Not all Roads are Created Equal: A Framework to Align Travel Speeds with Road Function, Design, Safety and Use

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Abstract

The newly developed Speed Management Framework, introduced as part of New Zealand Transport Agency's Speed Management Guide, provides a single assessment method for determining safe and appropriate speeds at a network level. The framework aims to better align travelling speeds with road function, design, safety and use, while linking into wider planning and investment programmes. This paper presents the findings of applying the framework to the Waikato region, including analysis of the assignment and prioritisation of intervention strategies to road sections where speed management interventions have high benefit safety and efficiency opportunities. This paper will be of interest to all those involved in network management and those interested in understanding the potential safety benefits of speed management interventions.

Introduction

In September 2015, the New Zealand Transport Agency (the Agency) published the draft Speed Management Guide, which is an Agency responsibility under the second Safer Journeys Action Plan (2013-15). In order to progress the guide to final status, the Agency initiated a Speed Demonstration Project in the Waikato Region to demonstrate the guide and inform the refinements to the newly developed speed management framework published in the draft guide. The Waikato is one of the worst performing regions for road safety outcomes in New Zealand and has been subject to considerable focus for improving safety outcomes in recent years. The demonstration therefore also provided technical support to the Waikato Regional Council and local Road Controlling Authorities (RCAs) which had been progressing a speed management project for some time. The Waikato Speed Demonstration Project is an essential element in proving the robustness of the assessment framework and building confidence in the process, both in the Waikato Region and also for other regions observing the demonstration.

Speed Management Guide

The fundamental premise of the Speed Management Guide is to reduce deaths and serious injuries by determining vehicle speeds that are safe and appropriate for the function, design, safety and use of each road. It is designed to contribute to the 'Safe Speeds' pillar of the Safe System approach to road safety and to network efficiency where that is appropriate according to the road classification. It is important to acknowledge that the safe and appropriate speeds identified in this Guide are not fully safe system compliant speeds. Whilst they represent a strong move in the right direction towards safer speeds, there will still be many roads without directional separation that are assigned travel speeds in excess of 70km/h.

The stated objectives of the Speed Management Guide are to:

- *Ensure a consistent sector-wide approach is adopted to manage speeds so they are appropriate for road function, design, safety, use and the surrounding environment; and*

- *Help RCAs and other system designers identify and prioritise the parts of their networks where better speed management will contribute most to reducing deaths and serious injuries, while supporting overall economic productivity.*

- *Support a new conversation on speed by demonstrating that not all roads are equal*

The Speed Management Guide contains a step by step Speed Management Framework to help RCAs plan, invest in and operate an effective speed management plan. It outlines how speed management can achieve both safety and efficiency, and enable RCAs to effectively engage with their communities to build support for an evidence-based, network-wide strategic approach to achieve these twin outcomes.

Speed Management Framework

The Speed Management Framework is primarily governed by the One Network Road Classification (ONRC). The ONRC involves categorising roads based on the functions they perform as part of an integrated national network. The classification helps RCAs and the Agency to plan, invest in, maintain and operate the road network in a more strategic, nationally consistent and efficient way.

The safe and appropriate speed matrix shown in Figure 1 has been approved by the National Road Safety Committee[1]. It is based on the ONRC, a simplified horizontal alignment classification (straight, curved, winding/tortuous) and generalised land use category. The matrix is the fundamental building block upon which the Speed Management Framework has been developed.

Classification	Straight open road /urban motorways	Curved open road	Winding open road	Urban (not motorway)
Class 1 High volume national	**100–110km/h[7]** * Depends on design and safety risk (e.g. divided 4-5 star, grade separated intersections, safety barriers) and factoring in enforcement thresholds			
Class 2 National, Regional, Arterial	**80-100km/h** Depends on safety risk and whether volumes justify investment to bring the road up to 3 star equivalent, also enforcement thresholds		**60-80km/h**	50km/h 60-80km/h where safety risk allows, e.g. fewer intersections, mode separation for active users
Class 3 Primary and secondary collector				30-50km/h 30km/h if high volumes of cyclists/pedestrians Recognise access and place 10km/h for Shared Spaces
Class 4 Access and low-volume access All winding/tortuous	**60-80**km/h Depending on roadside development, pedestrian and cyclist volumes, whether sealed or not			

Figure 1. Recommended Safe and Appropriate Speed Ranges for Road Classes (NZTA, 2015)

[1] The National Road Safety Committee (NRSC) is a group of government agencies with responsibilities for road safety. The NRSC developed and is responsible for implementing the Safer Journeys strategy and Safer Journeys action plans. The NRSC members include the Ministry of Transport, NZ Transport Agency, Police and the Accident Compensation Corporation. NRSC associate members include Local Government NZ, the Energy Efficiency and Conservation Authority, the Ministries of Justice, Health, Education and the Ministry of Business, Innovation and Employment (Department of Labour).

* It should be noted that 110km/h is not yet a legal speed limit in New Zealand. However, processes are in motion to modify legislation to enable the introduction of this higher speed limit.

The Speed Management Framework sets criteria for a range of safe and appropriate speeds in urban and rural environments. The Speed Management Guide defines safe and appropriate speeds as travel speeds that are appropriate for the road function, design, safety and use.

The key factors in the Speed Management Framework that are used to derive the safe and appropriate speed for any given section of road are:

- **ONRC**, which represents the function of the road within the whole network.

  The ONRC factor provides the overarching basis for aligning travelling speeds with road function, design, safety and use, as it takes traffic volumes, freight networks and place functions into account. The ONRC factor provides the essential network efficiency component into the analysis, ensuring the results are both safe and appropriate for the network function.

- **Road safety risk metrics**, primarily Personal Risk, which is a measure of the actual safety performance of a road for individual road users based on historic crash data.

  The Personal Risk of a road is calculated using the formula:

$$Corridor\ Personal\ Risk = \frac{(Corridor\ Collective\ Risk\ x\ 10^8)}{Qcorridor\ x\ 5\ years\ x\ 365\ days}$$

  Where:

  Collective Risk is calculated by applying death and serious injury severity indices to all injury crashes along a road and dividing the summed severity index by the length of the road in kilometres.

  Qcorridor is the weighted average daily traffic volume along a corridor. (Brodie et al).

- **Infrastructure Risk Rating (IRR)**, which is a road assessment methodology designed to assess road safety risk based on design features, operational characteristics and interactions with adjacent land use, independent of crash history. IRR is designed for assessing risk on roads where Personal Risk can be an unreliable indicator of safety risk because of low traffic volumes. Full details of the IRR assessment methodology, application and results are presented in 'An Automated Process of Identifying High-Risk Roads for Speed Management Intervention' (Zia et al.).

Incorporating the reactive Personal Risk metric and the proactive IRR metric into the safe and appropriate speed assessment acknowledges the intrinsic link between travel speeds and safety outcomes.

The criteria associated with all safe and appropriate speed outcomes for urban roads is shown in Table 1. A road section needs to satisfy the criteria in each of the 'Function / Feature', 'Road Safety Performance' and 'Infrastructure Risk Rating' assessment categories to justify the safe and appropriate speed.

The safe and appropriate speed for each road section is then compared to the existing speed limit. If the safe and appropriate speed and speed limit are the same, the road section is deemed to be 'in alignment' with the Speed Management Framework. Equally, where the safe and appropriate speed and speed limit are different, the road section is deemed to be 'not in alignment'.

A key purpose of the comparison between the safe and appropriate speed and the speed limit is as an initial filter to reduce the number of road sections taken through for subsequent assessment, classification and prioritisation. It is not a confirmation that a lower or higher speed limit is justified. The overarching aim of the framework is to achieve regionally and nationally consistent outcomes and enable road controlling authorities to prioritise speed management efforts and available resources to risk.

Table 1. Proposed Safe and Appropriate Speed Criteria – Urban Roads

Function / Feature	**Personal Risk**	**Infrastructure Risk Rating**	**Safe and Appropriate Speed (km/h)**
• ONRC is Class 1 or 2 • Identified as a Freight Priority Route in a Network Operating Framework • Limited Access Road controls • Median Divided	≤ Low-Medium	Low or Low-Medium	80
• ONRC is Class 1 or 2 • Non-commercial adjacent land use	≤ Medium	Low or Low-Medium'	60
• ONRC is Class 1 or 2 • Non-commercial adjacent land use	*No road safety metric used in the assessment*	Any IRR	50
• ONRC is Primary Collector • Residential adjacent land use	≤ Medium High	Low to Medium	50
• Any ONRC • Non-commercial and non-residential adjacent land use	≤ Medium-High	Low to Medium	50
• Any ONRC • CBD/town centre • Residential neighbourhoods	*No road safety metric used in the assessment*	Low to Medium-High	40
• Any ONRC • CBDs or town centres with high place function and concentration of active road users	*No road safety metric used in the assessment*	High	30

Understanding Current and Future Operating Speeds

Road sections not in alignment with the Speed Management Framework are assessed in further detail to identify speed management intervention strategies and to assign implementation priorities. A fundamental aspect of this secondary assessment process is the understanding of travel speeds – both current operating speeds and estimated future operating speeds if the speed limit is changed to the safe and appropriate speed.

For the Waikato Speed Demonstration Project, current operating speeds for high-speed roads were calculated for 9,629 km of roads using an automation of the Austroads Operating Speed Model

(Austroads, 2009; Harris et al, 2015). The model is based on maximum desired speeds established from the speed limit, horizontal geometry and vertical terrain, and typical driver acceleration and deceleration behaviours approaching, travelling through and exiting curves. The use of a speed model is necessary where incomplete or unreliable actual speed data exists across a network.

As the Austroads Operating Speed Model is only applicable to high-speed roads, operating speeds for urban road sections needed to be estimated. Based on the analysis of some speed data in Hamilton, the following coarse assumptions were used in the estimation of existing operating speeds:

- All road sections with 'Winding' or 'Tortuous' alignment, Operating Speed = Speed Limit – 5 km/h
- If ONRC is Class 3 or 4, Operating Speed = Speed Limit
- Otherwise, Operating Speed = Speed Limit + 5 km/h

Understanding the current operating speed for a road section and how this compares with the existing speed limit and calculated safe and appropriate speed, is a critical component of the speed management process for assigning intervention strategies and priorities. Equally important is an awareness of the likely change in operating speed if changes are made to the posted speed limit. For rural parts of the network, the future operating speed is normally calculated by simulating the automated operating speed model with the speed limit set to the safe and appropriate speed. However, given the scale of the Waikato region, a different method was used to estimate future operating speeds. The method involved the detailed analysis of network-wide speed modelling completed for the Top of the South region (Marlborough, Nelson and Tasman districts) and correlating current operating speeds with future operating speeds for different speed limit and safe and appropriate speed combinations.

An example of the relationship between the change in modelled operating speed as a result of a speed limit change is shown in Figure 2. In this instance, the modelled operating speeds are based on an existing speed limit of 100km/h and a future speed limit of 80km/h.

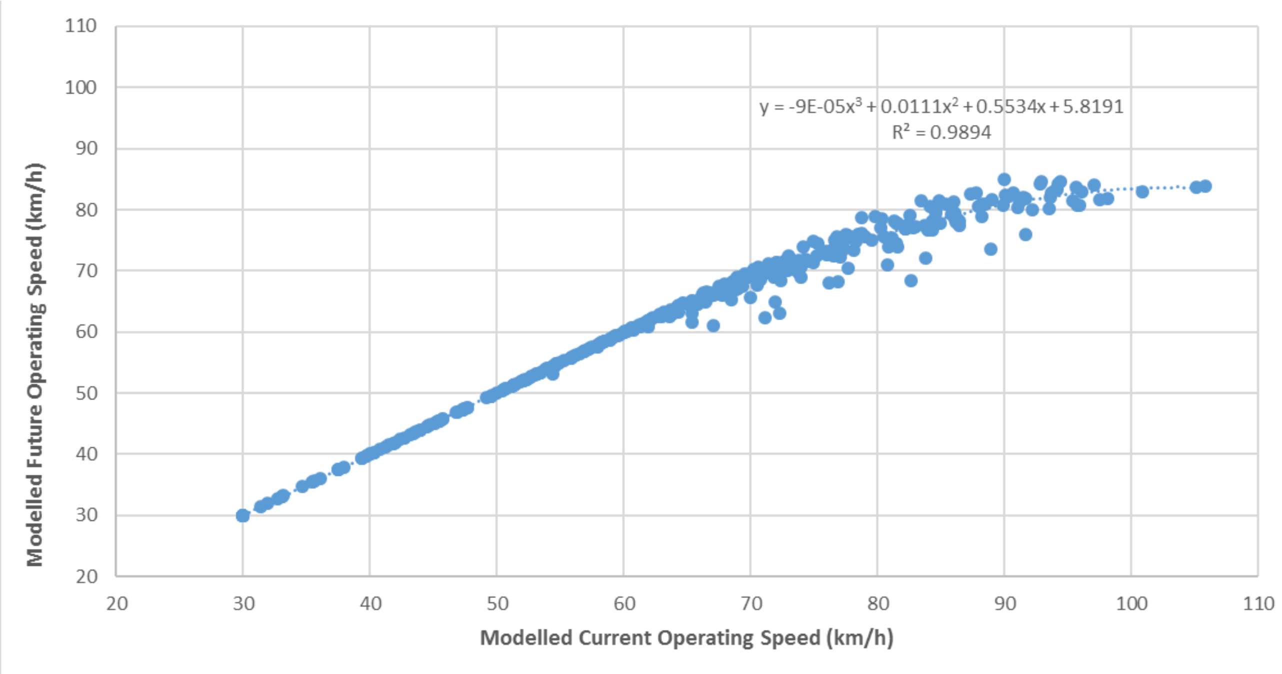

Figure 2. Relationship between Modelled Operating Speed Change from 100km/h to 80km/h

Figure 2 demonstrates that the relationship between the change in operating speed as a result of a speed limit change fits a polynomial function:

$$\begin{aligned} &\mathit{Final\ Operating\ Speed} \\ &\qquad = \mathit{Existing\ Operating\ Speed} - (9E-05 \times \mathit{Existing\ Operating\ Speed})^3 \\ &\qquad + (0.01 \times \mathit{Existing\ Operating\ Speed}) + 5.82 \end{aligned}$$

The simplified predictive relationship was then applied retrospectively and found to deliver a R^2 value of 0.99 for 3,262 km of rural roads assessed in the Top of the South region. This provided sufficient confidence that the simplified predictive approach for future operating speeds could be applied to the Waikato region.

Assigning Intervention Strategies to Roads

Once all four speed values (existing speed limit, safe and appropriate speed, current operating speed and future operating speed) are known, each road section not in alignment with the Speed Management Framework is evaluated against the following four speed management intervention strategies:

- **Engineer Up** – a road section that satisfies specific criteria to justify investment to bring the road section up to standard to maintain the existing speed limit or to support a higher speed limit. The main criteria are Class 1 or 2 ONRC and High or Medium-High Collective Risk.

- **Challenging Conversations** – a road section where the calculated safe and appropriate speed is below the existing speed limit and the current operating speed. The criteria for Engineer Up is not satisfied but safety performance justifies intervention.

- **Self-Explaining** – a road section where the current operating speed is comparable to or lower than the calculated safe and appropriate speed, both of which are lower than the existing speed limit.

- **Potential Speed Limit Increase** – a road section where the calculated safe and appropriate speed is greater than the existing speed limit and criteria is satisfied for a potential speed limit increase.

The evaluation of road sections against the different intervention strategies is informed by a series of factors. The factors associated witheach intervention strategy are shaded in Table 2.

Table 2. Factors Incorporated into the Evaluation of Intervention Strategies

Factor	**Intervention Strategy**			
	Engineer Up	**Challenging Conversations**	**Self-Explaining**	**Potential Speed Limit Increase**[2]
ONRC				
Crash history				
Estimated DSi Saved*				
Estimated DSi Saved / km				
Existing operating speed relative to speed limit				
Potential change in operating speed				
IRR				

- * Refer following section of paper.

Each road section is scored on a scale of 1 to 5 against each of the factors and assigned to the intervention strategy for which it scores highest.

Estimating the Safety Benefits of Speed Limit Changes

The estimation of death and serious injuries (DSi) that can be saved as a result of speed management interventions is based on a form of Nilsson's Power Model. Recent studies undertaken by Elvik (2009) and Cameron et al. (2010) confirm that speed environment is an important moderator of Nilsson's Power Model. Elvik concluded that in general, changes in speed have a smaller effect at low speeds than at high speeds. Furthermore, the analyses show that the exponents proposed by Nilsson based on speed limit changes in Sweden during 1967-1972 overestimate the expected DSi reductions due to various safety improvements in the last 40 years. However, both authors acknowledge that the Power Model remains a valid model of the relationship between speed and road safety if the exponents are adjusted according to speed environment.

Elvik's study presents separate exponents that are considered to be the best estimate to calculate DSi reductions for rural and urban speed environment. The generic form of Power Model equation for calculating future DSi is:

$$Estimated\ Future\ DSi = Estimated\ DSi \times \left(\frac{Speed\ after}{Speed\ before}\right)^{Exponent}$$

[2] This intervention strategy is only evaluated on those road sections where the calculated safe and appropriate speed is higher than the existing speed limit.

Where the exponent is set to 2.0 for urban environments (speed limit ≤ 70km/h) and 3.5 for rural environments (speed limit ≥ 80km/h). ‘Speed after’ values derived from the operating speed modelling have been moderated to ensure that potential DSi savings are not overestimated. This has been achieved by limiting the difference between current operating speed and future operating speed to a maximum rate of change of 5km/h for every 10km/h change in speed limit. This is higher than national and international experience where the change in operating speed is rarely found to exceed 5km/h per 10km/h change in speed limit without supporting measures. However, as the rate of change is only used for the assignment and priroitisation of intervention strategies purposes, the implications of the maximum rate value applied is expected to have little impact on the outcomes in a network-wide context.

In practice the use of Nilsson’s Power Model has been found to translate to an average DSi reduction of 27% for 100km/h road subject to a proposed 80km/h speed limit, and 9% for a 50km/h road changing to 40km/h.

Road sections where the current operating speed is less than the existing speed limit will attract a lesser percentage reduction in DSi than road sections where the current operating speed is higher. Likewise, road sections where the current operating speed is lower than both the existing speed limit and safe and appropriate speed will generate few DSi savings, as the future operating speed will only reduce by a marginal amount, if at all. Road sections that fall into the latter scenario are most likely to be categorised as ‘Self-Explaining’ whereas those with a greater difference between current and future operating speeds are more likely to be categorised as ‘Challenging Conversations’, especially where the road section has an established safety issue. Despite the lack of direct safety benefits that are associated with the ‘Self-Explaining’ intervention strategy, the classification is important for helping to change the conversation and behvaiours with the public around what safe speeds mean. The alignment of speed limits with operating speeds is expected to drive safer travelling speeds on other similar roads and deliver safety benefits across a wider area.

Prioritising High Benefit Opportunities

The highest benefit opportunities for speed management interventions are developed from the intervention strategy evaluation process. The highest benefit opportunities are presented as a ‘Speed Management Map’ (SMM). The purpose of a SMM is to highlight to an RCA those road sections within a network that represent the highest benefit opportunities for speed management intervention.

The SMMis developed by identifying the highest priority road sections for interventions based on the assigned scores in the intervention strategy evaluation process. For the Waikato region, the highest ranking 10% of the network by length formed the SMM.

The SMM attempts to roughly balance the length of network categorised with ‘Engineer Up’ and ‘Challenging Conversations’ intervention strategies and those classified as ‘Self Explaining’. The purpose of the balancing is to ensure there is a two-fold focus on both potential for DSi reduction from speed management interventions and also improving the public acceptability of speed limit reductions, thus giving effect to the stated objectives of the Speed Management Guide.

An example of the scoring applied to a road section section is shown in Table 3.

Table 3. Example Scoring Applied to a Road Section

Factor	**Intervention Strategy**	
	Engineer Up & Challenging Conversations	**Self-Explaining**
ONRC	3	
Crash history	4	3
Estimated DSi Saved*	3	
Estimated DSi Saved / km	5	
Existing operating speed relative to speed limit		1
Potential change in operating speed		1
IRR		3
Score	**15**	**10**

The road section evaluated above scores highest for the Engineer Up and Challenging Conversations intervention strategies. The road section is assigned to the Challenging Conversations intervention strategy because it has an ONRC of Primary Collector i.e. Class 3, which is outside the ONRC criteria for the Engineer Up intervention strategy categorisation. The road section is then ranked alongside all other roads with a Challenging Conversations intervention strategy based on the score. This ranking is then used to determine if the road section will be included in the SMM.

Implementation

Implementation is much more difficult and important than the technical analysis. This is especially true of many aspects of transport where public and political interest is high. Speed is a particularly sensitive topic.

In introducing and applying the Speed Management Framework a new approach and perspective has been implemented. This has involved actively engaging with stakeholders and the public about speed management instead of speed limits, and achieving network efficiency as well as safety. Engagement has occurred at a much earlier stage before any formal consultations. In this way the strategic objectives for an RCAs network have been explained early to gradually build public understanding and support for speed management interventions.

The pace of change has also been important. The speed management framework supports the long term objective that speed limits (and travel speeds) should reflect the function, use and safety of the network, but this will not happen overnight. Change should be at a pace that the public can accept and support.

The Agency is acutely aware that implementation of speed management on a regional and national scale to achieve desired safety outcomes whilst supporting economic activity requires extremely careful planning and consideration. To help realise this, the Agency has invested significant time and energy in building confidence and support in the technical analysis by actively engaging key stakeholders, such as the Automobile Association, Police and Road Controlling Authorities, in the process.

Although the technical analysis provides the platform for speed management decisions; it does not replacement sound professional judgement. For the Waikato Speed Demonstration Project, safe and appropriate speeds, intervention strategies and priorities have been reviewed for numerous road sections of interest. Where there has been a mismatch between the technical analysis and professional judgement, the technical processes have been reviewed, and where necessary modified to reduce the number of anomolous outputs generated from the process. The authors acknowledge there are limitations with any network-wide analytical process; however the key in building confidence and gaining support is to reduce the number of such incidents.

A key part of the process used in the Waikato Demonstration process was a local ‘sense check’, where the high benefit SMMs were critically reviewed by the road controlling authority engineering staff. Even at this stage, further refinements were able to be achieved to further improve the acceptability of the process outputs.

The engagement and willingness to modify the technical processes has resulted in an upswell of confidence and support for the speed management process in Waikato. This is seen as critical to the success of implementing speed management interventions in a nationally consistent manner.

The technical outputs of the analytical process are now being used by RCAs in Waikato to develop Speed Management Plans for local consultation.

Conclusion

Safe speed is one of the four pillars of the Safe System approach to road safety. The New Zealand Transport Agency’s Speed Management Guide, has introduced a single assessment framework that takes the road function, design, safety and use into account, to determine safe and appropriate speeds at a network level.

Where the safe and appropriate speed is different from the speed limit, a road section is said to be not in alignment with the framework. These road sections are assessed in further detail to identify speed management intervention strategies and to assign implementation priorities. A key aspect of this process is the understanding of current and estimated future operating speeds. The change in operating speed that may be realised from speed limit changes is used to estimate DSi that can be saved as a result of speed management interventions based on a form of Nilsson’s Power Model.

High benefit opportunities for speed management are developed in a manner that attempts to balance the length of network between those roads sections categorised as ‘Engineer Up’ and ‘Challenging Conversations’ with those classified as ‘Self Explaining’. The purpose of the balancing is to ensure there is a twofold focus on both potential for DSi reduction from speed management intervention and improving the public acceptability of speed limit reductions.

Whilst the technical analysis provides the platform for speed management decisions, implementation is much more difficult and important than the technical analysis. The Agency is acutely aware that implementation of speed management on a regional and national scale to achieve desired safety outcomes whilst supporting economic activity requires extremely careful planning and consideration. Early engagement with key stakeholders and openness to modifying technical processes to reflect stakeholder views are key themes that are contributing to the building of public understanding and support for speed management interventions.

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