Delivering a risk-based Road Safety Strategy

Simon Hunt

Asset Management and Maintenance, Fulton Hogan, Christchurch, New Zealand

Email: simon.hunt@fultonhogan.com

Chris Pacey

Technical Engineer, Fulton Hogan, Christchurch, New Zealand

Email: chris.pacey@fultonhogan.com

Abstract

The One Network Road Classification (ONRC) was designed to standardise the performance of our roads throughout New Zealand. Several key performance areas have been determined i.e. safety, resilience, amenity, accessibility, and travel time reliability, and for each of these areas, performance measures have been developed – both customer outcome and technical output measures.

Two of the key contributors to road safety are rural out-of-context curves and the skid resistance of the road surface. We have developed a comprehensive risk-based safety framework for managing these. This framework has been designed so that it can be applied to any road controlling authority and tailored to reflect the asset inventory and condition data, which they have i.e. from basic asset inventory data to networks, which have been surveyed using a data collection vehicle, such as the SCRIM truck.

Our strategy is outlined below:

- Determine, with the road controlling authority, the skid demand for different safety risk situations, including curves, based on the New Zealand Transport Agency's (NZTA) skid resistance management specification (T/10)
- Split the roading network into segments, based on these skid demands *[this step can be undertaken by a data collection vehicle but our methodology can determine these segments from basic inventory data]*
- Score the criticality of each segment based on weighted safety factors
- Based on the data captured in the field, including a road video; crash data; the criticality of each segment and road classification, develop a suite of strategies *[this paper focuses on the development of a skid resistance management strategy]* that are integrated to form the safety management strategy
- Inspect the high-risk sites to determine the issue that is required to be mitigated or treated; the treatment options and any further investigation or testing required to better determine the treatment
- Develop a suite of cost-effective treatments, based on the actual safety issue(s)
- Develop and implement a monitoring programme to continually improve the strategy

This process demonstrates how the development and implementation of an actual risk-based safety strategy delivers a prioritised works programme, which cost-effectively meets our national (ONRC) safety performance measures, tailored for each Client.

Background

This paper is about the development of a comprehensive risk-based framework for developing a safety management plan for a Road Controlling Authority's (RCA) network, based on our national (ONRC) safety aims and performance measures. The framework has been designed so that it can be applied to any road network and it is tailored to reflect the detail and completeness of the RCA's asset inventory and condition data i.e. from basic asset inventory data to networks, which have comprehensive GPS-located condition data.

The Process

Our process demonstrates how the development and implementation of an actual risk-based approach delivers a prioritised and cost-effective safety management plan. The overall process is summarised in Figure 1: Development of Safety Management Plan.

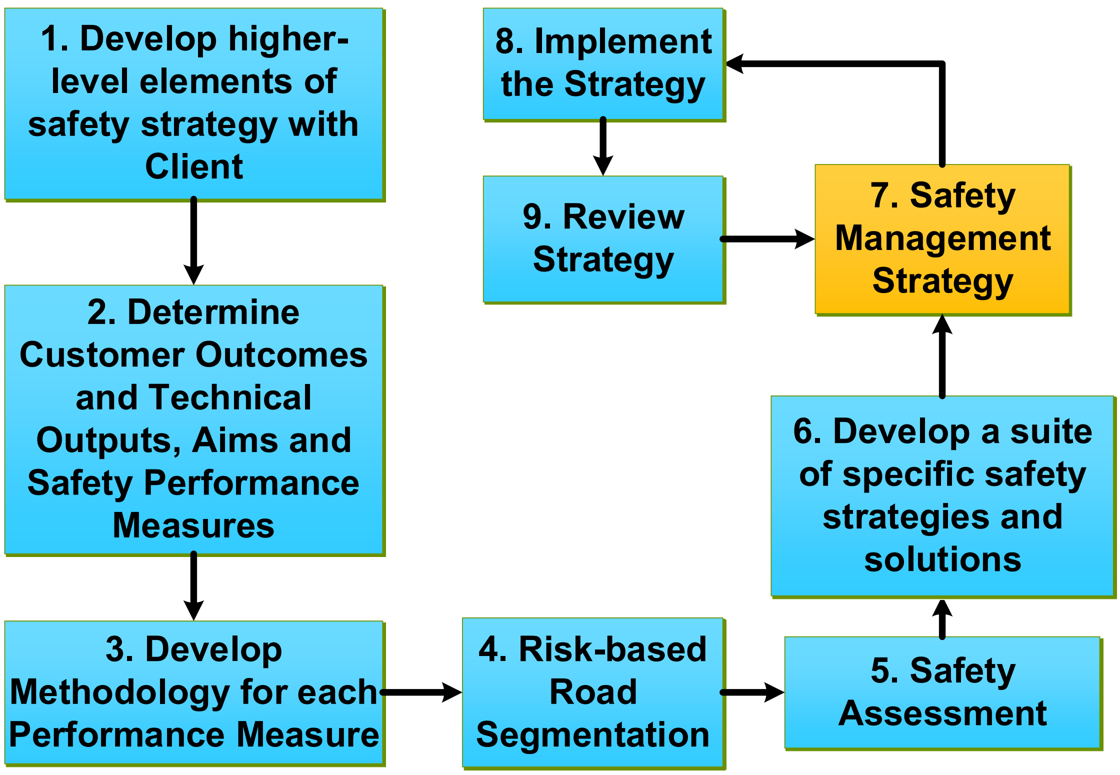

Figure 1: Development of Safety Management Plan

The key steps are detailed as follows:

Step 1: Higher-level Safety Strategy

The following documents underpin the safety management strategy and are the basis for its development.

One Network Road Classification (ONRC) – Safety Key Result Area

The One Network Road Classification (ONRC) was designed to standardise the performance of our roads throughout New Zealand. Several key performance areas have been determined i.e. safety, resilience, amenity, accessibility, and travel time reliability, and for each area, performance measures have been developed – both customer outcome and technical output measures. These safety aims and performance measures form the basis for the safety management strategy. The other important reference documents and strategies are:

- ***Road Controlling Authority's (RCA) Long-term Plan and Annual Plan***
  The RCA's Long Term Plan will contain key outcomes for the road / transportation sector, including their safety outcomes. The Annual Plan, and specifically the Roading or Transportation section of this document, will contain the road safety treatment programme for the upcoming financial year. Any element of these documents, which is relevant to the safety management strategy, needs to be considered and incorporated into it.

- ***Road Safety Management Strategy***
  If the RCA has developed its own Road Safety Management Strategy, this may contain a more detailed approach to managing some aspects of road safety, including expected outcomes, targets and performance indicators. The RCA then needs to consider which additional outcomes, targets and performance measures, it will incorporate and integrate with the ONRC outcomes, aims and performance measures.

- [1]***NZTA T/10: Specification for State Highway skid resistance management***
  This specification was developed by the Agency for the national State Highway network. It specifies the required skid demand for a variety of different situations based on personal risk i.e. the likelihood and consequence of a crash, and traffic volume. It is a proactive management approach, as it specifies the Investigatory Level (IL), which is a trigger point to investigate a particular site, for each skid demand situation. This level is 0.1 ESC (Equilibrium SCRIM Co-efficient) above the Threshold Level (TL), which is the minimum acceptable level that the skid resistance should be for a particular site category, and at which point a treatment is required. On the State Highway (national) network, skid resistance is measured

with a Sideway-Force Coefficient Routine Investigation Machine (SCRIM$^+$). The basic output is a skid resistance reading, which is adjusted by a sideway-force coefficient (SFC) factor and corrected for speed and temperature to provide the SC (SCRIM Co-efficient). This is normalised for within-year and between-year seasonal variations in the SC to produce an ESC.

Because skid resistance of the road surface is such an important element of the RCA's road safety management strategy, it is beneficial to develop a skid resistance management strategy as part of the overall safety management strategy. A key support reference document to the skid resistance management strategy is the [2]Maintenance Guidelines for Local Roads (an NZTA document). The key result area, in these guidelines, pertaining to skid resistance, is *'Safety Measures'*, and the relevant 'measure' is *'Adequate skid resistance on all sealed roads'*. Furthermore, the 'Explanation' states *"No section with a skid resistance insufficient for location"* with the method of measurement being *'visual inspection of suspect sites identified from desktop analysis'*.

- ***NZTA's Regional Safety Strategy and Safety Management Plans***

  For the State Highways Network Outcome Contracts (NOC) in New Zealand, NZTA has being developing Regional Safety Strategies for each of their regions based on a national template. NZTA and the network supplier then develop the Safety Management Plan, which sits under the Regional Safety Strategy, and this is also based on a national template provided by NZTA. These two documents are very useful reference documents, especially those relating to the same district as that of the RCA.

  - ***Urban KiwiRAP***

  KiwiRAP is the New Zealand Road Assessment Programme. It is part of the International Road Assessment Programme, otherwise known as iRAP. KiwiRAP focuses on state highway links that are typically outside the urban area between major town centres, beginning and ending at the major urban area speed limit changes i.e. state highway links that have speed limits of 80km/h or more. The objectives of KiwiRAP are:

  - to reduce deaths and injuries on New Zealand's roads by systematically assessing risk and identifying safety shortcomings that can be addressed with practical road improvement measures

- to have risk assessment as a key factor in strategic decisions on road improvements, crash protection and standards of road management
- to provide meaningful information on where the greatest levels of risk are faced, and in turn to influence behaviour.

Urban KiwiRAP is essentially KiwiRAP undertaken on local authority arterial roads i.e. the most important roads on an RCA's network from a functional perspective. The Accident Compensation Corporation (ACC), New Zealand, funded Urban KiwiRAP to help RCAs identify the highest safety risks on their networks. Urban KiwiRAP is therefore an important input into the RCA's Safety Management Strategy.

So, based on the ONRC Safety Outcomes and Outputs, Aims and Performance Measures, the Safety Management Strategy framework can be developed and then enhanced by referring to and utilising the relevant elements of the support documents detailed above.

Step 2: Determining Safety Customer Outcomes, Technical Outputs, Aims and Performance Measures

These are detailed in the Road Efficiency Group's ONRC Performance Measures (2016); the Safety Customer Outcomes and Technical Outputs, with the corresponding 'Aims' are as below in Table 1. The Road Efficiency Group (REG) was formed in 2012 on the recommendation of the Road Maintenance Task Force. It is a collaborative project between local government in New Zealand, and the NZ Transport Agency. Its aim is to create and embed a new national funding and activity management structure for roads (the One Network Road Classification); and improve value-for-money, customer focus, consistency, collaboration, and quality in road activity management.

Table 1: Safety - Customer Outcomes and Technical Outputs

Safety: Customer Outcomes & Technical Outputs	Aims
Customer Outcome 1: the number of fatal and serious injuries on the network	The road and roadside are becoming safer for road users.
Customer Outcome 2: collective risk (fatal and serious injury rate per kilometre)	The road and roadside are becoming safer for road users.
Customer Outcome 3: personal risk (fatal and serious injury rate by traffic volume)	The road and roadside are becoming safer for road users.
Technical Output 1: permanent hazards	Permanent hazards are marked consistently across

Safety: Customer Outcomes & Technical Outputs	Aims
	New Zealand
Technical Output 2: temporary hazards	Workers and people participating in events on roads are kept safe
Technical Output 3: sight distances	Drivers are able to navigate safely because they can see hazards, warning signs or delineation in time to respond
Technical Output 4: loss of control on wet roads	Reduce the number of fatal and serious injuries through loss of driver control
Technical Output 5: loss of driver control at night	Reduce the number of fatal and serious injuries in night time crashes
Technical Output 6: intersections	Reduce the number of fatal and serious injuries at intersections
Technical Output 7: hazardous faults	Reduce the number of maintenance-related hazards on roads requiring evasive action by road users e.g. detritus, ponding water, pot holes.
Technical Output 8: cycle path faults	Reduce the number of maintenance-related hazards on cycle paths requiring evasive action by cyclists e.g. detritus, ponding water, pot holes, broken glass.
Technical Output 9: vulnerable users	Reduce the number of fatal and serious injuries involving vulnerable users
Technical Output 10: roadside obstructions	Roadside areas are maintained free from unauthorised obstructions and new hazards are prevented from developing

In addition to the above Outcomes and Outputs, Aims and Performance Measures, there may be more emanating from the other important reference documents and strategies, detailed in Step 1: Higher-level Safety Strategy. These need to be added to the above table (including the Performance Measures).

Step 3: Develop Methodologies for Performance Measures

For each of the Performance Measures (there is one performance measure for each safety customer outcome and technical output, and corresponding aim), we have developed a methodology aimed at cost-effectively meeting or exceeding the Performance Measure, and a monitoring and review process (*explained later*) that drives continual improvement. For this paper, we have focused on the methodology, and the relevant manuals and guidelines, tools and systems, to address Customer Outcomes 1, 2 and 3. These are detailed below.

Table 2: Safety: Customer Outcomes and Technical Outputs - Methodologies

Safety: Customer Outcomes & Technical Outputs	Performance Measures	Methodology	Reference Manuals & Guidelines, Tools and Systems
Customer Outcome 1: the number of fatal and serious injuries on the network	The road and roadside are becoming safer for road users.	Develop and implement a risk-based skid resistance management strategy, and then build on this to develop and implement a full safety management plan *(detailed in this paper).*	• Road Maintenance Visual Guide (NZTA) • High-risk Rural Roads Guide (NZTA) • Urban KiwiRAP
Customer Outcome 2: collective risk (fatal and serious injury rate per kilometre)	The road and roadside are becoming safer for road users.		
Customer Outcome 3: personal risk (fatal and serious injury rate by traffic volume)	The road and roadside are becoming safer for road users.		

So the remainder of this paper focuses on the development of the skid resistance management strategy, and then using this as the basis to develop a full Safety Management Strategy.

Step 4: Risk-based Segmentation of Network

Two of the key contributors to road safety are rural out-of-context curves and the skid resistance of the road surface. Both of these are fundamental to the development of a skid resistance management strategy, and therefore reinforces why the skid resistance management strategy is a good basis from which to develop the full Safety Management Strategy. There are several ways to segment a network based on safety factors e.g. based on skid demand categories or 100m Urban KiwiRAP star ratings. Because of the importance of rural out-of-context curves and skid resistance in managing safety, we have chosen skid demand categories as the basis to segment the network from a safety perspective. However, the 100m Urban KiwiRAP star ratings can be overlaid onto the network map and be an input into the other strategies that make up the overall safety management strategy.

Step 4.1: Determining Skid Demand Categories

Determining the skid demand categories is a collaborative exercise with the Client. Based on the *Maintenance guidelines for local roads*, the key, to complying with it, is defining an ‘adequate’ skid resistance, based on the principles of NZTA’s T/10 specification e.g. for a local road network, this could be a skid resistance 0.5 ESC below that specified for the national State Highway network.

Step 4.2: Network Segmentation

The road segmentation phase involves splitting the network into segments based on similar skid demand. For national State Highways, this split is undertaken as per Table 3, which is an extract from the NZTA specification T/10, and it states the IL for skid resistance for different skid criticality situations (site categories) on the road network.

Table 3: Skid Resistance Investigatory Levels

Site Cat.	Skid Site Description	Investigatory Level (IL), units ESC					
		0.35	0.40	0.45	0.50	0.55	0.60
1	Approaches to: a) Railway level crossings b) Traffic signals c) Pedestrian crossings d) Stop and Give Way controlled intersections (where State Highway traffic is required to stop or give way) e) Roundabouts One Lane bridges: a) Approaches and bridge deck						
2	a) Urban curves < 250m radius						
	b) Rural curves < 250m radius			L	M	H	
	c) Rural curves 250 – 400m radius		L	L	M	H	
	d) Down gradients > 10%						
	e) On ramps with ramp metering						
3	a) State Highway approach to a local road junction b) Down gradients 5 – 10% c) Motorway junction area including on/off ramps d) Roundabouts, circular section only						
4	Undivided carriageways (event free)						
5	Divided carriageways (event free)						

The default ILs are the black areas for all site categories except for the rural curves shown in site categories 2b) and 2c). The greyed boxes either side of the black area indicate alternative ILs that may be considered (NZTA T/10 contains a section which lists reasons for decreasing or increasing the IL for each site category). For site categories 2b) and 2c), the ILs have the letters L, M and H inside the greyed areas which represent the IL for low, medium and high-risk curves, respectively.

Determination of the location of the start and end points of road segments, based on Site Categories 1, 3, 4 and 5, can generally be extracted from road asset inventory data, including sign types, centreline barrier installations, bridge abutments, etc. The process involves extracting the inventory data from the RCA's road asset maintenance management database, and putting it into an Access database in order to connect and strip excess data. Once pre-processed, an Excel processing template is then used to extract and sort the data, prior to segmenting the network. The curves require a different approach. The risk rating and therefore the IL for curves are determined using a curve assessment model, as described below.

Curve Assessment

Interpret (a subsidiary of Abley Transportation Consultants, Christchurch, New Zealand) undertook a joint-funded research project for the Agency and the Accident Commerce Commission (ACC). The project was the development of a risk prediction model using a curve assessment model and a speed model for 1500km of local roads and State Highway in the Eastern Bay of Plenty (New Zealand), to determine all the high-risk curves, independent of crash records. The curve assessment model involved arc-segmentation analysis of the centreline on curves. This is illustrated in Figure 2, below.

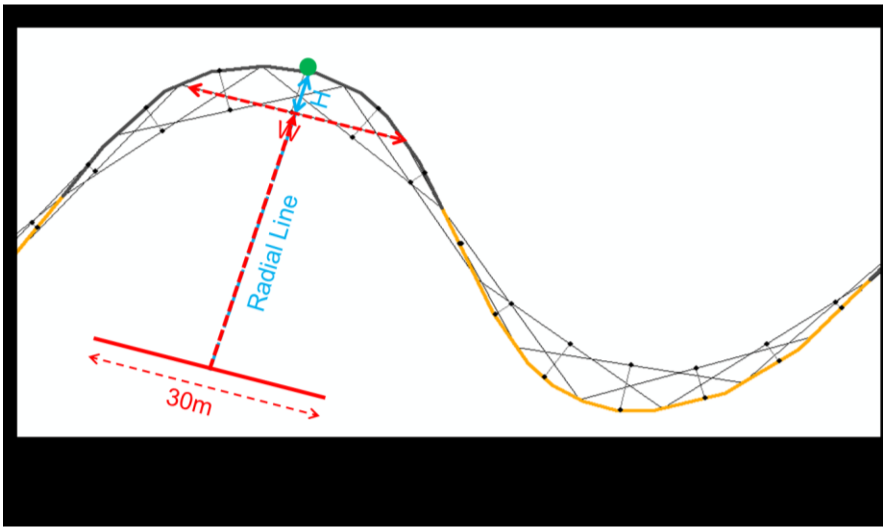

Figure 2: Arc-Segmentation Analysis

The results of this initial project were well-received and resulted in a second larger project being initiated by the Agency and ACC to test the repeatability; this was also successful. An interesting finding from these two projects was that 60% of out-of-control crashes occurred on 20% of curves identified as high risk, meaning that treating 20% of the out-of-control curves could reduce 60% of the crashes or mitigate the severity of the crashes. Because of these findings, ACC funded the curve assessment model project throughout the local authority road sector in New Zealand. So, this curve assessment model provided the curve data for the network segmentation element of the skid resistance management strategy; in particular, the GPS locations for the start and finish of each curve, and the curve radius or severity. This enabled the skid demand to be determined for Site Categories 2a), 2b) and 2c), as per Table 3, providing the final data set to complete the road network segmentation process.

In addition, as part of this exercise, a speed model was developed which was then used to determine the entry and exit speeds at each of the curves, so an additional benefit was the ability to check the appropriateness of the curve advisory speed signs in a network.

Step 5: Safety Assessment of Network

Each road segment is now rated, based on the consequence and likelihood of a crash, to give a total safety risk score. The following factors were chosen when determining the crash consequences and likelihood of a crash occurring:

<u>Consequence</u>

- Consequence of a vehicle leaving the road e.g. proximity to steep bank, lack of side protection, shoulder width, and presence of non-frangible roadside objects

<u>Likelihood</u>

- Road geometry e.g. poor super-elevation and / or a tight curve implying higher likelihood of a vehicle leaving the road
- Average Annual Daily Traffic (AADT) reflects the collective risk
- Speed limit – the faster the speed the increased likelihood of losing control
- Surfacing age – the older the surfacing, the more likely that the skid resistance is less than that required or specified

Each of these factors is weighted; the weightings are flexible and will be as deemed appropriate by the RCA. Each of these factors is given a score ranging from 1 to 5, reflecting the safety risk. The majority of the scoring assessment for each site can be done as a desktop exercise. The ‘Severity of the Geometry’ information is extracted from the Curve Assessment undertaken above; the other three ‘likelihood’ factors can all be extracted from the RAMM database. The ‘Consequence of Vehicle Leaving the Road’ can either be visually rated during a driveover, or assessed from a video of the network. A further site visit may be required to confirm some of these consequence ratings. On this basis, a safety risk score is determined for each likelihood factor, and then multiplied by its respective weighting before being aggregated to determine a total likelihood score for each treatment length. Table 4 is an example of the risk-based safety rating approach for determining which treatment lengths need to be considered for treatment, including possible testing.

Table 4: Risk-based Safety Assessment

Factors & Weighting	Consequence	Likelihood				
	Consequence of Vehicle Leaving the Road	Severity of Geometry 35%	AADT Score 25%	Surface Age 15%	Speed Limit (km/hr) 25%	Total Likelihood Score
Scores	Video e.g. Contour, or visual rating using a tablet	Curve Assessment Data	RAMM	RAMM	RAMM	
1	Flat – slight bank, and no objects	Straight road (> 800m)	< 2,500	< 5 years	50	
2	Moderate bank with poor quality guardrail or no guardrail but dense foliage	Slight curve or windy road (600 – 800m)	< 5,000	5 - 10 years	60	
3	Moderately sloped bank with no guardrail, no foliage	Moderate curve (400 – 600m)	< 10,000	10 – 15 years	70	
4	a) Steep bank > 5m from seal edge , no guardrail, or b) Immovable object > 5m e.g. large tree; bank, power pole, retaining wall	Isolated tight curve (250 – 400m), and / or moderate curve with poor super-elevation	< 20,000	15 – 20 years	80	
5	a) Steep bank < 5m from seal edge , no guardrail, or b) Immovable object < 5m e.g. large tree; bank, power pole, retaining wall	Isolated sharp curve (< 250m)	> 20,000	> 20 years	100	
SCORES	A	B	C	D	E	F

1. **RAMM** = Road Asset Maintenance Management system
2. **AADT** = Average Annual Daily Traffic

So, in the example above, the 'likelihood' is:

Likelihood (F) = (Bx0.35) + (Cx0.25) + (Dx0.15) + (Ex0.25)

The last part of this step is classifying high safety risk, moderate safety risk and low safety risk, by developing a safety risk matrix based on the 'likelihood' and 'consequence', as shown in Table 5 below. As with the 'likelihood' weightings, the low (L), moderate (M) and high (H) risk categories in this Safety Risk Matrix are determined by the RCA, and are able to be changed at any time.

Table 5: Safety Risk Matrix

Consequence	Likelihood				
	1	**2**	**3**	**4**	**5**
1	**L**	**L**	**L**	**M**	**M**
2	**L**	**L**	**M**	**M**	**M**
3	**L**	**M**	**M**	**M**	**H**
4	**M**	**M**	**M**	**H**	**H**
5	**M**	**M**	**H**	**H**	**H**

It is worth noting that the location and severity of the curves are used to segment and determine the skid demand for curves, as well as being one of the factors, used to determine each segment's safety risk rating, as per Table 4.

Site Assessment

The next step is to visit and inspect all the high-scoring sites, to confirm the safety issues and possible solutions. For example, if lack of skid resistance is identified as a possible issue, it may be prudent to arrange skid resistance testing, as the skid resistance cannot be quantified by observation. For sites suspected of polishing, mechanical testing can be used to quantify the degree of polishing. For a small number of one-off sites, mechanical test equipment such as a '[3]Griptester' or British Pendulum are appropriate, whereas for a larger quantity, the SCRIM^{+} truck should be considered. The final decision should be based on the economics, including consideration of the other high speed data, road geometry and video footage, which can be obtained using a SCRIM^{+} truck. For texture issues, which is binder rise causing flushing, sand circles or the use of laser technology can be used to quantify the extent.

Step 6: Development of a Suite of Specific Safety Strategies and Solutions

We now have the basis to develop a suite of specific safety strategies and solutions e.g. guardrailing strategy, delineation strategy, vegetation control strategy, safety in maintenance operations strategy and a skid resistance management strategy. In this paper, we will demonstrate the development of one of these strategies – the skid resistance management strategy.

Step 6.1: Development of Skid Resistance Management Strategy

The first steps of developing the skid resistance management strategy have already been detailed in Step 4: Risk-based Segmentation of Network, above.

Following on from the site assessment in the field, we are now ready to determine if any skid resistance testing is required.

Determine Skid Resistance Texture Testing Regime

Possible approaches are:

- Proactive – measure the skid resistance and / or surface texture on a set frequency on all or parts of the network, based on road classification and the volume of vehicles, and / or based on the risk score
- Reactive – measure skid resistance and / or surface texture at sites where loss of control wet crashes have already occurred
- No Testing

A common regime is to combine elements of all three approaches; an example of a programme for undertaking skid resistance and texture testing, is detailed below:

- All arterial roads e.g. regional strategic and national strategic every 2 years
- Segments with a high wet-weather crash rate where the road surface was a contributing factor e.g. > 4 wet weather crashes in the last 5 years. Only consider crashes since the last surfacing treatment. If the surfacing has been constructed within the last 5 years, convert to a crash rate per year, and determine what constitutes a high, moderate and low crash rate.
- Collector roads, based on the ranking of the safety risk scores
- Other roads based on safety risk score above a certain cut-off level

The testing regime can then be decided and the testing, analysis and reporting undertaken. Once the regime has been trialled and agreed with the RCA, then it can become a fixed item and the amount can be included within the roading budget.

The test data can be represented using a GIS product, e.g. Google Earth, MapInfo or ArcGIS, so that the variation in skid resistance can be easily understood with respect to low, medium and high priority locations.

Determine Skid Deficiencies

After implementing the skid resistance and texture testing, the results are plotted on a map of the road network and compared to the skid demand. As explained above, the low risk sections represent the segments that have skid resistance values greater than the IL for that segment's classification and demand category. Moderate risk segments represent the values between the TL and IL, and high risk sections represent those below the TL. Therefore, it is easy for the RCA to see which segments require treating.

Develop a Suite of Treatments

A list of all of the possible issues relating to poor texture, poor skid resistance and other issues contributing to loss of control crashes e.g. poor super-elevation or surface drainage, needs to be developed as a matrix with a corresponding suite of treatments or solutions, which either fix the listed issues, or are a possible solution or part-solution. This treatment and issues matrix will be tailored for each network. The treatment matrix is to be used as a guideline but engineering judgment will decide the actual treatment for a given situation.

The aggregate performance method, as detailed in the NZTA T/10 specification, is the preferred method for assessing the suitability of resurfacing treatments to resolve a skid resistance issue; actual performance of the aggregate and surfacing type in the field is used as the basis for aggregate and surfacing selection. For the aggregate performance method, all the surfacing data within the network (as well as available relevant data from adjacent networks) needs to be collated and then the performance of the different types of surfacings and the aggregates used in those surfacings need to be assessed to understand what has worked in the various polishing stress situations.

This data, for each treatment length, is then compiled for the entire roading network. After the skid resistance and texture testing have been completed and combined with the above information, an understanding starts to develop about which surfacing treatments and aggregates perform in which situations. A matrix of aggregate and surfacing types that suit particular stress situations on a particular network can then be developed.

It could be that a certain aggregate and surfacing treatment is more expensive to construct when compared to another option but as more certainty is developed around long-term performance of aggregates and surfacing treatments, Net Present Value (NPV) analysis can be undertaken to determine the least whole-of-life cost solution.

Develop Monitoring Programme

The monitoring programme comprises:

- An annual post-construction season inspection of the network to look at how the recent treatments are performing
- Monitoring of sites that were untreated due to budget constraints
- Analysis of the annual skid resistance testing results undertaken before the next construction season, together with photographs, videos and observations from the above inspection

Skid Resistance Management Strategy

The above process provides enough information, analysis, testing and methodology to develop the full Skid Resistance Management Strategy. This document pulls together all the above stages, and is a key element of the Safety Management Strategy.

Step 7: Safety Management Strategy

Similar to the Skid Resistance Management Strategy, the other strategies and solutions are developed i.e. the Guardrail Strategy, Sightline (Vegetation Control) Strategy, Delineation Strategy and the Safety in Maintenance Operations Strategy. Some of the key inputs into developing these strategies include Urban KiwiRAP, hazardous faults, roadside obstructions and crash records. The overarching Safety Management Strategy details these strategies and solutions, and integrates them. The data required is also detailed, including when and how it is collected, the analysis and the expected outputs. By using a risk-based safety rating approach, all the safety issues can be rated against each other. The Safety Customer Outcomes and Technical Outputs and their corresponding Performance Measures can be weighted dependent on their relative importance. The RCA's safety budget can therefore be tailored to suit the level of risk that they are prepared to accept. The last steps in developing the strategy are establishing the monitoring, measuring and reporting requirements. Once the initial Safety Management Strategy has been developed and agreed with the Client, the next steps are as follows.

Step 8: Implement the Strategy

The Safety Management Strategy is implemented and the outcomes and outputs are measured on an annual basis, and compared against the Performance Measures.

Step 9: Review the Strategy and the Solutions

Following the annual performance report, those involved in the safety management strategy meet to discuss the outcomes and outputs, and the opportunities to enhance the strategy, including the methodologies, and treatments and solutions. The agreed improvements arising from the workshop are made to the strategy and to the solutions or treatments. This is a key part of the continual improvement process.

Summary

The above process outlines a systematic, robust, and cost-effective approach to develop and implement the RCA's Safety Management Strategy to meet the aims of the national One Network Road Classification guidelines. The approach is risk-based ensuring that the sites and issues that present the highest risk to the RCA are treated with the appropriate solution in a timely manner. The monitoring and review process ensures continual improvement for both the treatments used and the strategy itself.

Acknowledgements

1. Jeff Waters (Fulton Hogan Corporate, Christchurch, New Zealand)
2. Matamata-Piako District Council, New Zealand
3. Dale Harris (Interpret Geospatial Solutions, Christchurch, New Zealand)
4. Robyn Gardener (Accident Compensation Corporation, New Zealand)

References

[1] **NZTA T10: Specification for state highway skid resistance management and Notes: 2013**
http://www.nzta.govt.nz/assets/resources/skid-resistance-investigation-treatment-selection/docs/T10-skid-resistance-investigation-treatment-selection-201306.pdf

[2] **New Zealand Transport Agency Maintenance guidelines for local roads (2012)**

[3] **GripTester, Findlay Irvine (2014)**
http://www.findlayirvine.com/products/grip-tester