

# The development of a proactive road safety assessment tool – KiwiRAP

Gina Waibl<sup>1</sup>, Dr Fergus Tate<sup>2</sup>, Colin Brodie<sup>2</sup>

<sup>1</sup>MWH New Zealand Ltd, <sup>2</sup>New Zealand Transport Agency

Email for correspondence: [gina.f.waibl@nz.mwhglobal.com](mailto:gina.f.waibl@nz.mwhglobal.com)

## Abstract

Road Assessment Programmes (RAPs) provide a proactive means of managing road safety which does not rely solely on death or injury to identify road safety problems. This proactive approach provides a key means for moving towards a safe system approach, promoted by the New Zealand road safety strategy, *Safer Journeys*.

KiwiRAP is the New Zealand Road Assessment Programme. KiwiRAP is helping to grow public awareness, and provides a common nationwide assessment methodology for highway network planners and managers. By understanding the deficiencies in road infrastructure features that increase crash risk through KiwiRAP, it is possible to proactively and more accurately identify and prioritise road safety investment to target resources to those routes and features where the greatest road safety gains can be achieved.

The KiwiRAP Star Ratings were developed following a trial application of the Australian star ratings model, AusRAP, in late 2007. This study determined that the AusRAP model would be unsuitable for direct application to New Zealand. This led to a decision to develop a New Zealand based star ratings model, KiwiRAP, which resulted in an extensive programme of research and development.

This paper outlines the three KiwiRAP protocols: - risk mapping, star rating and performance tracking, and focuses on the star rating protocol explaining how it was developed and how it is now being applied and embedded, as well as introducing the interactive KiwiRAP Analysis Tool (KAT), which is being used by practitioners nationwide to assess potential improvements and track performance across the state highway network. Specific attention is given to modifications to the star rating models and the impact these have had in achieving a strong relationship between the infrastructure rating and crash risk.

**Key words: KiwiRAP, star ratings, risk maps, KiwiRAP Analysis Tool, KAT, road assessment programme, safe system, safer journeys, high risk rural roads, safe roads and roadsides.**

## 1. Introduction

Road Assessment Programmes (RAPs) aim to significantly reduce road casualties by improving the safety of road infrastructure. They provide a proactive means of managing road safety, one that does not rely solely on death or injury statistics to identify road safety problems.

The Road Assessment Programme (RAP) started in Europe in the early 2000s when the Automobile Associations piloted a process for assessing the relative safety performance of different European roads (EuroRAP). It was then picked up in Australia (AusRAP) and some US states (usRAP). In 2006, an umbrella organisation iRAP (International Road Assessment Programme) was formed to oversee the global RAP programmes, to ensure some level of consistency and to promote them in developing countries.

KiwiRAP is part of this international set of road assessment programmes. Like its partner programmes, which have now been applied in over 70 countries, KiwiRAP incorporates three protocols:

1. Risk Mapping – uses historical traffic and crash data to produce colour coded maps which illustrate the relative levels of personal and collective risk on sections of the road network;
2. Star Rating – ratings of between one and five stars are awarded based on an assessment of how well the road is engineered for safety;
3. Performance Tracking – measuring changes in risk over time to determine if measures to improve safety have been effective.

KiwiRAP has been under development since early 2006 and from the outset it has been a joint agency initiative involving the Ministry of Transport, Automobile Association, NZ Police, Accident Compensation Corporation (ACC) and the NZ Transport Agency. KiwiRAP was the first Road Assessment Programme to use a joint agency approach, and this partnership model has now been adopted by iRAP as the preferred approach. The

first protocol, the KiwiRAP Risk Maps, was published in January 2008. The second protocol, the KiwiRAP Star Ratings, was published in June 2010 (Automobile Association, 2008). Finally, the KiwiRAP Analysis Tool (KAT), released for trial use in late 2010, has been developed as an important monitoring tool.

The remainder of this paper focuses on the second RAP protocol, the KiwiRAP Star Rating, including the development of the KiwiRAP Star Rating model and the strong relationship achieved between the infrastructure rating and actual crash risk. Additionally, this paper explains how KiwiRAP star ratings are being applied, and introduces the interactive KiwiRAP Analysis Tool (KAT), which is being used by practitioners nationwide to assess potential improvements and track performance across the state highway network.

## **2. Concept and objectives – why KiwiRAP star ratings were needed**

Traditionally New Zealand road safety investments have been targeted on the basis of historic crash performance, through crash reduction programmes, black-spot and black route analysis and treatment. While this approach has served New Zealand well and will remain a key strategy, it relies on crashes occurring and people being killed or injured. This reactive approach to road safety prompts public responses such as “do we have to wait until someone is killed before something is done”.

While treatment of isolated high crash locations provides a significant return on investment, this approach leaves sections of the highway network untouched, as the necessary improvements cannot be justified on economic grounds; the result can be a more variable network, the subtleties of which may not be apparent to the road users.

The New Zealand Road Safety Strategy 2010-2020, *Safer Journeys*, requires a focus on reducing deaths and serious injuries. However, treating those locations where the most recent fatal or serious injury crash occurred, particularly on low trafficked sections of highway, can be like chasing lightning - as many as four out of five fatal and serious crashes occur at sites with no significant crash history.

Therefore, a proactive approach to road safety management is required. Star Rating is such a proactive methodology. It relies on identified deficiencies in road infrastructure rather than crash history, to rate the safety potential of roads; and it can be applied to road corridors nationally in a consistent manner, to maximise the provision of safe travel. It is a tool that supports the safe system approach to road safety and initiatives aimed at providing safer roads and roadsides as outlined in *Safer Journeys*.

## **3. The star ratings model**

The star rating is derived from the Road Protection Score (RPS), which is a quantitative measure of the level of risk associated with roads. The RPS describes the expected safety performance of the road based on the presence or absence of 18 road and roadside features that international literature and NZ research suggests have an impact on the likelihood and/or severity of crashes. The 18 features are either rated visually from video or automatically coded from available road geometry data. The visual rating is based on data collected using four video cameras during highway drive-overs, with the features scored or rated for each 100 m section of highway. The RPS is used to determine the star rating, which ranges from one of five star bands from 1 star (poor) through to 5 stars (excellent). The star ratings are published for road segments, nominally 5 kilometres in length, and can be calculated for any road extent/length of interest.

The RPS for each road section is derived from three RPS sub-models which correspond with New Zealand’s three main crash types:

1. The Head-on RPS, which represents the factors that influence the likelihood and severity of head-on crashes; these include presence of a median and/or median barrier, traffic volume, cross section, horizontal alignment, terrain, overtaking, and delineation.
2. The Run-off-Road RPS, which represents the factors that influence the likelihood and severity of loss of control (off road) crashes; these are the type and proximity of roadside hazards to the carriageway, cross section, alignment, terrain, and delineation.
3. The Intersection RPS, which represents the factors that influence the likelihood and severity of intersection crashes; these are intersection type and form and side road volume.

These component RPS scores are then combined and averaged to generate the RPS over an extent of interest using the following equation (Equation 1):

Equation 1: RPS equation, for calculating the RPS over an extent of interest

$$\frac{\text{Length of section} * (A * \text{Run-off Road RPS} + (1-A) * \text{Head-on RPS}) + \sum 0.2 * \text{Intersection RPS}}{\text{Length of section}}$$

where A is defined as the split between run-off road and head-on crashes as it varies with traffic volume (Figure 1). The RPS is then converted to a star rating.

Each of the three RPS sub models follows the same basic form with three components:

1. Facility Type - represents the underlying base level of safety associated with a particular type or layout of a facility, road or intersection.
2. Road Engineering Features - relates to how various combinations of the key road engineering features may increase or decrease the likelihood of a crash given the base the level of safety associated with the particular facility under consideration.
3. Severity - represents those features that will impact on the severity of the crash outcomes.

The features are coded, typically as categorical variables, with multiplicative relative risks associated with each category e.g. the available sealed shoulder is coded to one of six categories, with relative risks ranging from 1.0 to 2.2. These relative risks mean that the crash rate on highways with sealed shoulders less than 600 mm is typically 2.2 times greater than that on highways with sealed shoulder widths of >2.4 m.

Detailed documentation of the KiwiRAP star ratings model is provided in the *KiwiRAP Summary Report* (Tate, Waibl & Brodie, 2011).

#### 4. KiwiRAP star ratings model development

The development of the KiwiRAP star ratings model began with the trial of a slightly modified version of the AusRAP model in the Waikato<sup>1</sup> in late 2007. This study found that:

- On average, the Waikato state highways have a lower star rating than the Australian national arterial network (AusLINK); and there was a desire to understand why this may be.
- The trial saw the majority of the Waikato state highways allocated a relatively narrow rating; predominantly two and three star. Again, this result appeared to be at odds with the general perception that the Waikato state highways cover a broad spectrum from median divided dual carriageways to narrow highways on tortuous alignments.
- A comparison of road section star ratings e.g. Karangahake Gorge and Thames Coast (Coromandel Peninsula) did not always match what may have been expected intuitively, relative to other sections.

The conclusion of this trial was that the AusRAP model would not be suitable for a direct application to New Zealand. The study further concluded that the New Zealand road environment is sufficiently different from Australia's to warrant further adapting the AusRAP methodology to the New Zealand situation and distinguishing it as KiwiRAP, as well as identifying a number of improvements to the methodology itself such as continuous rating of every 100 m length instead of breaking roads into "homogeneous" lengths, and the use of high speed data and automated data routines to improve the accuracy and efficiency of the rating process.

It was hypothesised by the project team that the counter-intuitive results achieved in parts of the Waikato may have been due to differences in the Australian crash risk parameters and New Zealand conditions; which are assessed in the Star Ratings model, particularly:

1. Proportional Split of Loss of Control and Head-On Crashes
2. Intersections
3. Horizontal Alignment
4. Overtaking
5. Terrain
6. Severity and the Impact of Speed

Further study of each of these elements was undertaken to reveal the following:

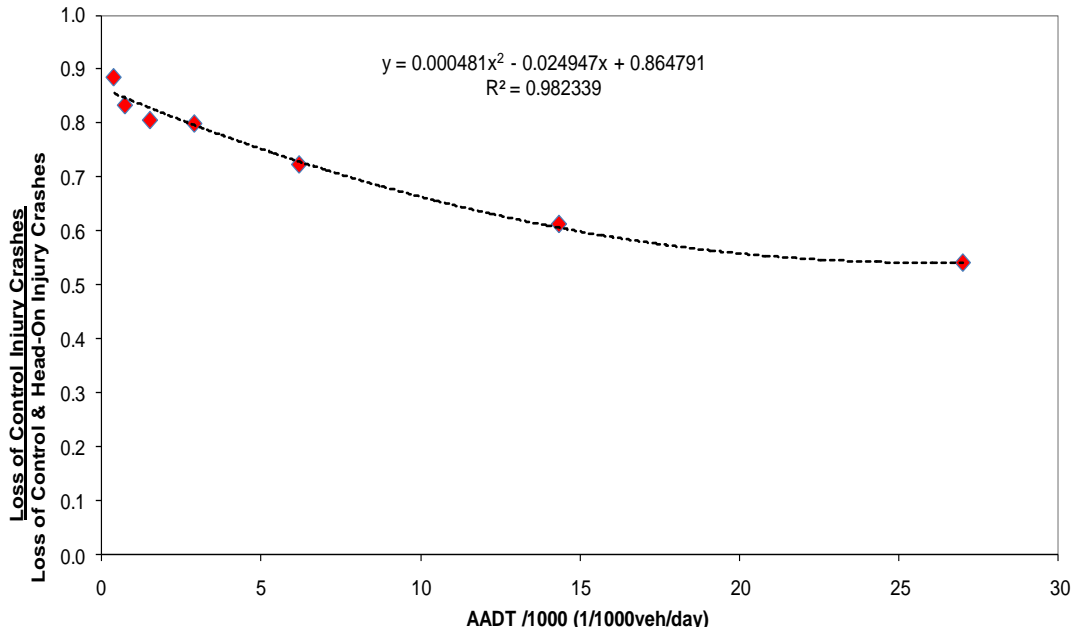
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<sup>1</sup> These modifications were to test a change in the proportional split of Loss of Control and Head-On crashes, an adjustment to the categories for hazard offset, and the use of an automated process to determine curve speed.

#### 4.1.1. Proportional Split of Loss of Control and Head-On Crashes

New Zealand crash data shows that head-on crashes, which are more severe than run-off road crashes, account for a greater proportion of crashes than in Australia, and New Zealand research has shown that the likelihood of a cross centreline departure resulting in a head-on crash, as opposed to a run-off-road crash, is a function of traffic volume, as shown in Figure 1.

Figure 1: Relationship between traffic volume and the proportion of run-off road to head-on crashes



As a result, the first improvement to KiwiRAP was to vary the weighting given to the head-on and run-off road road protection scores, based on the above relationship.

#### 4.1.2. Intersections

In the KiwiRAP and AusRAP methodologies intersections are treated as an “additional” risk load with an effective length of 200 m, and the crash risk at an intersection is determined as a function of the volume of traffic that must use the intersection as well as the intersection control type and form (alignment of legs, sight distance and turning provision).

In AusRAP, adjoining side roads were categorised as major, minor, and unsealed using visual judgement.

Ideally, adjoining side roads would be classified based on the side road volume, however, volume of side roads is generally not readily available for the purpose of RAP rating. As a result, a more robust method of classifying intersections was developed by studying some 500 side roads with available traffic volumes to identify the key characteristics present on the main road that indicate side road volume. This work was used to develop adjoining side road categories for the purposes of the KiwiRAP star rating as shown in Table 1. Further information is provided in the *New Zealand Updates to KiwiRAP Report* (Tate et al, 2010). It should be noted, however, that while this method provides some general guidance on the features associated with side road volume, further analysis, using a broader sample would be necessary to allow further rationalisation of correlated features, reducing the data collection required, and to provide a better categorisation.

Table 1: Adjoining side road characteristics adopted for KiwiRAP rating

Adjoining Road	Code	Risk Score	Descriptions / Notes
Unsealed road	1	0.1	The side road is unsealed and has no other features (other than a street name blade). The traffic volume will generally be less than 150 vehicles a day and the mean volume will be around 80 vehicles per day.
Local road	2	0.2	The side road is sealed and there is either no lighting or only flag lighting but no other features (excluding name blade). The side road traffic volume will generally be less than 500 vehicles per day with a mean volume of 260 vehicles per day

Adjoining Road	Code	Risk Score	Descriptions / Notes
Minor road	3	0.5	The side road is sealed, has full lighting and some form of (green) main road direction signing either at the intersection or in advance of the intersection. These roads are likely to have between 1,500 vehicles per day and 4,000 vehicles per day and the mean volume of this group will be in the order of 2,600 vehicles to day.
Major road	4	1	The intersection with a major adjoining road will include the following features: <ul style="list-style-type: none"> <li>• sealed</li> <li>• fully lit</li> <li>• right turn bay</li> <li>• left turn deceleration tapers from the main road</li> <li>• channellisation island(s)</li> <li>• advance direction signing</li> <li>• advance destination direction signing on the main road (and at the intersection itself)</li> </ul> It is likely that the adjoining road will carry more than 4,000 vehicles per day.

As a separate study, the relationships between Intersection RPS, crash data and intersection density were studied by Tate and Waibl (2007) as part of their review of the Waikato KiwiRAP trial outcomes to investigate how well the RPS models the crash patterns. They found that over the Waikato Region as a whole there is some general agreement between the proportion of RPS that is derived from intersections (16%<sup>2</sup>) and the 18% of injury crashes that are specifically related to intersections<sup>3</sup>. While future study and refinement of the Intersection RPS would be beneficial, this work does indicate that there is some general agreement between the proportion of Intersection RPS and intersection crashes.

#### 4.1.3. Horizontal Alignment

Horizontal alignment plays a significant role in the determination of both the Head-on and Run-off Road RPS. New Zealand research (Jackett (1992), Koorey & Tate (1997), and Cenek & Davies (2004)) has shown that crash rates on curves are strongly related to the difference between curve approach speed and curve speed. There are a number of concerns relating to the way horizontal alignment was assessed in AusRAP. In particular, the inability to take account of sequential changes in speed environment, or alignment consistency was a concern, i.e. horizontal alignment risk was assessed by subjective assessment of the curve speed in relation to the overall speed environment on a “homogeneous” section rather than in the context of the immediately preceding alignment. The use of the speed environment of the homogeneous length as an indicator of curve approach speed is a poor assumption, as they can be significantly different.

After considering several options, outlined in the *New Zealand Updates to KiwiRAP Report* (Tate et al, 2010), the adopted solution is the implementation of an advanced Poisson regression based crash prediction model developed for NZ state highways by Cenek & Davies (2004) for automatically assigning horizontal alignment scores. This model takes into account the context of the curve<sup>4</sup> as well as the alignment or negotiation speed<sup>5</sup> for every 10 m section of road. The model output is then averaged for both directions over each 100 m section and converted to a horizontal alignment score (see Table 2) based on calibration work undertaken to maintain the relative weighting of horizontal alignment within the KiwiRAP Star Ratings model.

**Table 2: KiwiRAP Horizontal Alignment Risk Scores**

Model Output	Code & Risk Score	Indicative Horizontal Alignment Description
<4.625	1	Consistently straight road (typically radii >3500m)
4.625 - <7.125	2	Easy curves (typically radii 1400m-3500m) with alignment/advisory speeds >100km/h
7.125 - <10.125	3	Easy-Moderate curves (typically radii 750m-1400m) with alignment/advisory speeds 90-100km/h, which may be slightly out of context

<sup>2</sup> Length weighted average of % intersection component of total RPS for KiwiRAP sections

<sup>3</sup> Movement types (Crossing – Direct, Crossing – Turning, Rear End) typically associated with intersections

<sup>4</sup> An Out of Context Curve factor is calculated from the difference between the calculated (average 500 m) approach speed and the “local” (average 30 m) speed for each 10 m section of road.

<sup>5</sup> Based on Rawlinsons equation

Model Output	Code & Risk Score	Indicative Horizontal Alignment Description
10.125 - <14.250	4	Moderate curves (typically radii 470m-750m) with alignment/advisory speeds of 85-90km/h and/or curves that are moderately out of context
14.250 - <19.000	5	Tight curves (typically radii 330m-470m) with alignment/advisory speeds of 75-85km/h and/or curves that are highly out of context
≥19.000	6	Very tight curves (typically radii <330m) with alignment/advisory speeds <75km/h and/or curves that are severely out of context

This rating is automated using data stored in the NZ Transport Agency’s Road Asset and Maintenance Management (RAMM) database as input, significantly improving the accuracy and efficiency of the rating process.

#### 4.1.4. Overtaking

The provision for overtaking may be as a result of clear, unrestricted sight distance on a two lane two-way road, overtaking lanes, or sections of dual carriageway.

Instead of using a subjective assessment based on the allocation of overtaking into three categories based on the overtaking opportunities present on a homogeneous section of road, a new rating system has been developed for KiwiRAP. It uses high speed road geometry data to automatically calculate the available sight distance<sup>6</sup> that provides for overtaking, used in conjunction with traffic volume data to assess the availability of natural passing opportunities, and a manual assessment of the provision of overtaking lanes and markings which restrict overtaking as shown in Table 3.

**Table 3: Overtaking codes and associated risk scores as they vary by traffic volume and terrain<sup>7</sup>**

Overtaking Provision Categories	Code	Flat			
		AADT >12,000	AADT 5,000-12,000	AADT 4,000-5,000	AADT <4,000
		Rolling or Mountainous			
		AADT >10,000	AADT 4,000-10,000	AADT 2,000-4,000	AADT <2,000
Divided carriageway (multi-lane); or Overtaking lane provided (in both directions)	1	1.0	1.0	1.0	1.0
Overtaking lane provided (in one direction only)	2	1.2	1.1	1.0	1.0
Overtaking permitted in both directions; and no solid yellow centreline (includes sight distance & overtaking restrictions)	3	1.4	1.2	1.1	1.0
Overtaking permitted in one direction only; or single solid yellow centreline (includes sight distance & overtaking restrictions)	4	1.45	1.3	1.15	1.05
Overtaking not permitted in either direction; or double solid yellow centreline (includes sight distance & overtaking restrictions)	5	1.5	1.4	1.2	1.1

#### 4.1.5. Terrain

The type of terrain a road passes through has an impact on the likelihood of head-on and run-off road crashes. The topography in New Zealand differs markedly from that in Australia and therefore the terrain classification and risk ratings have been modified accordingly. The resulting rating and risk scores were derived from the crash rates reported in the New Zealand Economic Evaluation Manual (EEM, 2006)<sup>8</sup> and a categorisation routine developed by McLarin (1995) which looks at the grade and curvature of a road section. The terrain type is determined by processing the High Speed road geometry data as defined in Table 4 below, and coded as level, rolling or mountainous based on the mode of the 500 m rolling average for every 10m length within a 100 m section.

<sup>6</sup> Using RGTRA, a software routine which is part of the road geometry data acquisition system (RGDAS), which has been refined and re-branded as Hawkeye

<sup>7</sup> The risk scores relate to the actual point of assessment with no adjustment for upstream or downstream effects

<sup>8</sup> using a traffic volume >4,000vpd and equating level terrain to a risk score of 1.0

This process is more sophisticated than the subjective visual assessment used in AusRAP to classify terrain.

**Table 4: Terrain risk scores and assessment criteria**

Terrain	Code	Risk Score	Assessment Criteria <sup>9</sup>	Descriptions / Notes <sup>10</sup>
Level	1	1	Average absolute gradient $\leq 1.5\%$ ; and Max. gradient – Min. gradient $\leq 6\%$ ; and Max. 1000/horizontal curvature – Min. 1000/horizontal curvature $\leq 5\text{rad/km}$	Level of gently rolling country, with gradients generally from flat up to 3%, which offers few obstacles to an unrestricted horizontal and vertical alignment
Rolling	2	1.5	$1.5\% < \text{Average absolute gradient} \leq 4.5\%$ ; or $6\% < \text{Max. gradient} - \text{Min. gradient} \leq 12\%$ ; or $5\text{rad/km} < \text{Max. 1000/horizontal curvature} - \text{Min.}$ $1000/\text{horizontal curvature} \leq 15\text{rad/km}$	Rolling, hill, or foothill country with moderate grades generally from 3% to 6% in the main, but where occasional steep slopes may be encountered.
Mountainous	3	2.0	Average absolute gradient $> 4.5\%$ ; or Max. 1000/horizontal curvature – Min. 1000/horizontal curvature $> 15\text{rad/km}$	Rugged, hilly, and mountainous country (and river gorges) often involving long, steep grades over 6%, and considerable proportions of the road with limited sight distance.

#### **4.1.6. Severity and the Impact of Speed**

The severity factors in KiwiRAP, which are applied to the run-off road, head-on, and intersection ratings, seek to account for the severity of a crash outcome, which relates to the speed of the vehicle(s) at the time of impact. Following the KiwiRAP trial in the Waikato, it was hypothesised that the speed environment factors were having too great an effect, leading to the counter-intuitive results. In particular, it was hypothesised that the low speed environment was having too great a weighting in reducing risk on curvilinear sections of road, such as Karangahake Gorge and the Thames Coast.

There are good arguments for both including and not including a speed environment adjustment. The argument for not including it is that lowering of the speed limit, and by association the speed environment should not result in a better star rating as the inherent safety deficiencies remain. Conversely, the argument for retaining the speed adjustment factors is that roads with lower operating speeds often have better safety performance.

During the development of KiwiRAP, various alternative speed severity relationships were trialled but none proved to be more appropriate than assuming a uniform speed. So in keeping with the revised AusRAP methodology<sup>11</sup>, KiwiRAP does not adjust the severity factors for speed limit or speed environment. The KiwiRAP star ratings model seeks to assess road infrastructure. It does not take into account driver behaviour or other factors. Speed limits can still be used to improve safety on a road with a poor star rating, but the infrastructure deficiencies remain and as such are reflected in the star rating.

The speed environment and the role it plays in influencing the likelihood of crashes is still accounted for when assessing the horizontal alignment risk which is a key contributor to road safety risk and the star rating.

In addition to applying a uniform speed to the severity factors, the factors were reviewed and New Zealand based factors developed by matching alignment speeds to New Zealand crash data and costs, with some assumptions around the crash cost most appropriate to represent the base risk score of 1.0. This review found that, in general, the New Zealand crash data and costs give a lower weighting than those used in AusRAP, with the exception of the more severe run-off road codes. As a result, these New Zealand based severity factors together with the use of a uniform speed to determine these factors were adopted in KiwiRAP.

#### **4.1.7. Other Implemented Improvements**

<sup>9</sup> From McLarin (1995). The average absolute gradient is the average of the absolute gradients within the 500m rolling average that is calculated for every 10m length; the gradient is the % of longitudinal gradient; horizontal curvature is the radius of curvature

<sup>10</sup> Terrain classifications, New Zealand Economic Evaluation Manual (2006) (Section A6.5)

<sup>11</sup> Current in 2008

In addition to the changes outlined above, a number of other changes were made when developing KiwiRAP. One of the most significant changes has been to implement rating of every 100 m length rather than allocating percentages to identified “homogeneous” lengths. This has enabled RPS scores to be provided for every 100 m section<sup>12</sup> of road rather than simply having star ratings available for the much longer “homogeneous” lengths. Further changes to the star rating model include:

- Introduction of a continuous relationship to convert the Road Protection Score to a star rating, enabling star ratings to be calculated to decimals (where other models simply calculate whole star ratings).
- Adjustment of lane and shoulder width categories to reflect New Zealand design standards, and development of risk scores based on New Zealand crash rate models and crash data.
- Amendment of the intersection type codes to distinguish between signalised and priority intersections, and including merge and diverge/exit lanes in place of coding each grade separated interchange as one intersection.
- Adoption of new Head-on RPS carriageway, alignment and traffic condition weightings and the horizontal alignment and terrain sub-weightings to better represent the New Zealand situation.
- Amendments to the Road Section Layout/Type categories, hazard severity offset categories, and severity run-off road rating codes to better reflect New Zealand state highways and standards.
- Additional delineation category included to represent profiled markings, such as rumble strips or Audio Tactile Profiled (ATP) marking, so that the benefits associated with these delineation tools are recognised.

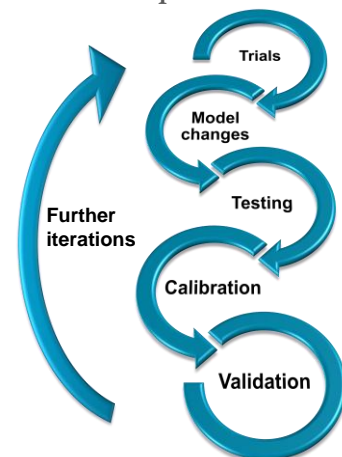
The preceding sections have provided a broad overview of the more significant improvements made in the development of KiwiRAP. The driver for many of these changes was to adapt the scoring and weighting factors to better reflect New Zealand crash patterns and design standards, and to utilise existing road attribute data to automate the rating process, improving accuracy and reducing the demand on the person undertaking the rating/coding from video. However, as with all such models a trade-off has been made between the practicalities and cost associated with data collection and the value of additional variables and the accuracy of recording. There is still considerable scope for further study, as many potential improvements were not implemented due to lack of evidence or inclusive results together with the need to contain development costs.

## 4.2. Calibration and Validation

An extensive programme of calibration and validation was undertaken to test, adjust, and prove the star ratings model and to ensure its robustness. This included testing and calibration of model components and the interaction between sets of variables to ensure that results made intuitive sense both in terms of the relative magnitude of contributing features and between different sections of road. This also included extensive analysis of individual model components to understand their interactions and influence on the result, as well as scenario testing to see the effects of potential infrastructure improvements. The final calibration step was the calibration of the Road Protection Score / Star Rating relationship to ensure compliance with iRAP principles and comparability of the star rating results with the Australian AusRAP star ratings e.g. so that a five star road in New Zealand is comparable to a five star road in Australia.

The key validation statistics were to achieve an inverse correlation between star rating and average crash rates nationally over all highways i.e. the average crash rate on 1 star roads is higher than the average crash rate for all 2 star roads which is higher than all 3 star roads etc. Validation was then taken several steps further by breaking down the star ratings to 1/10<sup>th</sup> (1 decimal place) level to achieve the 87% correlation shown in Figure 3. Drilling down to KiwiRAP Region<sup>13</sup> level, the relationship follows the national level trend generally but becomes influenced by low reported injury crash numbers and low numbers of data points resulting in more variability and greater spread in results.

**Figure 2: An iterative calibration and validation process**



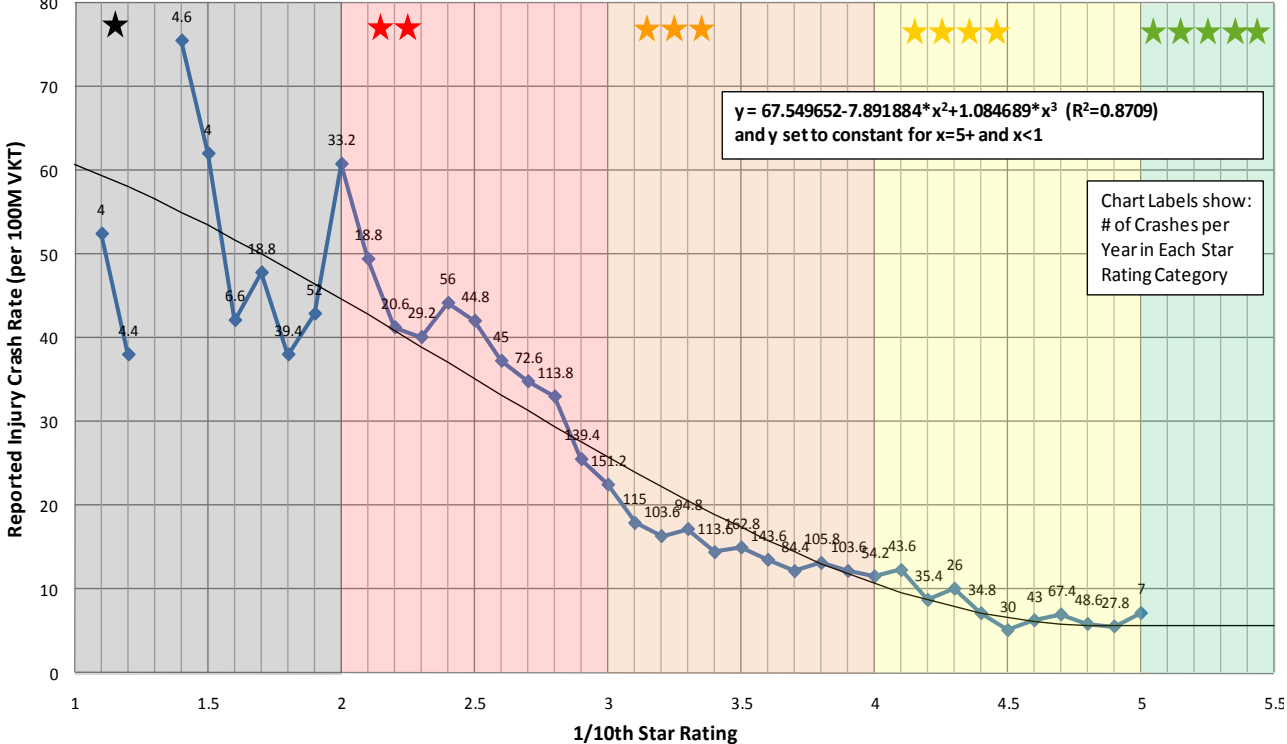
<sup>12</sup> Sections are nominally 100 m in length but may vary. As such, a modified RPS formula is applied to individual sections to enable direct comparison and plotting.

<sup>13</sup> KiwiRAP Regions vary slightly from NZ Transport Agency Regions, principally in the Rotorua and Taranaki areas



The development of the star ratings model, including the calibration and validation of the star ratings was an iterative process, first applied to the Waikato trial, which was then followed by trials in the Hawkes Bay and Northland, prior to star rating all 10,000 km of the rural state highway network providing a rich data source to enable finalisation of the improvements, and enabling the final calibration and validation to be undertaken.

Figure 3: Correlation between star rating and crash rate (Tate, Waibl & Robertson, 2011)<sup>14</sup>



### 4.3. Adoption, including the KiwiRAP Analysis Tool (KAT)

The correlation achieved between crash rates and star ratings demonstrates the strong technical basis underlying KiwiRAP and provides confidence that the model accurately replicates the impact of road infrastructure on safety, and that the infrastructure improvements derived from KiwiRAP will achieve the expected benefits. As such, KiwiRAP is being embedded into a wide range of policies and guides, and is being used as a key network performance monitoring tool. This has been further supported by the development of the KiwiRAP Analysis Tool (KAT).

KAT is a web-based tool which enables registered users to view the star rating results and underlying road infrastructure data by searching for road sections by location or by criteria to identify high risk locations and corridors, and can also be used to test the effects of potential road improvements using a “what if” analysis which determines the change in risk associated with various options for upgrades or projects involving multiple treatments. Finally, KAT provides a mechanism for updating the KiwiRAP road infrastructure data once road works have been completed.

KAT is a tool that has been developed specifically to enable KiwiRAP to be used as a key input to support future asset management plans, resource targeting and funding applications, and to monitor improvements across the highway network. The “what if” analysis and other innovations in KAT are now being adopted by iRAP, and in Australia, with interest recently expressed from China as well.

KiwiRAP has been incorporated in a wide range of policies and plans, and together with KAT is a key tool for the NZ Transport Agency’s prioritisation of resources. For example:

- The star rating of the state highway is included in the briefing given to the Minister of Transport on every road death;

<sup>14</sup> Data for star rating categories with <2 reported injury crashes per year associated with them have been removed

- KiwiRAP Star Rating forms a key part of the NZ Transport Agency's High Risk Rural Roads Guide; and
- State highway network managers and consultants are using the model to enable better identification and prioritisation of minor safety works and capital projects. A Safety Works Improvement Prioritisation Process (SWIPP) tool has been developed which uses star ratings to predict casualty savings enabling practitioners to quickly assess and compare projects based on their expected safety outcomes. SWIPP is now being used to develop a national programme of prioritised minor safety works.
- The NZ Transport Agency has also adopted a policy that all Roads of National Significance (RoNS) should be at least four star. The safety benefits associated with ensuring that the RoNS achieve a high standard in terms of road safety will not be inconsequential, as this policy will see a significant increase in the proportion of travel that occurs on four star roads. An analysis of four RoNS (Levin to Wellington, Puhoi to Wellsford, Tauranga Eastern Link, and Waikato Expressway) using KiwiRAP predicts that almost 200 injury crashes will be saved per year when these RoNS have been built (Tate, Robertson & Waibl, 2010).

By enabling such analyses to be undertaken, KiwiRAP is also encouraging work to be bundled into programmes, rather than undertaking safety projects on an individual basis. This has ensured that KiwiRAP is not only a useful tool and source of information for practitioners but it is an effective way of communicating with policy makers and politicians. This increasing support for road safety will hopefully see more funding put into safety related projects, and will ensure that increasing levels of safety are incorporated in all road designs. KiwiRAP Star Ratings is also influencing the types of treatments that will be implemented. This includes the use of more cost effective solutions that provide a greater safety benefit return, such as increased use of median and roadside barriers.

While these are key project objectives in terms of highway management, the KiwiRAP star ratings are also an effective communications tool providing information to the wider population, particularly the travelling public. By quantifying the risk, in the form of a star rating, drivers understand that not all roads are equal, and that different roads pose different levels of safety risk. Star ratings provide road users with information on the road environment that enables them to drive to these road conditions.

Now that the methodology has been developed and proven on the state highway network, work is underway to support the transfer of KiwiRAP to the local authority rural network and to investigate the potential for an urban corridor model or Urban KiwiRAP.

The first set of monitoring of risk maps shows excellent results and it is expected that future targeting of resources based on both star rating and risk maps will continue to deliver such results. Risk map monitoring of changes in personal and collective risk between the two five year periods 2002-2006 and 2007-2011, indicates that resource targeting of the highest risk routes (identified as High and Medium-High using risk maps<sup>15</sup>) has seen significant improvements. Fatal and serious injury crashes on 2002-06 High collective risk routes have reduced by 31%, almost twice the national average reduction; and fatal and serious injury crashes on 2002-06 High personal risk routes have reduced by 35%, more than twice the national reduction. These crash reductions have resulted in almost two thirds (63%) of these high collective risk routes, and almost three quarters (73%) of high personal risk routes are no longer classified as High risk routes. In addition to targeting high risk routes identified using risk maps, resource targeting is now being focused on improving the star ratings of high volume roads.

## 5. Conclusions

The KiwiRAP programme has become a key tool in supporting the drive to achieve safer roads and roadsides which forms a cornerstone of the New Zealand road safety strategy 2010-2020, *Safer Journeys*. Resource targeting on high risk routes has seen significant crash improvements, and now that the star ratings methodology has been developed and proven, proactive assessments which are further enabled by the KiwiRAP Analysis Tool, are raising the profile of road safety and are being embedded throughout the NZ Transport Agency's work. KiwiRAP is becoming a key monitoring tool assisting with resource targeting and prioritisation throughout the country.

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<sup>15</sup> Routes/road links, are categorised into bands as High, Medium-High, Medium, Low-Medium, or Low risk

## 6. Acknowledgements

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