TYPICAL ACCIDENT RATES FOR RURAL PASSING LANES AND UNSEALED ROADS

Transfund New Zealand Research Report No. 89

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M.W. MCLARIN
Opus Central Laboratories, Lower Hutt

Transfund New Zealand Research Report No. 89

ISBN 0-478-10547-9
ISSN 1174-0574

P O Box 2331, Lambton Quay, Wellington, New Zealand
Telephone (04) 473-0220; Facsimile (04) 499-0733

M.W. McLarin 1997. Typical accident rates for rural passing lanes and unsealed roads. *Transfund New Zealand Research Report No. 89.* 30 pp.

Keywords: accident rates, passing lanes, unsealed roads, New Zealand

AN IMPORTANT NOTE FOR THE READER

The research detailed in this report was commissioned by Transit New Zealand when it had responsibility for funding roading in New Zealand. This is now the responsibility of Transfund New Zealand.

CONTENTS

EXECUTIVE SUMMARY

1. This report presents the results of accident rate calculations, made in 1995, for rural passing lane sections of New Zealand state highways and for rural sections of unsealed state highway and local roads. Where data is sufficient and reliable the calculated rates could be used as input in project evaluation cost/benefit analysis

2. Rates were calculated from national Traffic Accident Records (TAR) and road description databases (Road Assessment and Maintenance Management - RAMM, National Traffic Database - NTD, and Road Geometry Data Acquisition System - RGDAS) and are expressed as the number of reported injury accidents per 100 million vehicle kilometres of exposure.

3. Use of the road description databases allowed the calculation of rates in several traffic volume (AADT) sub-categories and, for the state highway passing lanes, in three terrain severity sub-categories (flat, rolling, mountainous).

4. In all the state highway passing lane cases where there was a reasonable volume of data, accident rates were found to be not substantially different from those currently being used for accident cost/benefit project evaluations of similar road types. Thus the overall accident rate for "4-lane divided rural state highway" was equal to 12, the value currently used for motorways. Also, the accident rates for "3 or 4 lane undivided rural state highways" lay within the range of rates (15 - 31 depending on AADT and terrain) currently used for rural sealed two lane roads.

5. Accident rates for rural unsealed state highways and local roads are not considered sufficiently robust to be used with confidence in general project evaluation studies and it is recommended that current practice (i.e. seeking accident and vehicle exposure data specific to the area being evaluated) should continue.

6. Location matching of accidents and road type/use was found to be a major inadequacy with the current organisation of the source databases. It is recommended that no further studies of the type undertaken here be carried out until a co-ordinate based (or other absolute) location system is implemented in all relevant databases.

ABSTRACT

National accident records and road description databases are used to calculate accident rates (expressed as the number of reported injury accidents per 100 million kilometres) for some selected types of road. Rates were calculated for three classes of passing lane on rural sections of New Zealand state highways, and for rural unsealed sections of state highways and local roads. Where there was sufficient data, rates were also calculated for several traffic volume and terrain severity sub-categories. While apparently sound indicative results were obtained in some cases, there was too much uncertainty in database matching of accident locations to allow confidence in many of the sub-category rates. It is recommended that similar studies not be undertaken until database information is improved.

1. INTRODUCTION

The inclusion of accident rates in the economic analysis of roading projects has become a significant requirement of Transit New Zealand's "Project Evaluation Manual" (PEM), 1991. As the cost per accident has been raised (to $2 Million in 1991 dollars for a fatality), the procedures for assessing cost savings from projected accident reductions have had to be made more thorough.

An important part of the assessment process is to decide on the likely accident rate reduction (if any) when a particular existing type of road section is replaced by an improved type. (The improvement may be in features other than accident rate, although it is usually safe to assume that improved types will at least not intentionally make accident rates any worse.) To assist with the assessment, the PEM provides typical injury accident rates for some categories of road section, intersection and curves. At present, rates are given for urban intersections, urban and rural mid-block sections, motorways and curves in 100 km/h areas.

The purpose of the current study was to evaluate rates for some additional categories of rural mid-block road sections. Values were derived for passing lanes in 100 km/h areas of state highway (three lane undivided, four lane undivided, and four lanes divided two-lane by two-lane), and unsealed sections of local roads in 100 km/h areas. Values for unsealed sections of state highway were also sought, but there was insufficient data to allow reliable rates to be derived. Where data allowed, the rates were further subdivided by traffic volume and by terrain type, as in PEM Table A6.4 that gives rates for 100 km/h speed limit two lane roads, and is reproduced for reference as Table 1.

Table 1. Reproduction of PEM Table A6.4.

	Reported Injury Accidents/10^8 veh-kms		
AADT	**Terrain type**		
	Flat	**Rolling**	**Mountainous**
<500	15	24	31
500-2,500	22	23	26
2,500-12,000	20	27	28
>12,000	24	18	N/A

The report first describes the data sources, and documents the extraction from four parent databases of information pertinent to this study. Vehicle exposure is listed in four AADT ranges and reported injury accidents in three severity classes. The totals for vehicle exposure and numbers of accidents in four categories (two rural passing lane and two rural unsealed road) are used to calculate preliminary overall accident rates against which sub-category rates calculated after database linking could be compared. The assumptions inherent in the preliminary rate calculations are also discussed. Rate calculations after database linking showed that the preliminary rates do approximate those found in the four categories with the exception of the "rural unsealed state highway" category where the preliminary rate appears unrealistically high.

In Section 3, accident rates for rural passing lanes and unsealed roads are calculated in various AADT categories of interest. This is achieved by location linking of the vehicle exposure database (RAMM or NTD) and the accident record database. Accident rates are reported in all sub-categories where there is sufficient data. The location linking procedure is presented and problems with unlocatable (or imprecise location) accidents are described. A scaling technique is used to approximately allow for these. Accident numbers are also presented in two terrain sub-categories (Flat or Hill) taken from the accident record "FLATHILL" field. In the case of passing lanes these numbers can be compared with the terrain classifications given in the next section.

In Section 4, state highway passing lane accident rates are calculated (where data is sufficient) for three terrain categories in each of four AADT categories. Terrain classification is achieved by location linking with the sealed state highway road geometry database RGDAS. In some cases a few accidents cannot be terrain classified because they occurred on sections of the state highway not present at the time of the 1992 RGDAS survey.

The report ends with a discussion of the results confidence (Section 5) and some concluding remarks (Section 6). It is argued that automatic location matching, given the current organisation of the source databases, is too unreliable to permit high confidence in the resulting calculated accident rates. It is recommended that no further studies of this type be undertaken until location information in all databases is improved.

2. DATA SOURCES AND DESCRIPTIONS

2.1 Parent Databases

The data for the work was assembled from two sources. Three Transit New Zealand-sourced databases (RAMM, NTD, RGDAS) provided information on the condition, use, and geometry of New Zealand state highways and local roads, and a database from the Land Transport Safety Authority (TAR) provided the information on accidents. A description of the four databases follows.

- **RAMM (Road Assessment and Maintenance Management)**

  This database is used by Transit New Zealand and roading authorities throughout the country for monitoring and maintenance operations. A full description of the database can be found in the current RAMM User's Manual. For the purposes of the work here, an extract (June 1995) of rural state highway sections (but not motorways) that were multi-lane (divided or undivided) or unsealed was made. The location (route position start and end), annual average daily traffic (ADT and date), number of lanes, road direction (if divided) were obtained for each section. Annual vehicle exposure levels for each section, derived from the length and ADT values, were added to the extract.

  A total of 425 multi-lane sections were identified, of which 297 were three lane and 33 were four lane undivided highway, the rest being either more lanes or divided sections of highway. In the case of four lane divided highway (specifically two lane by two lane), 52 two lane sections were identified, by manual inspection of the data, to form approximately matching parts of discrete or adjoining four lane divided highway.

  A total of 46 sections of unsealed state highway were identified.

  Later an extract of sections from sealing records was made, giving "first coat" and "two coat" seals that had been applied to the multi-lane sections since 1 January 1990. It was intended to use this to date possible construction of multi-lanes over the accident sample five year period.

  The sealing records extract identified a total of 76 first coat and two coat seals, and by manual inspection 23 of these were judged to be wide enough and long enough to likely be the result of passing lane construction.

- **NTD (National Traffic Database)**

  This database was compiled for Transit by Works Consultancy Services Ltd from data collected during the second half of 1994. The database gives a breakdown of road usage by road section location and vehicle class. A full description is given in the four volume report to Transit New Zealand entitled "National Traffic Database". In the report, Volume 1: Contents and Operation of Database, details the overall structure, but for the purpose of obtaining ADT values for unsealed local roads only the road section location records were needed. The particular fields used were those relating to location (road name, start feature, end feature, local authority code), speed zone and surface (rural/urban, sealed/unsealed), and traffic level (ADT, length). It is worth noting that the local authority code used in NTD does not correspond to that used in the TAR accident recording described below. Again, annual vehicle exposure levels for each section were added to the extract.

Traffic exposure data was extracted for rural unsealed local roads using the following criteria:

- A local road (SH_loc equal to L)
- Unsealed (S_U equal to U)
- Rural (U_R_adj equal to R)

This produced a total of 17140 sections.

- **RGDAS (Road Geometry Data Acquisition System)**

  Comprehensive road geometry data for sealed sections of the state highway network was collected by Transit New Zealand in the Autumn of 1992. The collection was carried out for travel in both directions and was aligned to the network route position locations as defined in the Transit New Zealand Reference Station List dated 23 August 1991. The nature and use of this data has been described in detail elsewhere (Rawlinson 1983, Transit New Zealand 1995, Wanty *et al* 1995) and was to be used here for terrain classification of state highway passing lanes. The particular data used here was the "summary statistics of 10 m interval data" assembled for each direction of the surveyed network divided into adjoining 200 m segments. The primary statistics recorded were the average, maximum and minimum of the 10 m data in each 200 m, and for terrain classification in this study the grade and horizontal curvature were used.

- **TAR (Traffic Accident Records for Reported Injury Accidents)**

  The record structure and notes on using the database were supplied by the Land Transport Safety Authority ("Preparing SAS Jobs", August 1994) along with data for the five year period 1990 to 1994 inclusive. The data is divided into environment, vehicle, and casualty sections. For the work here only the environment section data was needed - accident location, time, severity and number of vehicles, the road condition and layout, and the weather and lighting conditions. In particular, it was possible to select groups of accidents that met the following conditions appropriate to the study.

Mid-block reported injury accidents on multi-lane rural state highways, i.e.

- On a state highway (SH equal to 1)
- Not on a motorway (BCORM not equal to M)
- Not at an intersection or driveway (INTER not equal to I or D)
- Speed limit of 100 km/h (SPDLMT equal to 100)
- More than two lanes (TOTLANES greater than 2)

produced a total of 1080 accidents in the five year period.

Mid-block reported injury accidents on unsealed rural state highways, i.e.

- On a state highway (SH equal to 1)
- Not on a motorway (BCORM not equal to M)
- Not at an intersection or driveway (INTER not equal to I or D)
- Speed limit of 100 km/h (SPDLMT equal to 100)
- Unsealed (RDSURF equal to U)

produced a total of 87 accidents in the five year period.

Mid-block reported injury accidents on unsealed rural local roads, i.e.

- On a local road (SH equal to 0)
- Not on a motorway (BCORM not equal to M)
- Not at an intersection or driveway (INTER not equal to I or D)
- Speed limit of 100 km/h (SPDLMT equal to 100)
- Unsealed (RDSURF equal to U)

produced a total of 814 accidents in the five year period.

A terrain-related field in the TAR database was used in subsequent work as an additional parameter in presenting results. The field name is "FLATHILL" and records if the accident site was a flat road (F) or a hill road (H).

2.2 Data Scoping

To get an idea of data levels in other sub-categories of interest, the main category data extracts described above were subdivided further. The vehicle exposure data from RAMM and NTD was divided into AADT ranges that have been used in Transit New Zealand's Project Evaluation Manual, Volume II, for accident cost analysis (refer PEM Table A6.4). Reported injury accident data from TAR was divided into the three recorded severity categories of fatal, serious, or minor.

2.2.1 Vehicle Exposures and Numbers of Accidents

Table 2. Vehicle exposure - rural state highway passing lanes, three lane and four lane.

	Three lane (undivided)			Four lane (both divided 2x2 and undivided)		
AADT	**No. of lengths**	**Length (km)**	**Exposure (10^6 v-km)**	**No. of lengths**	**Length (km)**	**Exposure (10^6 v-km)**
<500	0	0	0	0	0	0
≥500, <2500	57	46.03	25.92	1	0.30	0.16
≥2500, <12000	207	187.24	376.13	27	18.51	47.37
≥12000	33	23.92	152.21	31	34.28	357.52
Totals	297	257.19	554.26	59	53.09	405.05
	Annual exposure (10^8 v-km) = 5.54			Annual exposure (10^8 v-km) = 4.05		

Table 3. Reported injury accidents (1990-1994 inclusive) - rural state highways, three lane and four lane.

Accident severity category	Three lane		Four lane	
	No.	**%**	**No.**	**%**
Fatal	44	6.6	21	6.6
Serious	199	29.6	68	21.4
Minor	429	63.8	229	72.0
Totals	672		318	
Average annual numbers	134.4		63.6	

Table 4. Vehicle exposure - rural unsealed state highways.

AADT	No. of lengths	Length (km)	Exposure (10^6 v-km)
<500	40	116.02	6.77
≥500, <2500	6	22.36	9.80
≥2500, <12000	0	0	0
≥12000	0	0	0
Totals	46	138.38	16.57
	Annual exposure (10^8 v-km) = 0.166		

Table 5. Reported injury accidents (1990-1994 inclusive) - rural unsealed state highways.

Accident severity category	Mid-block accidents	
	No.	%
Fatal	8	9.2
Serious	22	25.3
Minor	57	65.5
Totals	87	
Average annual numbers	17.4	

Table 6. Vehicle exposure - rural unsealed local roads.

AADT	No. of lengths	Length (km)	Exposure (10^6 v-km)
<500	17049	33761.67	678.48
≥500, <2500	88	164.17	38.01
≥2500, <12000	3	0.88	0.96
≥12000	0	0	0
Totals	17140	33926.72	717.50
	Annual exposure (10^8 v-km) = 7.175		

Table 7. Reported injury accidents (1990-1994 inclusive) - rural unsealed local roads.

Accident severity category	Mid-block accidents	
	No.	%
Fatal	59	7.3
Serious	307	37.7
Minor	448	55.0
Totals	814	
Average annual numbers	162.8	

2.2.2 Preliminary Overall Accident Rates

If it is assumed that the total vehicle exposure and total accident count in each category above are complete for that category, then overall accident rates for each category can be calculated. The rate will be the annual number of reported injury accidents divided by the annual vehicle exposure, and these are presented in Table 8. (Also shown are 95% confidence limits due to statistical error only as derived from accident numbers. Refer Section 5.1.)

Table 8. Preliminary overall accident rates.

Reported injury accidents / 10^8 v-km (95% confidence limits)			
Rural state highway passing lanes		**Rural unsealed**	
Three lane undivided	**Four lane undivided and divided 2x2**	**State highways**	**Local roads**
24 (±7%)	16 (±11%)	105 (±21%)	23 (±7%)

There are a number of aspects to the above assumption, viz:

- The AADT values used to derive vehicle exposure are assumed to be reasonable average values for the five year time period. AADT values in the RAMM extract have dates ranging from 31 December 1988 through to 31 December 1994 with about 50% either side of the mid-period date of 30 June 1992, so they should provide reasonable overall average vehicle exposures. The values in the NTD when assembled were adjusted to be current at the end of 1994, so will on average give an over-estimate of vehicle exposure over the previous five years.

- The use of data from road section categories in existence at the end of the five year period within which accident data is assembled, only gives correct vehicle exposure values if the section existed in that category for the whole period. There will be some rural multi-lane sections of state highway in existence in June 1995 (the date of the RAMM extract) that have not existed through all the previous five years, and consequently the vehicle exposure values will be an over-estimate of the true average annual value. The situation is reversed for rural unsealed sections (state highway or local) since some sealed sections in existence at the end of the five year period would have been unsealed for part of it. Thus, in this case, the unsealed sections vehicle exposure values are missing a part contribution when sections were sealed during the period and the value is an under-estimate of the true exposure.

- There are also the converses of the above to consider, but these are thought to be less significant. Reversion in the previous five years of rural multi-lane state highway sections to sections with less lanes, is possible but is probably rare. An increase in unsealed rural road sections is likely from new road construction in the local road category, but may also occur in the state highway category if new highways (or highway sections) have been constructed or declared from existing local road sections in the previous five years.

- For the above location of multi-lane state highway sections and their accidents, it is necessary to rely on the "total number of lanes" value recorded both in the RAMM and the TAR databases. This is a parameter of importance in the road maintenance and management functions of RAMM and is consequently expected to be reliably recorded there. In the case of traffic accident recording the parameter is not so central to the function of the database and it may not be so reliably recorded. It could be anticipated that the most likely error would be under recording of the number of lanes at an accident site since the lanes in one direction only may be recorded rather than the total number of lanes at the site. (It is hard to envisage how more than the actual total number of lanes could be recorded.) The most likely outcome from errors in lane numbers is therefore to under-estimate accident numbers and rates in the multi-lane categories.

With these provisos in mind, the preliminary accident rate figures given above should be considered as only a guide to the likely overall rates in the different categories. It is still notable that the rate on rural unsealed state highways is more than four times as high as that for rural unsealed local roads. This big difference in unsealed rural rates could be related to substantial under-reporting on local roads. However, assuming for example that minor accidents are the only significant numbers under-reported, say by a total of 300, then the local road total number of accidents would be 1114 (5% fatal, 28% serious, 67% minor), but the overall accident rate would still be less than a third of that on the rural unsealed state highways. Anyway, data given in the next section, after exposure and accident databases are linked, indicate that the preliminary rate for rural unsealed state highways is unrealistically high. It is argued that this is most probably because accidents at road works on otherwise sealed highway have been included (refer Section 5.3).

3. DEPENDENCE OF ACCIDENT RATES ON AADT

3.1 State Highway Rural Passing Lanes (Three Lane Undivided, Four Lane Undivided and Divided)

The data from RAMM, for the three classes of passing lane to be considered (382 sections), was to be linked to the TAR data, for all mid-block accidents recorded as occurring on a state highway but not on a motorway (11747), by checking the TAR location against the RAMM start and end locations of the passing lane section.

Prior to linking, a construction date field was added to RAMM and the vehicle exposure data was recalculated to take account of cases where sealing data (significant first coat and two coat seals) indicated that the section may have been constructed during the five year period. A total of 14 sections of undivided three and four lane highway, and 9 two lane sections of four lane divided highway were modified in this way. A nominal construction date of 31 December 1989 was entered if there was no evidence of construction during the 1990-94 period.

Also prior to linking, the TAR accident location data from the "AXROAD" field was decoded to the route position components of State Highway Number, Reference Station Number, and Offset Distance, for direct matching with the RAMM route position data. (The "TRAFDIST" field was also used to enable differentiation of SH 1 in the North Island from SH 1 in the South Island, as is done in RAMM.) The AXROAD field contains the name of the road the accident occurred on and for accidents on state highways this has been converted (where possible) to an 11 digit numeric code containing the above route position components. In the decoding process it was found that almost a quarter of the mid-block state highway accidents (2773) had an incomplete AXROAD code. Of these, most (93%) were missing just the Offset Distance component. It was concluded that nothing practical could be done to resolve this missing location data, and it was decided to assume that the missing set would be representative of all mid-block state highway accidents. (For instance, the percentage severity division Fatal:Serious:Minor in the total was 9.9 : 29.2 : 60.9 and this is well preserved as 9.4 : 30.0 : 60.6 in the sub-group of located accidents.) On this basis, any accident rate results derived from the located set of accidents would be scaled up by a factor of 1.309 (11747/8974) to allow for the missing numbers.

The actual link was performed using all locatable mid-block state highway accidents (8974), and the 382 passing lane RAMM sections. The criteria were as follows:

- The same state highway number;
- The same reference station number;
- A TAR location offset distance within the RAMM section start and end offset; and
- An accident date later than the added passing lane construction date.

The link extracted a total of 606 accidents. However, when other fields in the accident records were checked this number was reduced to 551. The 55 rejects were cases where the records showed the total number of lanes as less than two, or the speed limit as less than 100 km/h, or the surface as being unsealed. It was considered that these cases probably represented accidents either wrongly located or occurring under atypical conditions for the sections (e.g. at times of roadworks). The division of the 551 accidents grouped by AADT range and by the accident record "F" or "H" terrain measure are given below. Using corresponding total vehicle exposure values from the RAMM data, the scaled accident rate for each AADT category has also been calculated. The flat or hill terrain division was included for comparison with that obtained using RGDAS data and reported in Section 4.

Table 9. Rural state highway passing lanes - AADT and TAR terrain subdivision.

(a) Three lane undivided.

AADT	Terrain (TAR)	No. of accidents	No. of lengths	Total length (km)	Annual vehicle exposure (10^6 v-km)	Annual no. of accidents (scaled)	Accident rate (scaled) accidents / 10^8 v-km	Statistical error 95% confidence limits
<500	**All**	**0**	**0**	**0**	**0**	**0**	**-**	-
≥500, <2500	Flat	4				1.05		
	Hill	21				5.50		
	All	**25**	**57**	**46.03**	**25.92**	**6.55**	**25**	17-35
≥2500, <12000	Flat	73				19.11		
	Hill	156				40.84		
	All	**229**	**207**	**187.2**	**376.1**	**59.95**	**16**	14-18
≥12000	Flat	54				14.14		
	Hill	34				8.90		
	All	**88**	**33**	**23.92**	**152.2**	**23.04**	**15**	12-18
All	Flat	131				34.30		
	Hill	211				55.24		
	All	**342**	**297**	**257.2**	**554.3**	**89.54**	**16**	15-17

(b) Four lane undivided.

AADT	Terrain (TAR)	No. of accidents	No. of lengths	Total length (km)	Vehicle exposure (10^6 v-km)	Annual no. of accidents (scaled)	Accident rate (scaled) accidents / 10^8 v-km	Statistical error 95% confidence limits
<500	**All**	**0**	**0**	**0**	**0**	**0**	**-**	-
≥500, <2500	**All**	**0**	**1**	**0.3**	**0.16**	**0**	**-**	-
≥2500, <12000	Flat	8				2.10		
	Hill	13				3.40		
	All	**21**	**22**	**17.4**	**40.39**	**5.50**	**14**	9-20
≥12000	Flat	43				11.26		
	Hill	6				1.57		
	All	**49**	**10**	**7.8**	**48.08**	**12.83**	**27**	20-34
All	Flat	51				13.35		
	Hill	19				4.98		
	All	**70**	**33**	**25.5**	**88.63**	**18.33**	**21**	17-25

Table 9. (cont'd)

(c) Four lane divided (two lane by two lane).

AADT	Terrain (TAR)	No. of accidents	No. of lengths	Total length (km)	Annual vehicle exposure (10^6 v-km)	Annual no. of accidents (scaled)	Accident rate (scaled) accidents / 10^8 v-km	Statistical error 95% confidence limits
<500	**All**	**0**	**0**	**0**	**0**	**0**	-	-
≥500, <2500	**All**	**0**	**0**	**0**	**0**	**0**	-	-
≥2500, <12000	Flat Hill **All**	1 0 **1**	**1**	**0.37**	**1.55**	0.26 0 **0.26**	-[+]	-
≥12000	Flat Hill **All**	131 7 **138**	**25**	**27.22**	**314.87**	34.30 1.83 **36.13**	**11**	9-13
All	Flat Hill **All**	132 7 **139**	**26**	**27.59**	**316.42**	34.56 1.83 **36.39**	**12**	10-14

[+]Insufficient Accidents (refer Section 5.1)

3.2 Rural Unsealed Sections of State Highway and Local Roads

This time data from RAMM (for state highways) and from NTD (for local roads) was to be linked with TAR accident records.

The link for state highways was a repeat of the process used above for passing lanes and therefore final accident rates again needed to be scaled up by the factor 1.309. (For the 87 mid-block accidents recorded as being on rural unsealed state highways, 21 were not able to be located by decoding the AXROAD field. This gives a missing rate of 24.1% and a scale up factor of 1.318, but it was considered better to use the overall figure of 1.309 derived from the total mid-block accident data for scaling purposes.)

The actual link was performed using all locatable mid-block state highway accidents (8974), and the 46 unsealed rural state highway RAMM sections. The criteria were as follows:

- The same state highway number;
- The same reference station number; and
- A TAR location offset distance within the RAMM section start and end offset.

The link extracted a total of seven accidents. However, two of these were recorded in TAR as being on sealed highway (dated 12 January 1990 and 9 February 1993). Although this number of accidents is too low to provide reliable accident rate figures, for completeness a two category AADT breakdown is given in Table 10.

Table 10. Rural unsealed state highway - AADT and TAR terrain subdivision.

AADT	Terrain (TAR)	No. of accidents	No. of lengths	Total length (km)	Annual Vehicle exposure (10^6 v-km)	Annual no. of accidents (scaled)	Accident rate (scaled) accidents / 10^8 v-km
<500	Flat	4				1.05	
	Hill	1				0.26	
	All	**5**	**40**	**116.0**	**6.77**	**1.31**	-+
≥500, <2500	Flat	2				0.52	
	Hill	0				0	
	All	**2**	**6**	**22.4**	**9.80**	**0.52**	-+

+Insufficient Accidents (refer Section 5.1)

The link for local roads, of the NTD data and the TAR data, was more difficult to resolve. Location is primarily by road name in both databases, but there appears to be considerable scope for ambiguity and duplication. After some trialing of techniques, the following scheme was used to get a reasonable degree of matching of local road accident sites with local road usage data.

The link was performed using all mid-block accidents recorded as being on unsealed, rural, local roads (814) and all sections of local roads in the NTD recorded as being unsealed and rural (17140). The criteria were as follows:

- The same local authority region; and
- From the TAR field "AXROAD", the first five characters and the last five with "RD" or "ROAD" or "ST" or "STREET" appended, were contained within the NTD field "ROADNAME".

This link extracted 516 accidents but they were matched with multiple road sections (on average about three sites each). An inspection of some of the extract showed that there were cases where a better match could be obtained because there was some correspondence of the road name in the TAR field "SIDEROAD" and the name in either the "FROM_DESC" or "TO_DESC" fields in the NTD definition of the road section. When this was the case there would typically be two sections that matched, and further resolution would not be practical.

The purpose of the link was to obtain an AADT value at the site of each accident in order to place them in particular AADT categories. It was decided that the best that could be practically obtained would be an average AADT for all road sections that were matched as above, but where a sideroad match could be found only, those sections would be used in calculating the average. This process was automated for the 516 accidents (which include three that were unrecorded as "flat" or "hill") and 1588 road sections, and produced the AADT distribution shown below. (A sideroad match was obtained for 39% of the 516 accidents.) Also shown are the vehicle exposure values for the total number of unsealed rural road sections and the resulting accident rates. A scaling factor of 1.578 (814/516) was used to allow for accidents that could not be located in the NTD data. As before, this invoked the assumption that the unlocated accidents were representative of the rest, and this is considered reasonable. (For instance, the percentage severity division Fatal:Serious:Minor for the total was 7.3 : 37.5 : 55.0 and this was well preserved as 6.6 : 38.2 : 55.2 in the sub-group located.)

Table 11. Rural unsealed local roads - AADT and TAR terrain subdivision.

AADT	Terrain (TAR)	No. of accidents	No. of lengths	Total length (km)	Annual vehicle exposure (10^6 v-km)	Annual no. of accidents (scaled)	Accident rate (scaled) accidents / 10^8 v-km	Statistical error 95% confidence limits
<50	Flat	60				18.93		
	Hill	74				23.35		
	All	**134**	**8893**	**16680**	**143.2**	**42.28**	**30**	26-34
≥50, <100	Flat	96				30.29		
	Hill	87				27.45		
	All	**184**	**5967**	**12689**	**286.1**	**58.05**	**20**	18-22
≥100, <500	Flat	82				25.87		
	Hill	102				32.18		
	All	**186**	**2189**	**4393**	**249.2**	**58.68**	**24**	21-27
≥500	Flat	8				2.52		
	Hill	4				1.26		
	All	**12**	**91**	**165**	**39.0**	**3.79**	**10**	6-15
All	Flat	246				77.61		
	Hill	267				84.24		
	All	**516**	**17140**	**33927**	**717.5**	**162.80**	**23**	21-25

4. TERRAIN DEPENDENCE FROM RGDAS FOR STATE HIGHWAY PASSING LANES

The RGDAS data collected in 1992 for the sealed state highway network was used to classify passing lane sections (three lane and four lane undivided, and four lane divided) into the three terrain categories defined in Transit New Zealand's Project Evaluation Manual - Volume II. The definitions are as follows:

Flat:	Level or gently rolling country, with gradients generally from flat up to 3%, which offers few obstacles to an unrestricted horizontal and vertical alignment.
Rolling:	Rolling, hilly, or foothill country with moderate grades generally from 3% to 6% in the main, but where occasional steep slopes may be encountered.
Mountainous:	Rugged, hilly, and mountainous country (and river gorges) often involving long, steep grades over 6%, and considerable proportions of road with limited sight distance.

They were translated to the following RGDAS data criteria:

Flat:	$|GAV| \le 1.5\%$ and $(GMAX-GMIN) \le 6\%$ and $(HMAX-HMIN) \le 5$ rad/km
Rolling:	$1.5\% < |GAV| \le 4.5\%$ or $6\% < (GMAX-GMIN) \le 12\%$ or $5 < (HMAX-HMIN) \le 15$ rad/km
Mountainous:	$|GAV| > 4.5\%$ or $(GMAX-GMIN) > 12\%$ or $(HMAX-HMIN) > 15$ rad/km

where GAV, GMAX, GMIN, HMAX, and HMIN are grade and horizontal curvature primary statistic values derived for each 200 m segment of highway from RGDAS survey data at 10 m intervals.

When applied to the passing lane sections the average grades in both directions were calculated from the 200 m segment values over the total length of the section and the criteria above applied to the larger (absolute) of the two. Similarly the maximum and minimum values of grade and horizontal curvature were found for both directions over the total length of the section, and the pair giving the greatest difference was subject to the criteria above.

The table below gives the resulting subdivision of accident and exposure values by AADT and terrain. In many cases there is a small discrepancy between the sum of the number of accidents and the number of road sections in the sub-categories and the total for the AADT class. They represent cases where the passing lane section was not located in the RGDAS database. This will only occur if the section did not exist as part of the sealed state highway network at the time of the RGDAS survey. The unclassified accident numbers are small and never exceed 5% of the sub-category total.

Table 12. Rural state highway passing lanes - AADT and RGDAS terrain subdivision.

(a) Three lane undivided.

AADT	**Terrain (RGDAS)**	**No. of accidents**	**No. of lengths**	**Total length (km)**	**Annual vehicle exposure (10^6 v-km)**	**Annual no. of accidents (scaled)**	**Accident rate (scaled) accidents / 10^8 v-km**	**Statistical error 95% confidence limits**
<500	**All**	**0**	**0**	**0**	**0**	**0**	-	-
≥500, <2500	Flat	0	3	0.96	0.54	0.00	-+	-
	Rolling	23	47	35.02	20.72	6.02	29	19-39
	Mountainous	1	2	5.99	2.71	0.26	-+	-
	All	**25**	**57**	**46.03**	**25.92**	**6.55**	**25**	16-34
≥2500, <12000	Flat	7	19	11.03	33.01	1.83	-+	-
	Rolling	215	167	162.10	317.80	56.29	18	16-20
	Mountainous	4	9	5.31	10.64	1.05	-+	-
	All	**229**	**207**	**187.20**	**376.10**	**59.95**	**16**	14-18
≥12000	Flat	24	11	5.84	49.93	6.28	13	9-17
	Rolling	60	19	16.83	95.19	15.71	17	13-21
	Mountainous	0	0	0	0	0	-	-
	All	**88**	**33**	**23.92**	**152.20**	**23.04**	**15**	12-18
All	Flat	31	33	17.83	83.48	8.12	10	7-13
	Rolling	298	233	214.00	433.70	78.02	18	16-20
	Mountainous	5	11	11.30	13.35	1.31	-+	-
	All	**342**	**297**	**257.20**	**554.30**	**89.54**	**16**	15-17

+Insufficient Accidents (refer Section 5.1)

(b) Four lane undivided.

AADT	**Terrain (RGDAS)**	**No. of accidents**	**No. of lengths**	**Total length (km)**	**Annual vehicle exposure (10^6 v-km)**	**Annual no. of accidents (scaled)**	**Accident rate (scaled) accidents / 10^8 v-km**	**Statistical error 95% confidence limits**
<500	**All**	**0**	**0**	**0**	**0**	**0**	-	-
≥500, <2500	Flat	0	0	0	0	0	-	-
	Rolling	0	1	0.3	0.16	0	-+	-
	Mountainous	0	0	0	0	0	-	-
	All	**0**	**1**	**0.3**	**0.16**	**0**	-+	-
≥2500, <12000	Flat	3	7	1.74	3.58	0.79	-+	-
	Rolling	17	11	14.82	34.12	4.45	13	8-20
	Mountainous	1	3	0.51	1.34	0.26	-+	-
	All	**21**	**22**	**17.40**	**40.39**	**5.50**	**14**	9-20
≥12000	Flat	22	3	4.32	27.79	5.76	21	14-30
	Rolling	27	6	3.35	19.45	7.07	36	25-50
	Mountainous	0	1	0.13	0.84	0	-	-
	All	**49**	**10**	**7.80**	**48.08**	**12.83**	**27**	20-34
All	Flat	25	10	6.06	31.37	6.55	21	14-29
	Rolling	44	18	18.48	53.73	11.52	21	15-27
	Mountainous	1	4	0.63	2.18	0.26	-+	-
	All	**70**	**33**	**25.50**	**88.63**	**18.33**	**21**	17-25

+Insufficient Accidents (refer Section 5.1)

Table 12. (cont'd)

(c) Four lane divided (two lane by two lane).

AADT	Terrain (RGDAS)	No. of accidents	No. of lengths	Total length (km)	Annual vehicle exposure (10^6 v-km)	Annual no. of accidents (scaled)	Accident rate (scaled) accidents/10^8 v-km	Statistical error 95% confidence limits
<500	**All**	**0**	**0**	**0**	**0**	**0**	-	-
≥500, <2500	**All**	**0**	**0**	**0**	**0**	**0**	-	-
≥2500, <12000	Flat	0	0	0	0	0	-	-
	Rolling	1	1	0.37	1.55	0.26	-[+]	-
	Mountainous	0	0	0	0	0	-	-
	All	**1**	**1**	**0.37**	**1.55**	**0.26**	-[+]	-
≥12000	Flat	44	7	10.29	102.31	11.52	11	8-14
	Rolling	94	18	16.93	212.56	24.61	12	10-14
	Mountainous	0	0	0	0	0	-	-
	All	**138**	**25**	**27.22**	**314.87**	**36.13**	**11**	9-13
All	Flat	44	7	10.29	102.31	11.52	11	8-14
	Rolling	95	19	17.30	214.11	24.87	12	10-14
	Mountainous	0	0	0	0	0	-	-
	All	**139**	**26**	**27.59**	**316.42**	**36.39**	**12**	10-14

[+]Insufficient Accidents (refer Section 5.1)

5. RESULTS CONFIDENCE

The results have been presented with the statistical error shown as 95% confidence limits on the accident rates as discussed below. It is important to appreciate that this is a measure of the statistical error only and does not include any bias that may be present from errors in the assembled and linked databases. The latter errors are considered to be potentially more important given the level of basic uncertainties that were evident in the derivation of the results. It is generally not possible to quantify them. Some are compensatory, others are not, and there are some for which even the net sense of the error is not clear. Significant factors are also discussed below.

5.1 Statistical Error

The confidence interval for the expectation of a Poisson variable can be calculated from standard tables (Pearson and Hartley, 1966). For five year accident numbers (N) greater than 50, the 95% confidence limits on the accident rate are approximately given by:

$$\pm \frac{1.96 \sqrt{N}}{E}$$

where E is the five year exposure (i.e. Annual Vehicle Exposure x 5).

For smaller values of N the upper and lower confidence limits differ, ranging from +15.9/E and –12.9/E for N=50, through +10.9/E and –7.8/E for N=20, to +8.4/E and -5.2/E for N=10. When N<10 the magnitude of the statistical error makes a calculated rate so uncertain that it has been decided not to report accident rates for categories with such low accident numbers.

5.2 Location of Accidents

Possibly the largest area of uncertainty arises from the inability to systematically link particular accidents, by their location, to particular information in other databases. Even in the case of accidents on the state highways, with a long history of route position location, it was found that about 25% of accidents were not recorded with complete route positions. In an overall sense there is adequate information in most accident records (taking all location related fields into account) to return, with some confidence, to the actual piece of road on which the accident occurred. For instance the inclusion of grid coordinates now makes this self-evident. However, when it comes to systematically linking this location information to other databases it is found that too many uncertainties remain. Until all related databases use coordinate based location systems the grid coordinates in TAR cannot be used for systematic linkage in a desk study. Other techniques that depend on evolving definition or varied usage fields such as route positions or road names, will always (unless rigidly systematic in all databases) result in a significant level of uncertainty.

The mid-block accident location scale factors, of 1.309 for state highways and 1.578 for rural unsealed local roads, that needed to be used in this study are a measure of the location uncertainty experienced. In the case of local roads even this factor was kept lower than actual by accepting location matches that, while probably including the actual location, also had other spurious location matches that could not practically be resolved further.

The reason for the phrase "probably including the actual location" above is some evidence that totally spurious location matching can occur. This was found when a link was attempted between the 17140 unsealed rural local road sections in NTD and the 23408 mid-block accidents in TAR that are recorded as being on all local roads. A match with multiple sections (3914 in total) was found for 1432 of the accidents. This number is 618 more than the 814 total number of mid-block accidents on unsealed rural local roads as listed in TAR. Exceeding 814 must be due to totally spurious matching.

This outcome also made doubtful the results of a link that was carried out to see how many of the 298 missed location matches (814 total less 516 matched) could be located on sealed rural local roads. A link was carried out between the 37352 rural local road sections in NTD (i.e. sealed and unsealed) and the 814 rural unsealed mid-block accidents. A match with multiple sections (3001) was found for 576 of them, which is 60 more than before. It would be tempting to attribute the 60 to "sections sealed sometime in the previous five years" but it is believed that the level of spurious matching is too high to allow any confidence in this conclusion. In the event it was decided, on balance, to accept the missed matching of 298 and to scale up the results based on the 516 that were apparently located.

5.3 Data Reliability

Another significant area contributing to uncertainty in the results is the reliability of the source information. There were several pointers to unreliable source data in the present study. The sometimes very large disparity between the preliminary data, extracted from the source databases prior to linking them, and that obtained after linking them is the main one.

For instance, it remains unresolved why the extraction from TAR of mid-block accidents on rural three and four lane state highways should result in 990 accidents, while after location linking with RAMM data for rural three and four lane state highways only 721 accidents (after scaling up) were found to match. If anything, as argued before, it would be expected that the extract just from the TAR database would produce less multi-lane highway accidents. (This is based on the presumption that any miscoding of the total number of lanes in TAR would be most likely to err on the side of under counting of the lanes rather than over counting.) No satisfactory explanation for the sense or size of this disparity has been found.

A similar sensed disparity was observed in the smaller sample of mid-block accidents on rural unsealed sections of state highway, although in this case it appears that there is an explanation other than significant unreliable data. When this group was extracted from TAR a total of 87 accidents were identified, whereas after linking with the RAMM data only nine accidents (after scaling up) were found, and two of these were recorded in TAR as being on sealed highway so were not part of the first 87. Scrutiny of the state highway numbers of the 87 accidents showed that one was invalid and 54 were on highway numbers less than 10. State highways lower numbered than 10 would generally not have unsealed sections except in atypical situations such as roadworks. This may also explain many of the remaining 32 accidents that were recorded as being on unsealed sections of highways with numbers 10 or higher.

In consideration of the disparity in rural passing lane accident numbers, an inspection was made of the RAMM sections showing two-digit accident numbers. This isolated eight sections. Disturbingly one of the sections was shown as 2.5 km of undivided four lane highway on State Highway 1N starting 6.5 km south of Reference Station 931. This section of highway is known to be mostly two lane, although there is a short four lane section at the start and a three lane section at the end. Of the 25 mid-block accidents located on this RAMM section the TAR records show that 5, 2 and 18 occurred where the total number of lanes were four, three and two respectively. Thus the TAR records match better the known lane numbers over this whole section. It had been anticipated that the RAMM information on multi-lane highway would be reliable because the number of lanes is a central factor in highway maintenance and management. The discovery of the above miscoded section casts some doubt on the reliability that can be assumed of RAMM.

Another of the eight passing lane sections with high accident numbers was a 2 km section of State Highway 1N at Albany just north of Auckland. The section starts 6.7 km south of Reference Station 303. In this case there is agreement of the TAR and RAMM number of lanes. However, a problem is indicated with the "date of construction" as derived here from the application of a first coat seal on 2 December 1993. Of the 22 mid-block accidents located on this section, which RAMM classifies as three lane undivided, the TAR records show that 18, 3 and 1 occurred where the total number of lanes was recorded as three, two and one respectively. For the one-lane and one of the three two-lane instances the road surface is recorded as unsealed (dated 29 November 1993 and 26 February 1994 with speed limits of 30 and 100 km/h respectively) and at least for the one-lane instance this coincides with roadworks associated with the first coat seal. That the TAR records show three lanes for mid-block accidents on this section throughout the five year period 1990-94, and that the section is an old and well known passing lane, indicates that in this case the first coat seal was a reconstruction rather than a construction.

6. CONCLUDING REMARKS

Database descriptions of accidents and vehicle exposure on rural multi-lane state highways, and on rural unsealed state highways and local roads, have been combined to determine typical accident rates for these areas. A further subdivision into terrain type was also made in the case of the multi-lane state highways where road geometry data was available to provide the terrain grouping.

In all multi-lane state highway cases where there was a reasonable volume of data in the category, the accident rates were found to be not substantially different from those currently being used for accident cost/benefit project evaluations of similar road types. For instance, in Table 12 the overall rate for four lane divided rural state highway was found to be 12, and this equals the value already used for motorways. Also from Table 12, the rates for undivided three and four lane rural state highways generally lie within the range of rates (15 to 31) currently used for rural two lane roads (refer Table 1).

There is, however, some indication that rates for undivided rural passing lanes, in commonly occurring sub-categories, can differ from the corresponding rural sealed two lane rate. The most common sub-category by far (three lane undivided, rolling terrain, AADT 2500-12,000) shows a rate of 18 which is considerably less than the rate of 27 in use for the same sub-category of rural two lane road. This outcome can be contrasted with the next two most common sub-categories (rolling terrain with AADT $\geq$ 12,000 and either three lane or four lane undivided) which show rates of 18 and 36, respectively equalling and considerably exceeding the rate of 18 in use for the same sub-category of rural two lane road.

Accident rates for rural unsealed state highways could not be reliably calculated. The preliminary value reported in Table 8 is unrealistically high because it includes a substantial number of accidents that appear to be at road works on normally sealed sections of state highway. For these accidents there is no corresponding vehicle exposure contribution in the rate calculation. When "road works accidents" were removed the number remaining was so small (Table 10) that accident rates could not be calculated with any useful level of confidence.

The accident rates for rural unsealed local roads in four AADT categories (Table 11) are new and may be useful indicators in the absence of any better data. Rates from 20 to 30 do not appear unlikely for these roads when compared to the lowest AADT category in Table 1. The accident rate of 10 for AADT$\geq$500 reported in Table 11 is surprisingly low but accident numbers in this category are very small and the result must be considered unreliable. Because of significant location uncertainties the rates in all AADT categories are not considered sufficiently robust to be used with confidence in general project evaluation studies. Current practice of seeking specific accident and vehicle exposure data relating to the area being evaluated is still to be preferred.

It was found that location matching was a major inadequacy with the current organisation of the source databases, and it is recommended that no further studies of the type undertaken here be carried out until coordinate based location systems are implemented in all the relevant databases. In the interim if any similar studies are required, they should be planned with the expectation that specific road sections existence and five year history would need to be assembled case by case. Accident matching (also possibly case by case) to the known road section could then be expected to produce more reliable accident rate results.

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