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AN EVALUATION OF THE ECONOMICS OF NEW ZEALAND'S SKID RESISTANCE POLICY

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ABSTRACT

In this paper New Zealand's skid resistance policy is outlined, reviewed, and recent changes to the state highway specification outlined. This is followed by an evaluation from the perspectives of crash reduction, surfacing costs, surfacing lives and other skid resistance related costs, in order to evaluate the impact and economic outcomes of the policy. Prime consideration is given to the 11 years of data since the introduction of the new skid resistance policy in 1997, with some data extending further back. Comment is also made on the impact of increasing traffic volumes and increasing axle loads on surfacing lives.

A major revision of New Zealand's state highway skid resistance policy occurred in 1997 with the issuing of a skid resistance management specification, the T10 Specification for Skid Resistance. The T10 specification was implemented following the 1997/98 High Speed Data Collection (HSDC) survey of the entire state highway network, which involved simultaneous measurement of road condition and road geometry. The specification aimed to improve the safety of road users by equalizing, across the state highway network, the risk of having a skidding crash. This is achieved by assigning investigatory skid resistance levels for different site categories, which are related to different friction demands. As a consequence, skid resistance considerations are now a major factor in the choice of aggregate used for surfacing. For chipseal surfaces, skid resistance considerations are one factor in the programming of resealing.

The benefit - cost ratio of the policy has been assessed to lie between 13 and 35 indicating that the policy has been a very efficient and effective safety strategy.

INTRODUCTION

Skid resistance of road surfaces is one of the primary factors that determine the safety of roads. The probability of a wet skidding crash is lessened when the road surface skid resistance is high (AASHTO, 2008). Given the need for cost effectiveness in all forms of public expenditure, it is important to identify, implement and retain those measures that are shown to be effective in reducing crash rates. Although the improvement of road surface skid resistance is often cited as an engineering measure that can provide very good value for money, very little supporting evidence has been provided, particularly for skid resistance management at a nationwide level. This is the subject of this paper in which New Zealand's current skid resistance policy for state highways (SH) is evaluated from the perspectives of crash reduction, surfacing lives and specific skid resistance related asset management activities, in order to quantify the benefits and the costs. The policy is detailed in T10:2010 Specification for State Highway Skid Resistance Management, downloadable from the New Zealand Transport Agency web site: www.nzta.govt.nz

Note: Within this paper reference is made to SCRIM, SCRIM+,SCRIM Coefficient etc. SCRIM is a registered trademark and should strictly be SCRIM®. SCRIM+ is not a registered trademark, but refers to a vehicle with SCRIM® measurement equipment and the ability to measure texture, roughness, GPS location etc. Since 1997 all New Zealand national state highway surveys have been undertaken with SCRIM+ in various stages of development. In this paper SCRIM & SCRIM+ are used interchangeably.

NEW ZEALAND STATE HIGHWAY SKID RESISTANCE POLICY

Background

The New Zealand State Highway skid resistance policy was most recently reported in the paper Owen et al (2008)

In summary: Investigatory levels (IL) for microtexture (measured with SCRIM+ technology) are set with the objective of equalising the risk a wet road crash. These then define the target levels of skid resistance when designing a new surfacing. Target levels of macrotexture are also defined for new surfacings set with the objective of minimising the progressive loss of skid resistance with increasing speed on wet roads.

An annual survey is undertaken with the SCRIM+ vehicle, measuring a wide range of road parameters. For skid resistance the most important parameters are SCRIM Coefficient (SC) and macrotexture. The data from the survey is then used to assist with prioritisation of maintenance for the surfacing.

A Threshold level (TL) for SCRIM Coefficient (SC) is set at 0.1 SC below IL. These two levels of skid resistance are used to define three ranges of priority for maintenance of surfacings:

- Below TL, highest priority and treatment must be programmed promptly.
- Between IL & TL, skid resistance factors must be considered in production of the annual programme.
- Above IL, consider skid resistance when developing future annual resurfacing programmes.

SCRIM data is seasonally corrected for within year variation (Mean Summer SCRIM Coefficient, MSSC) and between Year variations of the network (Equilibrium SCRIM Coefficient, ESC) ESC data is used (when available) for maintenance decisions on the network.

SCRIM data is seasonally corrected at the end of summer. However, to enable prompt inspection and programming of treatment of sites with low skid resistance an Exception Report is produced detailing sections of the network where SC is below TL or macrotexture is low. There is a requirement on NZTA regions to inspect all sites on the Exception Report within 6 to 8 weeks and programme work to make sites safe. The process is further defined as:

- Decide the reason for low skid resistance,
- Assess probable fixes
- Chose the most economical long term strategy.

Note; Where resurfacing is the programmed treatment this work should generally not be undertaken till the next summer and signage or watercutting may be used as a temporary fix to make the site safe.

Specification for State Highway Skid Resistance Management, 2010

The specification, T10 Specification for State Highway Skid Resistance Management, 2010 (T10) was updated late last year. Once formally approved by NZTA it was issued and a full round of training implemented for both staff & suppliers.

There are limited supplies of aggregate resistant to polishing in New Zealand and the better aggregates are not uniformly distributed throughout the country. This was considered to make general increases in IL's uneconomic. However appropriate improvements to skid resistance have been obtained with a range of changes which are summarised below:

- Updating Curve Risk Analysis; this process rates the risk of a crash on a curve due to a variety of factors, but primarily the difference between the approach speed and the curve speed. This risk is used to allocate an appropriate IL to all rural curves. (Cenek et al 2011)
- Requiring all surfacing design or maintenance to have an estimated life for the surfacing and the aggregate, and requiring the performance of surfacings and aggregates to be monitored.
- Moving away from sole reliance on PSV of aggregates and requiring aggregates in high stress situations to have a proven on-road skid resistance record.
- Providing a methodology for regional staff to amend IL's in specific situations by ±0.05 SC and requiring IL's to be reviewed on a two year cycle to better manage local risk.
- Using the accuracy afforded by GPS location referencing to "Hardwire", or permanently locate features in the Road Assessment and Maintenance Management (RAMM) database, rather than the former system where significant features were located by the survey vehicle operator and their location could vary significantly from year to year. Note:
    - RAMM Road Assessment Maintenance System, the NZTA road database.
    - While GPS location is very accurate dropouts do occur. These are filled in by inertial systems. Where the dropouts are too long location referencing reverts to a linear system using reference stations spaced around 15km apart.
- Updated macrotexture requirements included in specification. They include requirements to minimise, progressive loss of skid resistance on wet roads, and tyres running on bitumen between chips on chipseals.
- Tightening requirements for watercutting to ensure macrotexture is higher outside the wheelpaths for the life of the watercutting treatments.
- Tightening requirements for design of maintenance on surfacings with the objective of ensuring the ESC does not fall below TL, and design of new surfacings with a target ESC of the IL (for the design life of the surfacing).
- Providing more detailed guidance on process for managing skid resistance.
- Requiring training and experience requirements for skid resistance practitioners.

THE INFLUENCE OF SKID RESISTANCE ON CRASH RATES

Statistical database analysis background

The paper Cenek, Loader and Davies (2002) discusses findings from two analyses: one analysis a global (nationwide) inter-year comparison of crash rates and road condition distributions on NZ's SH network; and the other a crash site specific (paired crash site analysis) considering changes in the number of crashes and road surface skid resistance at two different points in time at the same location in order to relate the probability of a skidding crash to a change in skid resistance.

Findings from these two analyses were that, generally, the wet skid injury crash rate on road sections displaying "low" skid resistance (i.e. skid resistance less than the threshold level specified in the T/10 specification, refer Table 2) is 4.5 to 9 times greater than that for all roads. This result confirms the benefit of targeted skid resistance maintenance interventions.

In addition, the results of the paired crash site analysis indicated that a 0.1 increase in skid resistance (measured in terms of Mean Summer SCRIM Coefficient, MSSC) causes a reduction in injury crashes of 30%on wet roads & 20% on dry roads for the New Zealand state highway network.

Taken overall, results from both the global and paired crash site analyses of the 2002 report are consistent and confirm that increasing the skid resistance of a road surface is a very effective way of reducing wet skid injury crashes.

Crash prediction model

Supporting the above, Figure 1 below (based on Figures 14 and 15 from Davies, Cenek and Henderson, 2005) shows that as skid resistance (as measured by the scrim coefficient) increases, the rate of both all crashes (the red line) and wet road crashes (the black line) reduces. Crash rate also reduces marginally with reducing texture (the green line), although the effect is much less marked than for that of skid resistance. (Note that the lines shown in the Figure below are derived using actual recorded crashes in the New Zealand Crash Analysis System (CAS) database and road condition data in the Road Assessment and Maintenance Management (RAMM) database. This therefore gives confidence that the relationships plotted in Figure 1 are valid.)

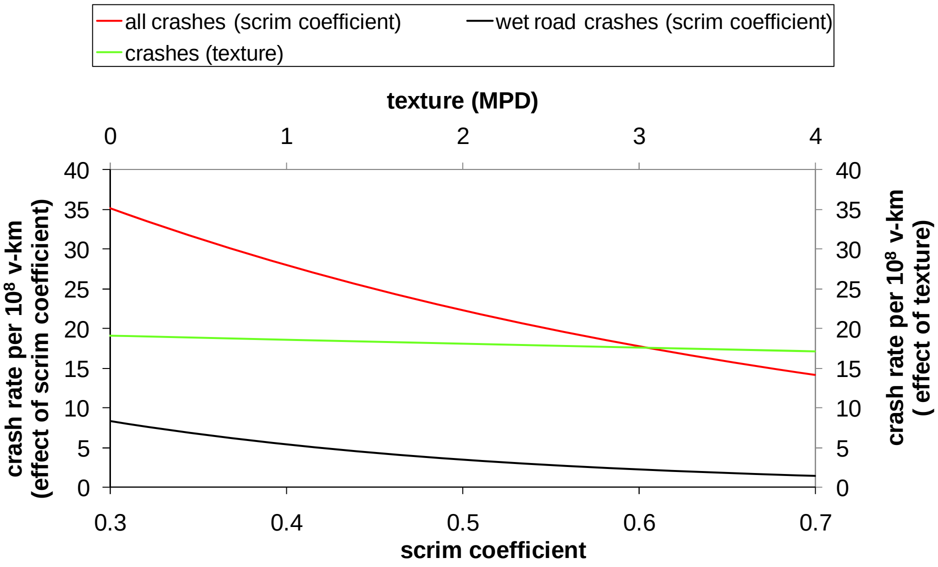

Figure 1: Effect of skid resistance and texture on crash-model predictions

SKID RESISTANCE MANAGEMENT PRIOR TO T10 SPECIFICATION

The skid resistance provided by a road is primarily a function of its surface texture. It is convenient to divide texture into two components: microtexture, which pertains to roughness on the surface of the aggregate less than 0.5mm in size and macrotexture, which pertains to asperities greater than 0.5mm and up to about 5mm in size. Microtexture is generated by the surface texture of the individual road aggregates. By comparison, macrotexture is generated by the size, shape and spacing of the road aggregates. Both microtexture and macrotexture may be reduced by the presence of bitumen binder, which is used to hold the road surface aggregates in place.

When the small-scale asperities that constitute microtexture come into contact with the tyre, an adhesive friction force (commonly referred to as grip) is generated. Under wet conditions, these small asperities penetrate the thin water film that remains between the tyre and the road to establish direct contact with the moving tyre. Macrotexture facilitates the drainage of water from the tyre contact patch area. It also causes deformation of the tyre in the vicinity of the contact patch, generating the hysteresis component of the friction force.

To summarise, microtexture determines the low speed skid resistance of a road, while macrotexture determines the drainage ability between the vehicle tyre and the road surface and therefore how effective the microtexture will be when the road is wet and especially for higher speeds

Under wet conditions at low speeds (up to 20kph) microtexture dominates skid resistance. However, above this speed macrotexture is required to minimise the progressive loss of skid resistance with increasing speed. (In the limit state, at higher speeds and deeper water films, aquaplaning may occur.)

NZTA's predecessors, National Roads Board (until 1989), and Transit New Zealand (Transit) (1989 – 2008) had, prior to 1997, a policy in place for state highways that required a minimum macrotexture value and a minimum microtexture value as determined by the British Pendulum (BP) Tester to be maintained (National Roads Board, 1983). These minimum values are tabulated in Table 1 below for different speed environments and surfacing types.

Loss of macrotexture was typically assessed by visual means. The use of the BP tester to measure microtexture was not common because being a static instrument measurements were slow and offered only partial coverage (a test area of 76mm by 130mm) of a road. Therefore, resealing on the state highway network because of aggregate polishing was relatively rare. Instead reseal programming was dominated by flushing (i.e. reduced macrotexture due to the upward migration of binder) because it was relatively easy to identify visually.

Table 1: Skid resistance criteria adapted from NRB's Standard Levels of Maintenance Service for State Highways (1983)

Operating Speed	**Macrotexture Equivalent (MPD derived from Sand Circle Diameter)**		**Area Demand Level**	**British Pendulum Number**	
	On AC	**On Chipseal**		**Minimum value for the average of 5 points**	**Minimum Value for one point**
70 km/h and over	1mm	1mm	High*	55	50
			Other	50	45
Under 70 km/h	0.7mm	1mm	All	50	45

**High demand areas are sections of road where drivers are more likely to make sudden evasive manoeuvres, brake heavily, or corner harder than average. It is impractical to make a complete definition for all cases, as individual judgement is required. Clear examples are isolated controlled intersections in high speed areas, speed posted curves, or lower standard geometry situations.*

OVERVIEW OF THE T10 SPECIFICATION

Transit's T10 specification for skid resistance investigation and treatment selection (TNZ, 2002) was introduced progressively from 1997 (Owen and Donbavand, 2005). There was an expectation that it would reduce significantly the occurrence of wet road injury crashes on New Zealand's state highway network. The essence of the T10 specification is summarised in Table 2 below which reproduces Table 1 from the T10 specification (2002).

Table 2: T10 site categories and corresponding investigatory and threshold skid resistance levels (TNZ, 2002)

Site Category	Site Definition	Investigatory Level (IL)[2]	Threshold Level (TL)[2]
1	Approaches to: - railway level crossings - traffic lights - pedestrian crossings - roundabouts - Stop and Give Way controlled intersections (where the State Highway traffic is required to stop or give way), - One Lane Bridges (including bridge deck).	0.55	0.45
2	- Curve < 250m radius - Down gradients > 10%	0.50	0.40
3	- Approaches to road junctions (on the State Highway or side roads). - Down gradients 5-10% - Motorway junction area including On/Off Ramps	0.45	0.35
4	- Undivided carriageways (event - free)[1]	0.40	0.30
5	- Divided carriageways (event - free)[1]	0.35	0.25

1. Event-Free = Where no other geometrical constraint, or situations where vehicles may be required to brake suddenly, may influence the skid resistance requirements.
2. Note: units of IL & TL are Equilibrium SCRIM Coefficient (ESC)

The approach followed in the T10 specification is one of equalisation of crash risk: surfacings offering the highest levels of skid resistance are applied to sites where they are most required (i.e. Site Category 1 approaches to intersections and traffic signals etc).

The T10 2002 specification did not specifically address macrotexture in the management of skid resistance. This was subsequently addressed through the issue in December 2005 of technical memorandum TNZ TM 5003 “Macrotexture Requirements for Surfacings.

TM 5003 and T10 are downloadable from http://www.nzta.govt.nz

THE CONSEQUENCES OF THE T10 SPECIFICATION

General

The importance of skid resistance was stressed in Transit’s Bituminous Sealing Manual (1993), which contained a description of the factors affecting skid resistance. Therefore, the introduction of the T10 specification simply reinforced what had been the policy on skid resistance management of state highways for a number of years.

However, the introduction of the T10 specification saw the commencement of annual High Speed Data (HSD) surveys of the state highway network with SCRIM$^+$ (Sideways-force Coefficient Routine Inspection Machine), which measures both skid resistance (as SCRIM Coefficient) and macrotexture (as MPD) for the full length of the state highway together with other road parameters. As a consequence, engineering inspections to determine whether resealing is required because of texture loss or premature aggregate polishing due to the action of heavy traffic are better directed to sites where HSD shows lower skid resistance.

The T10 specification has also resulted in the requirement to use sealing chip with the appropriate resistance to aggregate polishing to ensure that the surfacing maintains the appropriate level of skid resistance.

Some concern has recently been expressed that continued adherence to the T10 specification may not be sustainable as it reduces useful chipseal surfacing lives to the extent that cost may become a limiting consideration. To address this concern the change in chipseal lives and all other costs associated with the skid resistance policy are recorded in this paper.

CRASH ANALYSIS

In order to monitor the effectiveness of the T10 specification, inter-year comparisons of crash rate were undertaken on a nationwide basis using the 11 years of SCRIM data from 1998-2008 (latest data available at the time of analysis). This time period spanned the introduction of the T10 specification allowing both its initial and continuing impact on crash rates to be investigated. The results of these comparisons are detailed partially here and more fully in the report of Henderson and Cenek (2010).

Methodology

Since 2004, it has been a requirement that all roading authorities implement a skid resistance policy in order to receive maintenance funding as part of the National Land Transport Programme (NLTP), administered by NZTA. But in comparison to NZTA, Territorial Local Authorities (TLA's) are variable in their management of skid resistance. Where traffic flows are high, many implement a skid resistance policy similar to T/10 (TNZ, 2002), but none implement this over the whole of their network. The relative effectiveness of the different approaches to skid resistance management of road networks adopted by the NZTA for state highways and TLA's (for local roads) can be established through time-series movements of crash rates for wet and dry surfacings over the period from 1998-2008

Generation of crash rate database

The method by which the database used for crash analysis (i.e. crash numbers, exposures, and road surface moisture) was generated is outlined in detail by Henderson and Cenek (2010). Numerical results are tabulated in Appendix A.

Crashes in this paper were studied in three categories: "all", "dry" and "wet".

- "All" crash numbers were defined as: All injury and fatal crashes on the roading network
- "Dry" crash numbers were defined as the number of injury and fatal crashes where CAS's 'road wet' field was 'D' (dry). "Dry" crash rates were derived from these crash numbers.
- "Wet" crash numbers were defined as the number of injury and fatal crashes where CAS's 'road wet' field was 'W' (wet). "Wet" crash rates were derived from these crash numbers.

TRENDS

Exposure

The Vehicle Kilometres Travelled (VKT) increased over the years 1989-2008. This is exemplified in Figure 2 below for both "All" traffic and "Heavy" vehicles.

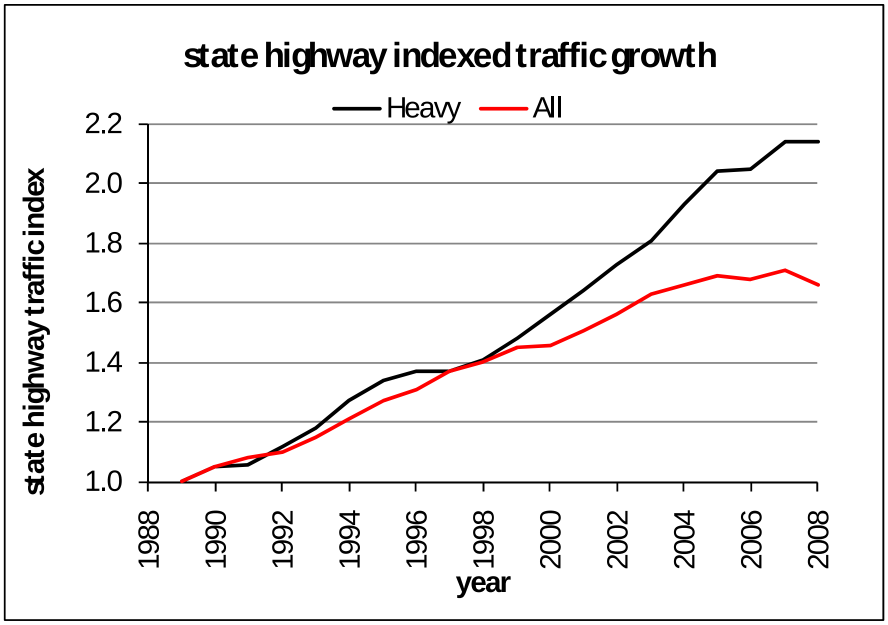

Figure 2: Traffic exposure growth (1989-2008)

Of particular interest in this Figure is the increase in heavy vehicle traffic (labelled 'Heavy') as heavy vehicles passes are the major factor determining chipseal lives rather than total traffic, other factors being equal. It should also be noted that freight efficiencies, more backloads and heavier axle loads have led to a greater increase in tonne.km than traffic numbers above. Insufficient data is available to record this increase since 1998.

NIWA rainfall data

Using data published by the National Institute of Water and Atmospherics (NIWA), the annual average of the total annual rainfall (mm) at an average of 61 nationally distributed weather stations (http://cliflo.niwa.co.nz/) is plotted in Figure 3 below.

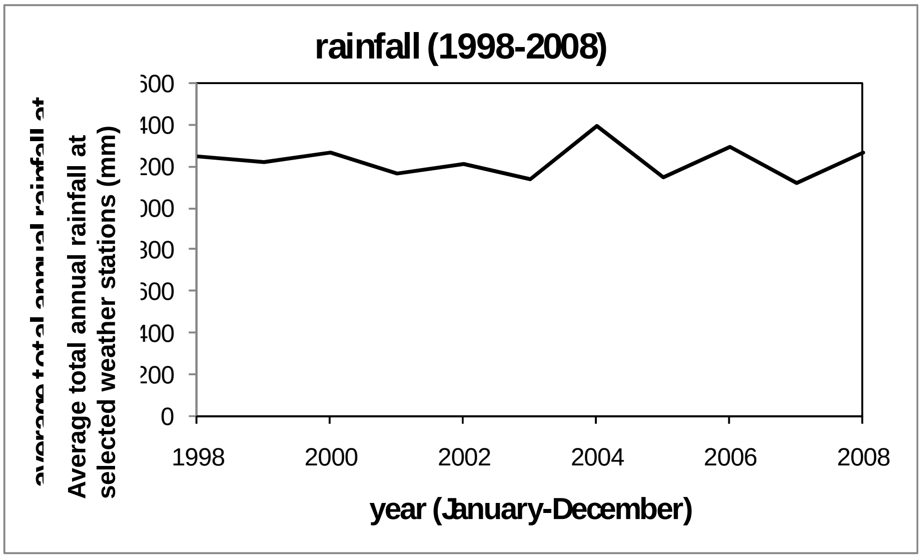

Figure 3: Rainfall data (1998-2008)

This Figure shows that there was not a significant change in New Zealand annual rainfall over the years 1998-2008. While the possibility of rainfall distribution changing has not been checked it is assumed that the crash trends discussed in this paper are not substantially influenced by rainfall changes for the years 1998-2008.

Crash numbers

Fatal and injury crash numbers are shown in Figures 4 (rural) and 5 (urban). The majority of SH crashes occur on rural roads whereas the majority of TLA crashes occur on urban roads.

Note: Figures 4 and 5 indicate that there was a substantial drop in crash numbers between 1995 and 1998. This is thought to result both partly from crash number database issues in this period and partly from the 1995 supplementary Road Safety Package (SRSP) which was mainly an anti-speeding and alcohol package of road policing and a support advertising campaign targeted at road users.

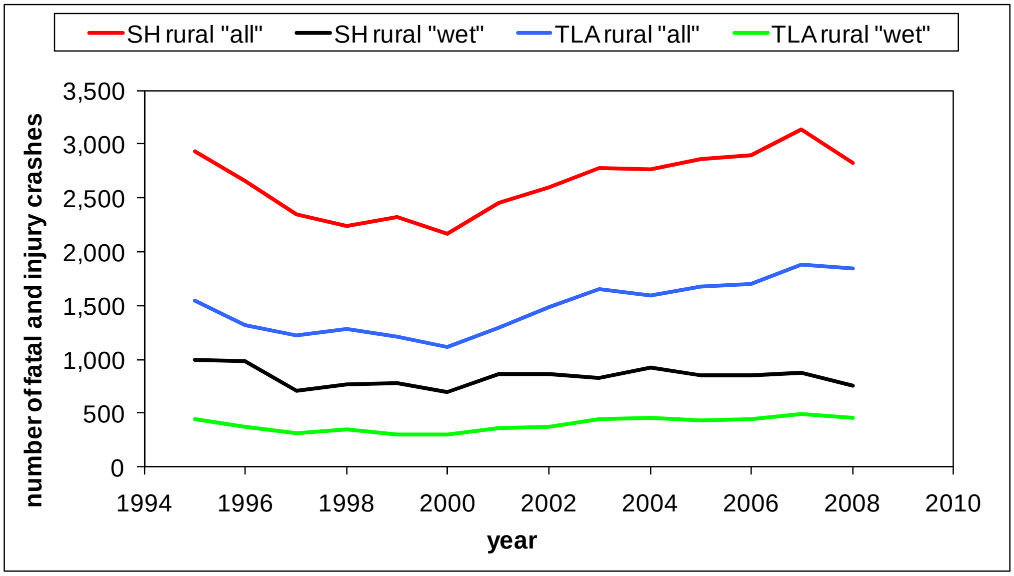

Figure 4: Rural fatal and injury crash numbers (1995-2008)

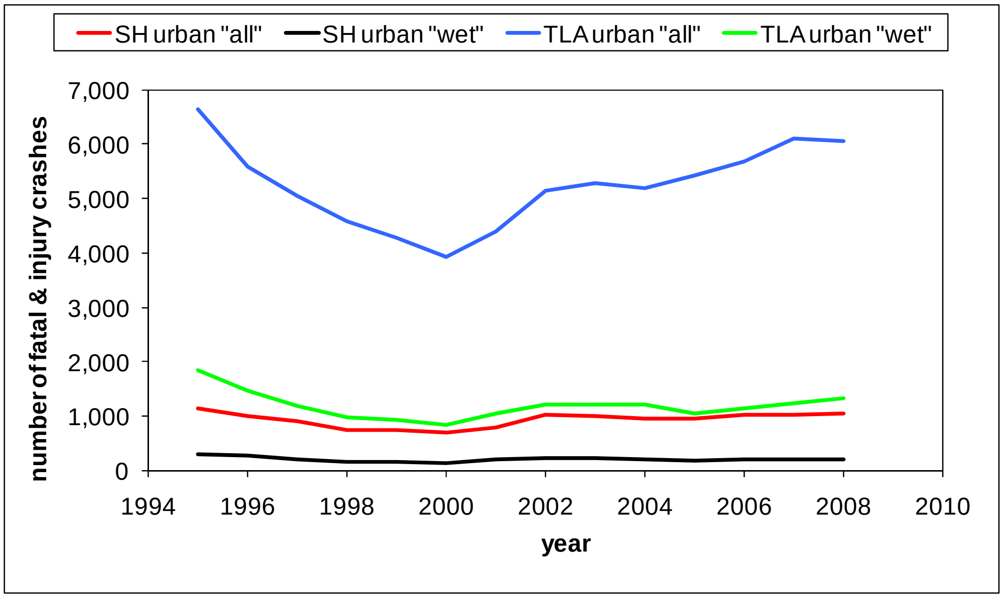

Figure 5: Urban fatal and injury crash numbers (1995-2008)

Crash rates

In the analysis that follows, the change in crash numbers is taken from a base of 1998. This is because the T10 skid resistance specification was issued in 1997 but as a result of progressive implementation its full effect does not become apparent until a number of years after.

Rural

The "wet" crash rate on the rural state highway network is trending downward for the period 1998-2008 (Figure 6). In comparison, the "wet" crash rate for the same time period on rural TLA networks is trending upward. In addition, the state highway rural "Wet" crash rate has trended downwards faster than state highway rural "All."

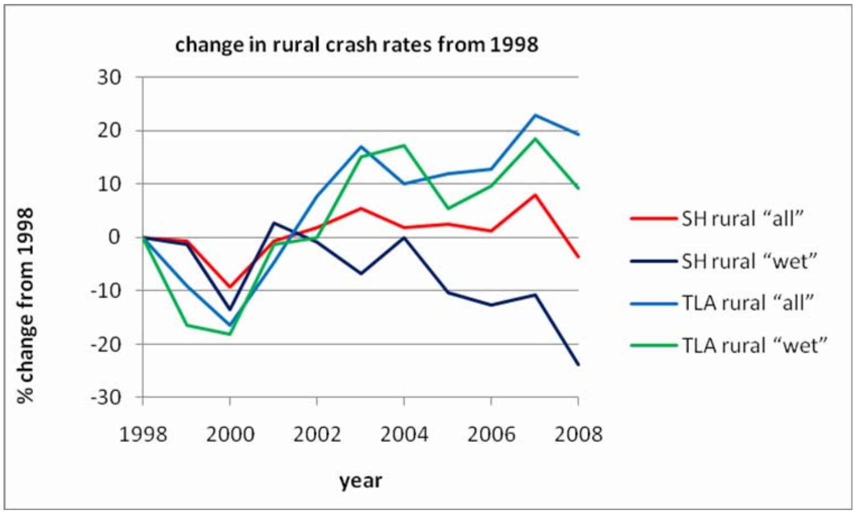

Figure 6: Rural crash rates, "all" and "wet" (1998-2008)

Urban

Urban roads have many more conflicts and crash types than rural roads, which will tend to mask the influence of improved skid resistance compared to rural roads. However significant trends have emerged since 2004. Urban SH "wet" crash rates are now (2008) around 18% less than urban state highway"all" and urban TLA "all" and "wet".

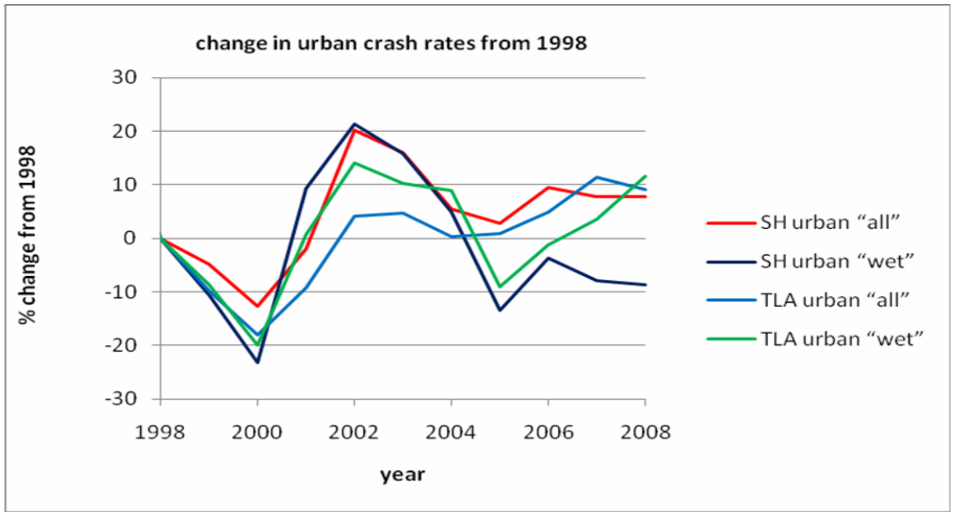

Figure 7: Urban crash rates (1998-2008)

FURTHER ANALYSIS OF CRASH RATES

Over the 1998-2008 period, crash reducing factors other than the introduction of the T10 specification are mainly common to both TLA and state highway networks. Such factors include the introduction of the highway patrol in 2002, (which was accompanied by reduced tolerance to infringements by the NZ Police) ABS & ESC in cars, education, advertising, weather patterns, traffic volumes, safety advertising, heavy traffic volumes, axle weights. By comparing changes in crash rates for both wet/ dry SH and, wet LA/ wet SH, the influence of extraneous variables is minimised.

Urban crash rates

For the purposes of this evaluation, a conservative approach has been adopted and no benefit has been allocated to reductions in urban crash rates i.e. only the reduction in crash rates associated with rural highways has been considered despite the benefits indicated in Figure 7.

Rural crash rates

Figure 6 shows that only the state highway rural “wet” crash rates are showing a downward trend, whereas the TLA rural “all” and “wet” crash rates are both trending upwards and the state highway rural “all” crash rates are relatively constant.

Figure 8 below compares the difference in percentage reduction of rural crash rates of state highway “wet” and state highway “all” and also state highway “wet” and TLA “wet” since 1998.

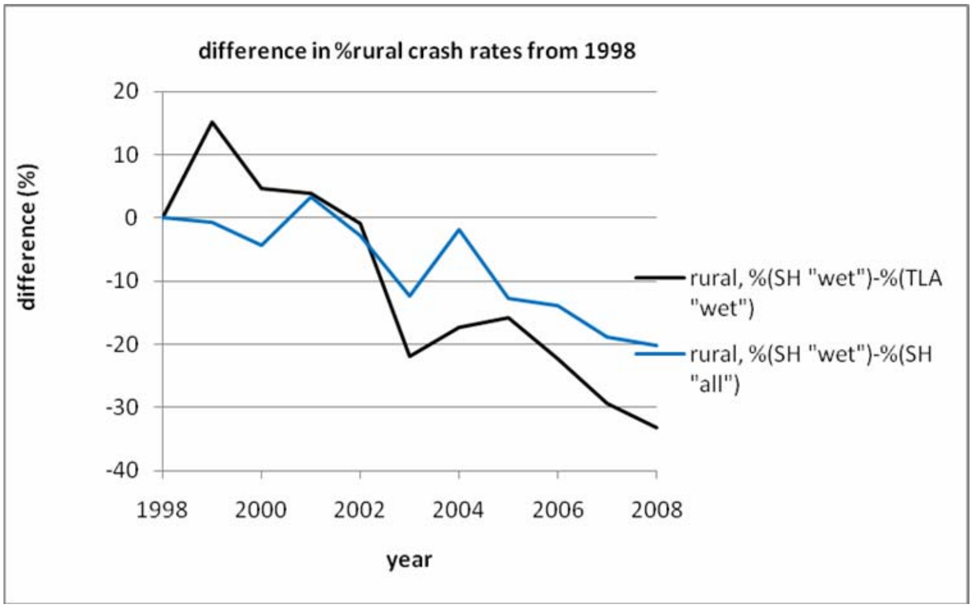

Figure 8: Percent changes in rural crash rates (1998-2008)

The effect of the introduction of the T10 skid resistance specification on crash rates on the state highway network could be considered to be represented by either the difference in rural crash rates in the wet between TLA’s and state highways or between state highway rural “all” and state highway rural “wet” crash rates. Figure 8 suggests that it took until 2003 for significant differences between these two indicators to emerge.

By 2008, the difference between the “all” and “wet” state highway rural crash rates was approximately 20% and between TLA rural “wet” and state highway rural “wet” crash rates it was approximately 33%. Using linear trend lines, the difference between the “all” and “wet” SH rural crash rates was 17.5%. Therefore, it is argued that the introduction of the T/10 skid resistance policy has had a significant effect in reducing the "wet” SH rural crash rate and this rate would have stayed constant or increased if it had not been introduced as occurred with “all” urban state highway and TLA rates. Furthermore, with reference to Figure 8, it is argued that by 2008 the T10 specification has resulted in a reduction in the state highway rural wet crash rate of over 15%.

COST OF IMPLEMENTING THE T10 SPECIFICATION

The implementation of the T10 specification for skid resistance management of state highways has not been without cost. For a period after introduction of T10 an extra $3M was allocated to the state highway resealing programme to remedy areas of low skid resistance. This was seen as a reasonable “carrot” to bring the network up to the recently mandated standard for skid resistance. Once the new programme level was established this special funding was dropped.

Seal lives

Contrary to the perception of some practitioners, reseal rates are not increasing on the New Zealand state highway network. With reference to Figure 9, while the percentage of the SH network sealed each year shows an increase over the years 1997 to 2000, the reseal rate has decreased again. There is nothing in Figure 9 to suggest that the introduction of the T10 specification has resulted in a long term increase in the length of SH that is resealed annually, despite a large increase in heavy traffic (See Figure 2). In addition, the increase over the 1998-2000 period was as expected and budgeted for at the introduction of the T10 specification.

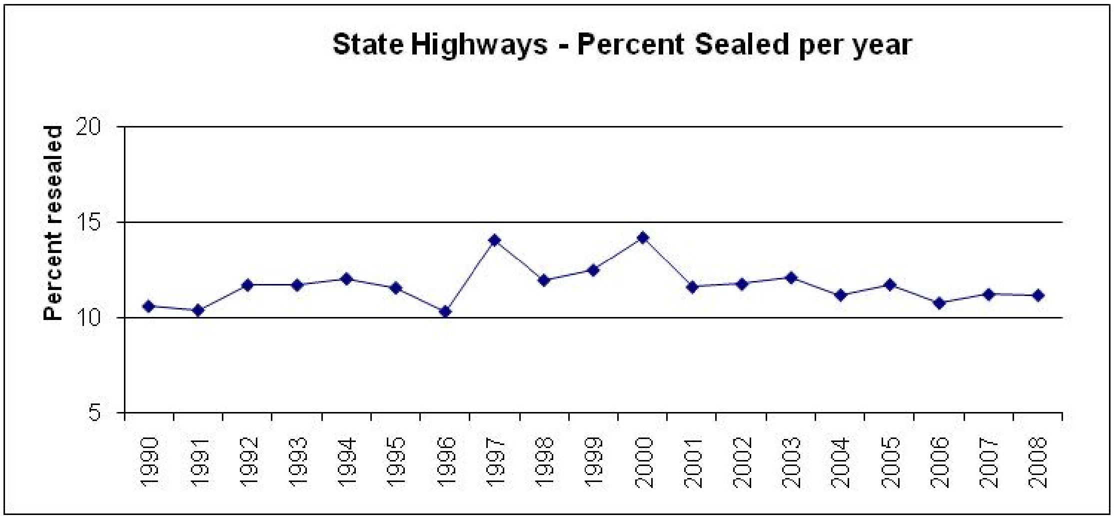

Figure 9: State highway seal life changes over 1990-2008

Summarising some data from Figure 9: In the period 1990 to 1997 an average of 10.9% of the network was resealed. In the period 2002 to 2008 11.5% of the network was resealed.

In determining the reseal programme, the surfacing engineer in each of NZTA’s regions is required to indicate the dominant reason. In 2008, 6.2% of reseals were performed because of aggregate polishing whereas over 9% of reseals were for this reason in 2002 (Towler et.al, 2010). Although there is some concern that the engineers’ reasons for resealing may not reflect the true surface condition in that low values of skid resistance as determined from SCRIM$^+$ surveys can be caused by factors other than aggregate “polishing,” it has been assumed the 6.2% of reseals in 2008 are entirely due to the T10 specification. This implies that the long term effect of the skid resistance policy could be requiring an extra 0.6% of the network to be resealed.

Flushing was stated as a reason for 17% of reseals performed in 2008, but as mentioned previously loss of texture has always been a major reason for resealing. Therefore, the introduction of the T10 specification has not changed the decision to reseal because of flushing but rather has identified areas of aggregate polishing. Therefore, it is contended that the introduction of the T10 specification is responsible for only 6% of reseals currently programmed. With approximately 12% of the network being resealed each year, the T10 specification is only affecting 0.72% of the SH network.

In summary it has been assumed the extra resealing is 6.2% of the total state highway resealing programme. (Noting that all of this could have been due to increases in heavy traffic, but improved surfacing technology could have lead to a reduction in resurfacing, all other things being equal)

Component costs

High and low estimates of the extra costs of adopting the T10 specification (i.e. the skid resistance survey, supervision costs and, transporting aggregate highly resistant to polishing) are tabulated in Table 3 below and discussed in the following text.

Table 3: Cost components of the T10 specification

Cost Component	**Estimated Annual Cost**	
	High	**Low**
Resealing	$5.2M	$3.4M
SCRIM^{+} Survey (skid component)	$0.7M	$0.5M
Consultancy services	$0.5M	$0.2M
Transporting high PSV aggregate	$0.8M	$0.4M
Total cost of T10 specification	**$7.2M**	**$4.5M**

The total cost of resurfacing in 2008/09 was $84M. Of this, $55M was for chipsealing and the remainder for thin hot mix surfacings. If it is taken that 6.2% of the total resurfacing was attributable to the T10 specification, than the cost is $5.2M. If only the resealing with chipseal surfacings is considered, than the cost reduces to $3.4M.

The state highway skid resistance survey is performed with the same high-speed data collection vehicle that records roughness, rutting, surface texture, road geometry and also collects right-of-way videos of the network. The cost of the SCRIM skid resistance component is therefore only a portion of the total cost. This has been conservatively estimated at between $0.5M and $0.7M.

The extra supervision (i.e. consultancy service) costs are estimated at between $0.2M and $0.5M.

Sources of aggregate with a PSV greater than 60 are not plentiful in New Zealand, but these aggregates are required on high-demand, high-traffic volume areas to meet T10 skid resistance requirements. Consequently, since the introduction of the T10 specification, there has been a cost associated with transporting out of region aggregates to site. Such high PSV aggregates are only normally required on T10 site categories 1 and 2 (refer Table 2), which are normally of short length. Of the 1006km resealed in 2007-08, 62km would have been for polishing and may have required a high PSV chip. The average cost of resealing in 2007/08 was $63,000/km. The NZTA cost indices for resealing assigns 20% of the resealing cost to aggregate, which would equate to $12,600/km. For 62km of sealing, the total cost would be $781,200. If it is assumed that the high PSV aggregate was between 50-100% greater in costs than low/medium PSV aggregate, the extra cost would be $0.39M to $0.78M.

Economic Evaluation

It can therefore be inferred that the annual cost of implementing the T10 specification is in the range of $4.5M to $7.2M (table 3 above). The societal benefits attributable to the T10 specification have been assessed as a minimum at 15% and possibly up to 25% reduction in state highway rural "wet" crash rates as discussed previously. (More than the benefits of the previous policy)

Considering only these state highway rural wet crash rate reductions, the corresponding monetary benefits are calculated as follows:

- In 1998 the wet VKT on the rural SH network was 34.4*108 v-km/y with a crash rate of 22.2 fatal and injury crashes per 108 v-km/y and 764 crashes (refer Tables A1.1-A3.1, in the Appendix, multiplying the exposures of A2.1 by 0.25 since only "wet" road exposures are of interest).
- By 2008 the wet rural SH VKT had increased to 45*108 v-km/y (Table A2.1, multiplying by 0.25 as noted in the text below the Table). Using the 1998 crash rate (of 22.2 fatal and injury crashes per 108 v-km/y), the number of fatal and injury crashes on wet rural SH roads would have been 999 (i.e. 22.2x45).
- A 15% crash rate reduction would therefore result in a saving of 150 crashes on "wet" SH rural roads. A 25% reduction would have resulted in a saving of 250 crashes.
- The social costs of crashes recorded in the NZTA Economic Evaluation Manual (2010) are: rural fatal $3.881M, rural serious injury $680,000, rural minor injury $83,000. The rural crash ratios recorded in the same reference are: fatal/serious/minor = 1:2.1:6. This gives a weighted social cost of a rural crash as $638,000.
- For a saving of 150 crashes the monetary benefits are 150x$638,000=$95.7M and for a saving of 250 crashes the monetary benefits are $159.5M.

The benefit-cost ratio (B/C) of the various scenarios i.e. high cost/high benefit to low cost/low benefit are summarised in table 4 below.

Table 4: 2008 Benefit-Cost ratios of the T10 specification

Total Annual Cost ($M)	Total Annual Benefit ($M)	B/C
7.2	95.7	13.3
7.2	159.5	22.2
4.5	95.7	21.3
4.5	159.5	35.4

Crash reductions

Findings from this comparative study of reported fatal and injury crashes on NZ roads since the issuing of the NZTA T10 specification in 1997 shows that:

1. Crash rate reductions were greater for rural roads than for urban roads and generally for "wet" crashes than for "all" crashes.
2. The fatal and injury crash rate on "wet" rural SH's over the period 1998-2008 is trending downwards, whereas the rate of "all" rural SH crashes is largely static for this period. (By comparison, both "all" and "wet" crash rates on local authority rural roads are trending upwards.)

Asset Considerations

1. The percentage of the state highway network sealed each year went up immediately after the T10 specification was introduced for three years but then settled to a rate similar to that before the specification's introduction. This has occurred despite large increases in heavy traffic.
2. It is contended that as low texture criteria has always been used in the assessment of the need to reseal, the only "extra" sealing resulting from the T10 specification for skid resistance management of NZ SH's has been associated with sealing chip aggregate

polishing. The "extra" resealing associated with the T10 specification is approximately 6% by length.

3. The approximate total cost of implementing the T10 specification is between $4.5M per year and $7.2M per year and the benefits, in terms of "wet" rural SH fatal and injury crash reductions, are costed at between $95.7M per year and $159.5M per year.

Summary

The NZTA skid resistance policy has resulted in a significant reduction in the rural state highway network "wet" road crash rate. While the policy has significant costs, we are confident that the policy is very effective and efficient. When costs are compared with benefits it is calculated that the benefit cost ratio is between 13 and 35.

It is acknowledged that the certainty of the benefit calculations could be improved. However the benefits could be halved or the costs doubled and the policy would still be an extremely efficient safety strategy. In addition the benefits of improved skid resistance on dry roads, that some local authorities have significant skid resistance policies, nor the benefits of the earlier skid resistance policy have been included in these benefit calculations.

The NZTA skid resistance policy has also has also been used by other safety staff when studying black spots. A permanent increase in skid resistance is one action available to crash investigators.

In addition the skid resistance policy has assisted in development of a safety awareness among NZTA staff and contractors that spreads to other safety areas.

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DISCLAIMER

The views expressed in this paper are those of the authors and are not necessarily those of NZ Transport Agency.

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David Cook works for New Zealand Transport agency on skid resistance, surfacings and associated safety areas. He has over 40 years experience in a wide range of roading issues from construction supervision, major project development and roading maintenance and construction. He has been involved in a variety of roles relating to the development of the state highway skid resistance policy. He managed the initial High Speed Data Collection contract that included skid resistance. Recently he retired as chairman of STAG (Skid Technical Advisory Group), the group responsible for overview and management of the state highway skid resistance policy, following a period of 8 years as chairman.

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Dave Whitehead holds the position of Senior Asset Manager at the NZ Transport Agency's National Office in Wellington. He has over 30 years experience, mainly UK based, in a wide range of roading projects. Initially in major road design and construction supervision but for the past 15 years primarily in roading maintenance and asset management. He has recently become chairman of STAG (Skid Technical Advisory Group), the group responsible for overview and management of the state highway skid resistance policy. He is responsible for specifications relating to skid resistance, and is also involved in a wide range of projects related to Asset Management.

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Joanna Towler has had 15 years experience in the roading industry. Joanna holds the position of Operations Engineer at the New Zealand Transport Agency's National Office in Wellington. Joanna is responsible for specifications relating to road surfacings and delineation for New Zealand state highways and has been involved in a wide variety of projects, ranging from performance based chipseal specifications, to skid resistance, to road markings.

Joanna has also had local authority experience, working at Wellington City Council prior to joining Transit New Zealand, now the NZ Transport Agency, in the year 2000.

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APPENDIX A

A1 CAS crash data

Table A1: CAS crash numbers 1995–2008.

year	Crash Numbers: Fatal & Injury															
	SH								TLA							
	urban				rural				urban				rural			
	"all"	"dry"	"other"	"wet"	"all"	"dry"	"other"	"wet"	"all"	"dry"	"other"	"wet"	"all"	"dry"	"other"	"wet"
1995	1,139	831	8	300	2,931	1,869	65	997	6,638	4,731	65	1,842	1,544	1,075	29	440
1996	1,001	713	10	278	2,658	1,576	99	983	5,600	4,058	65	1,477	1,318	924	18	376
1997	915	697	10	208	2,351	1,592	54	705	5,046	3,800	68	1,178	1,221	888	24	309
1998	742	567	6	169	2,242	1,447	31	764	4,572	3,547	37	988	1,278	914	16	348
1999	737	571	8	158	2,318	1,501	32	785	4,284	3,314	33	937	1,207	892	14	301
2000	689	547	4	138	2,166	1,440	26	700	3,924	3,062	35	827	1,115	799	18	298
2001	802	592	6	204	2,450	1,488	97	865	4,397	3,294	50	1,053	1,289	877	50	362
2002	1,015	776	6	233	2,602	1,678	62	862	5,151	3,882	50	1,219	1,488	1,088	24	376
2003	1,005	772	4	229	2,774	1,857	85	832	5,293	4,055	35	1,203	1,652	1,171	39	442
2004	946	728	4	214	2,761	1,748	88	925	5,194	3,941	34	1,219	1,591	1,083	46	462
2005	946	762	3	181	2,858	1,953	56	849	5,429	4,346	24	1,059	1,682	1,212	39	431
2006	1,036	825	4	207	2,900	1,945	106	849	5,672	4,490	31	1,151	1,704	1,202	51	451
2007	1,030	824	5	201	3,135	2,153	101	881	6,108	4,865	18	1,225	1,884	1,358	32	494
2008	1,043	839	3	201	2,821	1,998	64	759	6,050	4,686	29	1,335	1,846	1,364	22	460

A2 Exposures

Table A2: Per-annum exposures (10^8 vkt).

Year	SH			TLA		
	urban	rural	total	urban	rural	total
1995	22.8	123.3	146.1	118.4	54.6	173
1996	23.6	128.1	151.7	121.2	56	177.2
1997	24.5	132.8	157.3	124.1	57.3	181.4
1998	25.4	137.5	162.9	127	58.6	185.6
1999	26.4	143.1	169.5	131.9	60.9	192.8
2000	26.9	146.1	173	132.8	61.3	194.1
2001	27.9	151.7	179.6	134.4	62	196.4
2002	28.8	156.5	185.3	137.3	63.4	200.7
2003	29.6	161	190.6	140.3	64.8	205.1
2004	30.6	166.4	197	143.9	66.4	210.3
2005	31.4	170.7	202.1	149.5	69	218.5
2006	32.2	175.5	207.7	150.1	69.3	219.4
2007	32.6	177.7	210.3	152.2	70.3	222.5
2008	33	179.8	212.8	154	71.1	225.1

Note:

The exposures listed in the Table above are for any road moisture level. Accordingly, they must be multiplied by 0.25 to determine “wet” exposures if it is assumed that the road is wet for 25% of the time (Henderson and Cenek, 2006).

A3 Crash Rates

Table A3: Crash rates (fatal and injury crashes per 10^8 v-km/y).

Year	SH					TLA				
	urban		rural		total	urban		rural		total
	"all"	"wet"	"all"	"wet"	all categories	"all"	"wet"	"all"	"wet"	all categories
1995	50	52.7	23.8	32.3	158.8	56.1	62.3	28.3	32.2	178.9
1996	42.4	47	20.8	30.7	140.9	46.2	48.7	23.5	26.9	145.3
1997	37.4	34	17.7	21.2	110.3	40.6	38	21.3	21.6	121.5
1998	29.3	26.7	16.3	22.2	94.5	36	31.1	21.8	23.7	112.6
1999	27.9	23.9	16.2	21.9	89.9	32.5	28.4	19.8	19.8	100.5
2000	25.6	20.5	14.8	19.2	80.1	29.5	24.9	18.2	19.4	92
2001	28.7	29.2	16.2	22.8	96.9	32.7	31.3	20.8	23.4	108.2
2002	35.2	32.4	16.6	22	106.2	37.5	35.5	23.5	23.7	120.2
2003	34	30.9	17.2	20.7	102.8	37.7	34.3	25.5	27.3	124.8
2004	30.9	28	16.6	22.2	97.7	36.1	33.9	24	27.8	121.8
2005	30.1	23.1	16.7	19.9	89.8	36.3	28.3	24.4	25	114
2006	32.1	25.7	16.5	19.4	93.7	37.8	30.7	24.6	26	119.1
2007	31.6	24.6	17.6	19.8	93.6	40.1	32.2	26.8	28.1	127.2
2008	31.6	24.4	15.7	16.9	88.6	39.3	34.7	26	25.9	125.9

Note:

The "wet" crash rates Tabulated above assume that the road is wet for 25% of the time (Henderson and Cenek, 2006).