St Lukes to Newton Gully (eastbound) the 2013 report states:

*"…73% of the weaving related accidents are in the eastbound direction. In addition to this the eastbound direction experiences an increased number of crashes during the morning and evening peak, 24% and 16% of total crashes respectively.*

*It is important to note that the crash analysis only extends as far as the Newton Road on/off-ramps and so most of the CMJ ramps are not included in these results.*

*There are two main issues that contribute to this high crash rate which are as follows:*

*The high number of potential movements with the SH16 motorway splitting into 5 separate ramps.*

*Unbalanced ramp capacity at the CMJ;*

*The high number of potential movements is inherent of the CMJ's function and although physically demanding for user, is thought to be the lesser of the two main issues. In part the confusion of the multiple destinations is mitigated by having each lane with a single destination; however this results in very high demand on some lanes and very low demands on others.*

*In terms of the unbalanced capacity, the SH16 eastbound approach to the CMJ is dominated by two flows, the SH16 to Hobson St / north and SH16 to south. During the evening peak all of the flows reduce however the unbalance remains…'*

Additionally, a number of other carriageway characteristics have been identified along this section of SH16 and further contribute to operational performance;

- Operating speeds

  Under free-flow conditions vehicles operate 3km/h under the posted speed limit in 100km/h sections. In the 80km/h sections vehicles have been recorded to operate 5km/h over the posted limit.

- Road geometry

  Existing geometry provides for sight distances suitable for speeds of 85-110km/h. The geometry of SH16 in the vicinity of the Great North Road Interchange is currently suitable for speeds of 70km/h resulting in an 'out of context' driving environment. The geometry in this section is to be largely left as per the existing layout, therefore there is an increased likelihood of crashes due to the increase in traffic demand and complexity of the new SH20/SH16 connection.

- Shy-lines

  Shy lines are designed for 110km/h over this section of SH16 with the exception of Great North Road Interchange which suits a 60km/h operating speed with an expected resulting capacity reduction of some 5%.

***Understanding the problem and why it is important to address.***

As a result of the issues outlined above high numbers of weaving related crashes are occurring on SH16 over the area of this study. As deduced through previous assessments[3] this high crash rate is primarily attributed to congestion in the area resulting in high speed differentials. Congestion also contributes negatively to network efficiency, resulting in unreliable journey times and increased $CO_2$ emissions.

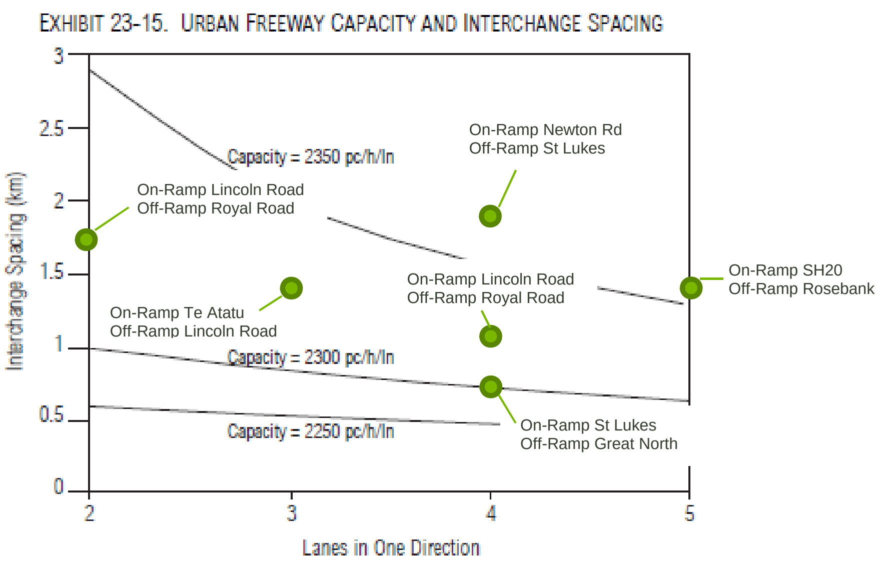



**Figure 3 – Highway Capacity Manual, Urban Freeway Capacity and Interchange Spacing Graph with SH16 Study Area Interchanges (westbound)**

Figure 3 above shows the inconsistencies of capacity over the study area on SH16, in the westbound direction. The random nature of the spread of capacity between each interchange along this section varies from 2,300pc/h/ln to 2,400pc/h/ln. This results in changes in speed during shoulder peak periods.

***Understanding Flow Breakdown and its consequences***

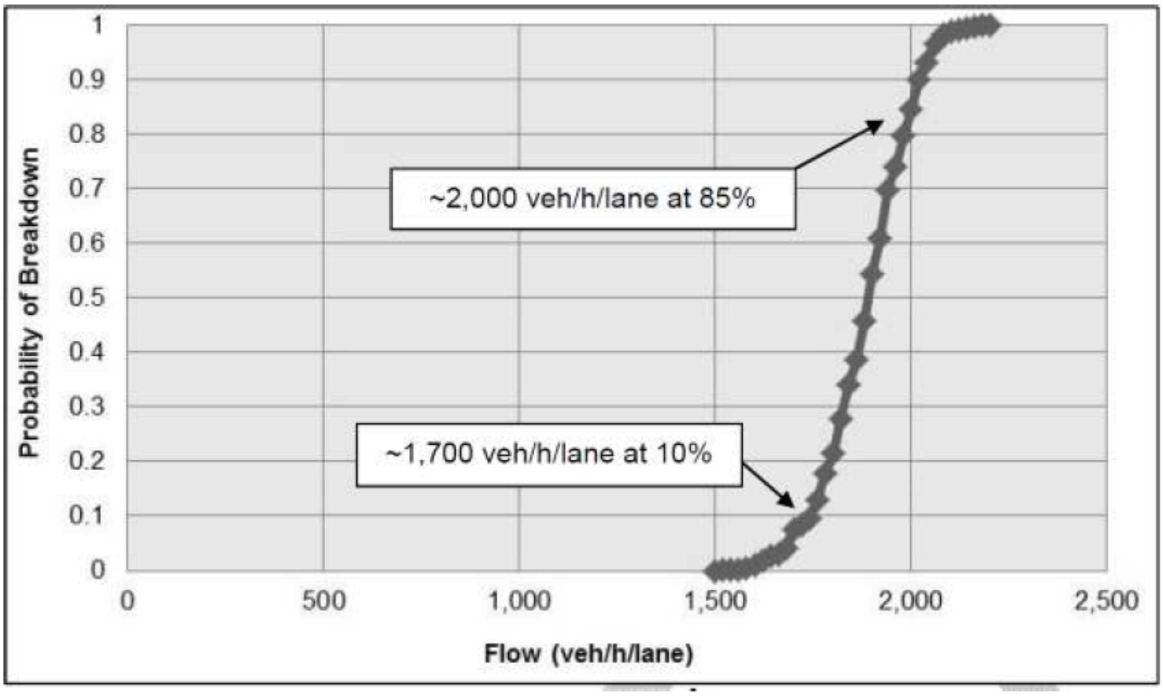
Areas where a mainline flow capacity drop or 'flow breakdown' occur are often complex and can be triggered by various events and factors, including the following

- Rapid increases in traffic density on a section of highway;
- Merging traffic at ramps or at lane drops;

[3] Posted Speed Limit Study, Aurecon, 4 December 2013

- Weaving and lane changing, and
- Geometric characteristics of the road such as gradients and transitions where drivers need to adjust their speed, and low radius curves.
- Combinations or close arrangement of features (for example, one feature such as narrow lanes may not reduce capacity but several such features in succession may start to slow traffic flow)

Figure 4 below has been sourced from Main Roads Western Australia and shows the probability of flow breakdown occurring as traffic demand increases




Source: Main Roads Western Australia

**Figure 4 – Probability of flow breakdown**

As previously reported, the SH16 Great North Road eastbound on-ramp is predicted to release some 1,500vph from the on-ramp and combine with around 1,200vph on the outer lane. This results in some 2,700vph of demand funnelled through one lane of traffic which, as highlighted in Figure 4 above, pushes the probability of flow breakdown to well over 100%.

The consequence of flow breakdown on a network include increased $CO_2$ emissions, inefficiency in the network resulting in unreliable journey times and non-conformance to posted speed limits.

***Establish the benefits (non-monetary) that solving the problem will deliver.***

The key benefits of variable speed management include;

- Reducing speed so that all lanes of traffic are travelling at a similar speed, thus reducing the propensity to weave
- By addressing this issue early enough keeps capacity at the optimum point of the speed flow curve

Secondary benefits include;

- A reduction in accidents, and the resulting negative effects on network operations, caused by nose to tails weaving manoeuvres

- Mitigation of negative effects resulting from variable traffic demand and peak flows
- Dynamic manipulation of speed to suit the environmental conditions and incidents on the network
- Improved efficiency and mitigation of effects of substandard shy lines
- Mitigation of negative effects resulting from weaving/merging and associated undesirable design attributes
- Mitigation of the negative effects resulting from short ramp spacing
- Improved journey time reliability on the network
- $CO_2$ emission savings/benefits

***Establish the response that will deliver these benefits.***

The implementation of a variable speed limit system has been internationally proven to provide a more robust method of managing varying traffic volumes than a static speed limit sign approach. Furthermore, a VSL system can significantly improve the operational performance of motorways by managing traffic flow dynamically, resulting in more reliable journey times and vehicle throughput during peak periods. By adjusting speed limits to suit traffic demand (including tidal flow demand characteristics), weather conditions and in response to unplanned incidents on the network traffic flow breakdown is avoided and network performance is managed effectively.

The following excerpts from Vic Roads and The Department of Transport and Main Roads in Australia provide further commentary on the use of VSL on motorway networks.

***Department of Transport and Main Roads, Queensland, Australia***

Variable Speed Limit and Lane Control Signs (VSL/LCS) and associated site controllers may be used as:

- part of an overall traffic management system to detect, monitor, manage and control traffic on the road network by altering the posted speed limit and/or lane control status throughout a defined zone, and as
- a standalone device able to be controlled manually during commissioning, maintenance and/or special operating activities.

***Vic Roads, Managed Freeway Guidelines, August 2014***

Variable Speed Limits (VSL) can assist in maximising safety in adverse conditions, such as high winds, roadworks and incidents. VSL can also assist in maximising capacity during heavy demand – this is best achieved in conjunction with Freeway Ramp Signals (FRS). Careful coordination of FRS and VSL is required to achieve optimum outcomes and FRS will perform the primary control function. VSL can also be provided as part of an integrated Speed and Lane Use Management System.

Variable Speed Limit (VSL) systems can improve road safety and traffic flow by displaying suitable safe regulatory speed limits under different conditions. These conditions can relate to environmental conditions such as wind or rain, incident/event or roadworks conditions, or the density of traffic flow. The use of VSL for roadworks and incident conditions assists in the provision of a safe working environment, but does not remove requirements for additional signs and traffic management measures. VSL are communicated to motorists by a series of roadside electronic variable speed limit signs. All VSL installations are to have variable signs mounted on the entry ramps to advise entering motorists of the applicable speed limit in the merge area.

VSL can be provided on freeways subject to a business case identifying:

- enhanced safety
- enhanced incident response

- improved capacity.

Overhead mounting of VSL should be considered under appropriate geometric and demand conditions.

On sections of urban freeway with both VSL and ramp signals, it is expected that ramp signals will play a greater role in optimising productivity, with VSL assisting. VSL would play a primary role in the provision of safe conditions, supported by ramp signals.

***Vic Roads, Managed Freeways Handbook, July 2013***

The modes of VSL initiation and operation within an integrated system need to vary according to the nature of the circumstance requiring the VSL activation. A hierarchy of control for initiating VSL within the VSL system needs to ensure that a speed limit can operate independently to address specific traffic management needs. For example during an event (incident, high winds, roadworks or planned events) the VSL needs to be able to activate independently to manage safety. However, under free-flow conditions the VSL would not activate until initiated to improve the ability to manage flow and efficiency.

***Recommendation***

As demonstrated in this technical note, sufficient justification exists for further investigation into the implementation of a variable speed limit on SH16 in response to well documented geometric issues on the state highway network coupled with the future increase in traffic demand - as a result of the completion of Waterview Connection - and associated major interchange and carriageway upgrade works along the Western Ring Route. VSL will also allow for appropriate dynamic response to incidents on the network, outside of peak operating conditions, to smooth traffic flow and improve journey time reliability.

The following stages of this study are outlined below;

**Stage 2 - Information Gathering and the case for Variable Speed Limit Signage (VSLS)**

Stage 2 comprises a gap analysis and information gathering on example VSLS schemes currently operational. This would recommend a series of possible outcomes that meet the requirements of this corridor. We suggest this takes the form of an Indicative Business Case to ensure consistency with NZ Transport Agency requirements.

The main areas to consider in Stage 2 include:

- Undertake a gap analysis which investigates the existing and proposed infrastructure on SH16 and the Waterview Connection project, including signage, gantries and communication technology. Typical considerations would include:
  - The existing and proposed lane control signals (LCS) on SH16 to determine the extent of the need for variable speed limit signs (VSLS) based on the current known problems including sections where significant weaving takes place on SH16.
  - Traffic control device (TCD) rules – Is this an approved application for the state highway network? What are the terms and conditions associated with its use?
- Undertake a desktop exercise to establish the typical infrastructure requirements necessary to support VSLS technology. This would reference VSLS systems in Wellington, the United Kingdom, Australia and Sweden. We have knowledge of, or experience working with various systems in each of these the countries. We would also consider at this stage the typical operational impacts of reducing the speed limit to 80km/h or below.

We propose the deliverable under Stage 2 is a report that outlines the extent of the problem, presents a clear understanding of the cause of the problem, the benefits of the intended solution and demonstrates the effects of VSLS and presents the gap analysis. This allows us to integrate the work done to date, the gap analysis and the best practice in use elsewhere under the guidance of the business case philosophy. This would be completed under contract PA2703, Western Ring Route Umbrella Project Management – SH16 Coordination Support Role.

**Stage 3 – Indicative Business Case**

Based on Stages 1 and 2 and consistent with the content of the Indicative Business Case, we suggest this process identifies a preferred way forward as part of the short-listed alternatives. Ideally, the development of a preferred outcome(s) would be in a workshop environment. This stage would also develop an anticipated benefit cost ratio and determine the requirements still to be addressed as part of the business case development.