Road Safety through Road Design Improvements
Lal Wadhwa

Introduction

The results of previous work have shown that roads with higher geometric standards are safer. In fact the freeways (or motorways) are the safest form of road, being four times as safe as other roads and can be as much as 20 times as safe as other arterial roads (Ogden, 1996, p. 155; Asfa, 2000, p. 2)). In Australia, where population is sparse except in the metropolitan cities, travel demand and economics do not permit all roads to be built to the highest standards. A significant proportion of Australian roads, especially in country areas, have been built to lower standards. Improving design standards will undoubtedly improve safety on roads. The design standards refer to strategic decisions concerning the geometric standards to which the road is built. Such decisions are possible to be made efficiently and rationally if the decision-makers are aware of the effect of improving standards on reducing accident risk.

Several researchers have recognised the link between safety and road design and have recommended the explicit incorporation of road safety into design of various elements of the road (for example, Wegman and Slop, 1998; Talens, 1999; Robinson and Smith, 2000). Armour et al (1989) showed that unsealed shoulders, narrow lanes and low skid resistance are associated with increased accident risk. Citing the higher mortality rates of traffic accident victims in Poland which are four times higher compared to the average rates in European Union, Jamroz et al (1998) have recommended the modification of design practices to improve road safety in Poland. Robertson and Goodwin (1987) identified road design features associated with stress, and discussed relationships between the road design features, stress and accidents. Chudworth and Stewart (1990) argue against the use of transition curves due to the difficulty in perceiving the true curvature of the horizontal curve. Hasson (2000) reported on an OECD study linking road design to road safety strategy suggesting that the basis of safe rural road design is a consistent, hierarchical road network in which each road category has a particular function to fill. Safety-related design elements covered in this study include cross-section, intersections, alignment and transition zones between rural and built-up areas. Gaudry and Vernier (2000) have developed multi-level structural models and Abdel-Aty and Radwan (2000) and several other researchers have proposed probabilistic models linking road design features to accident risk.

Rural roads account for disproportionate share of total as well as fatal accidents. Research conducted at James Cook University (Rankine, 2000) has established that the rural road accidents are significantly different in severity, frequency and causes of crashes compared to urban road crashes in Queensland. It has been premised that the differences are attributable to several factors – longer distances, higher speeds, casual driver attitudes, low levels of traffic enforcement by police, and roads of inferior quality in rural areas. This study is specifically targeted at identifying the limitations of the rural road network and determining the relative risk of driving on rural roads compared to urban roads.

To achieve the objectives of this study, the road accident data for provincial, rural and remote areas in Queensland have been analysed and compared to urban data. Quantitative models linking the distinguishing characteristics of roads and driving conditions can be developed with a view to estimating the relative risk factors. The results of this research would support the development of detailed rural road safety programs, and assist in the formulation of soundly based road safety policies for rural Queensland. The research is in progress and this paper presents the results of initial stages of a larger on-going study.

The study area and databases

The study has focussed on Queensland data for 1996 to 1999. Police reports and the Queensland Transport database are prepared from form P51, which is completed by the Police for each reported accident. The form provides the following information:

Driver:
Address, age, gender, racial appearance, licence details, BAC result, origin of journey (could be used for fatigue)

Time and location:
Location, Street/highway, intersection, distance from identification marker,

Road features:
Divided/undivided, number of lanes, horizontal features, vertical features, road surface, dry/wet, speed limit.

Unit details:
Rego. No., state of rego., make, model, colour, type, communication device, cruise control, window tint, bull-bar fitted. Commercial use, name/sign on vehicle, odometer reading, ownership, damage points, overall damage, number of occupants

Contributing circumstances:
Lighting, weather, road conditions, violation traffic law, vehicle defects, driver condition, excessive speed, others, statement from victims, description from the reporting officer

Persons killed or injured:
Surname, given names, address, phone, date of birth, gender, seat number, racial appearance, injury, hospital, severity, restraint, helmet, airbag, time and date of death if deceased

ARMIS and TARS databases

Maintained by the Main Roads in Queensland, ARMIS provides information on roads as per Austroads guidelines on rural and urban road classification. It includes number and width of lanes, divided/undivided, shoulder width and surface type. TARS is a traffic database, also managed by Main Roads. It is linked to the parent ARMIS database, as is the Roadcrash database.

Data acquisition

Queensland Transport road crash database has been obtained from Queensland Transport through four main files – injured.txt, crash.txt, circ.txt, and unit.txt. Thirty-two fields for each accident were selected for analysis. These included information relating to the

- time, place and the environment of accident (13 fields),
- details of crash including nature, severity, contributing circumstances, unit types and number (9 fields),
- road characteristics including alignment features, speed zone, traffic control (5 fields0, and
- persons involved (5 fields) .

Accidents are identified by a unique crash number which is used for linking separate files and different databases.

The database containing additional information on the geometric and physical characteristics of roads at accident locations has been provided by the Queensland Main Roads Department. In addition to the unique accident ID (crash number), sixteen fields specified information on road characteristics and traffic volumes. Specific information on speed zone, number of lanes, divided/undivided, total width, surface type and the right and left shoulder width is provided.

The data sets from the two databases have been linked using the unique crash numbers. This allows the analysis of crash data and the development of models to relate crash frequency, severity and nature to road characteristics and driver behaviour. Before linking the two data sets, all files were checked to ensure relevance and consistency and to safeguard against obvious errors.

Relative risk

The results of this study are proposed to be presented using the concept of relative risk. It represents the percent increase in the occurrence of an accident due to a deficiency in road standard.

The study is aimed at the investigation and development of models that relate relative risk with the deficiencies in road conditions in rural and remote areas. For instance, higher incidence of loss of control of the vehicle in rural areas could be related to the prevalence of roads with unsealed shoulders. Such findings would support an urgent need to improve the road systems in the country areas.

Analysis of road and accident data

Road and accident data has been analysed with respect to

(a) number of accidents by severity
(b) road length by geometric features by categories
(c) number of accidents on roads with varying geometric features
(d) accidents per kilometre of road with varying geometric standards.

Frequency and severity of road crashes on Queensland roads

The number of road accidents by level of severity is shown in Table 1 for 1996-1999.

Table 1 Accidents by severity for 1996-1999

Severity	1996	1997	1998	1999
Admitted to hospital	3573	3327	3525	3541
Fatal	338	321	257	272
Minor injury	2876	2705	2745	2623
Property damage only	9219	8248	8420	8497
Received medical treatment – not admitted	4925	4781	4608	4533
Total	20,931	19,479	19,555	19,466

Road characteristics

Accident frequency has been related to varying levels of following road characteristics:

- Surface
- Speed zone
- Number of lanes
- Divided/undivided
- Functional classification
- Horizontal alignment
- Vertical alignment
- Shoulder width

Each of these road features has been classified into two or more categories, as shown in Table 2.

Table 2 Road characteristics, Queensland Main Roads

Road feature	No. of categories	Description
Surface	5	Sealed-dry, sealed-wet, unsealed-dry, unsealed-wet, unknown
Speed zone (km/hr)	6	< 60, 60, 70, 80, 100, 110
Number of lanes	4	1-lane, 2-lane, 3-lane, and 4- or more lanes
Divided/undivided	2	Divided, undivided
Functional classification	4	Arterial, sub-arterial, collector, local
Horizontal alignment	4	Straight, curved - view open, curved - view obscured, unknown
Vertical alignment	5	Level, grade, dip, crest, unknown
Shoulder width	6	0-1 m, 1-2 m, 2-3 m, >3 m, unknown

Accident frequency by road feature

Road accidents have been classified on the basis of the road features at the location of crash. It is to be expected that the frequency of crashes on any feature will depend on the length and the amount of traffic on roads with a particular feature. However, the determination of the number of crashes on all categories of road features must be made before the relative risk associated with a road feature category can be estimated. Accident frequency by road features is shown in Table 3 for 1996-99 on Queensland roads.

Table 3 Accident frequency by road features

FEATURE	Class Description	1996	1997	1998	1999
SURFACE TYPE					
	Sealed, dry	4844	15411	15233	14881
	Sealed, wet	950	3038	3455	3416
	Unsealed, dry		629	590	619
	Unsealed wet		79	107	99
	Not stated	15137	235	170	142
DIVIDED/UNDEVIDED					
	Divided	14721	13773	13999	13837
	Undivided	6210	5610	5556	5746

Table 3 ..contd. **Accident frequency by road features**

SHOULDER WIDTH				
No shoulder	1598	1465	1336	1266
<1 m	333	317	334	343
1-2 m	731	772	815	878
2-3 m	1593	1590	1718	1811
>3 m	2179	2371	2518	1645
Unknown	3185	3509	2257	1872
NUMBER OF LANES				
One	315	286	266	273
Two	6947	7177	7065	7140
Three	595	691	728	692
Four or more	411	428	491	472
Not stated	1351	442	429	291
SPEED ZONE				
<60 km/hr	284	283	327	1585
60 km/hr	14259	13068	13050	11471
70 km/hr	471	536	717	938
80 km/hr	1357	1243	1401	1528
90 km/hr	99	66	73	89
100 km/hr	4302	4016	3802	3776
110 km/hr	158	170	179	215
HORIZONTAL ALIGNMENT				
Curved – view obscured	1309	1179	1205	1198
Curved - view open	3199	2772	2840	3009
Straight	16423	15432	15510	15388
VERTICAL ALIGNMENT				
Crest	961	864	885	930
Dip	513	497	505	485
Grade	4286	3831	3734	3658
Level	15171	14191	14431	14510

Accident frequency per kilometre of road length of varying features

Crash frequency and severity are examined with respect to all categories and levels of road features described above. For each category within each of the above eight road features, the number of accidents and accident frequency per kilometre of road for each year of the analysis are determined. An example of these descriptors is shown in Table 4.

These descriptors of accidents per kilometre of road length are useful in representing the road features with high accident occurrence but do not consider the traffic volumes using the roads. Thus a higher standard road may show higher accident frequency per kilometre of road compared to a lower standard road carrying much lower volumes of traffic. The conclusion that lower standard roads are safer is, of course, flawed.

Accidents per 100,000 vehicle-kilometer will be computed for each road category to draw conclusions about the relative safety (or risk) of roads of different standards.

Relative risk factors

The comparative analysis of relative safety of roads with different geometric and physical characteristics can be presented in the form of relative risk factors. These factors are based on the accident frequency per million vehicle kilometres travelled (VKT) on each road category. The descriptor of relative risk used in this study is the VKT per accident. Higher the value of this descriptor, safer is the road. The safest type of road is given a risk factor of 1. The risk factors on other road categories are expressed in relation to the safest category. Thus if the VKT per accident for a road of certain category is half of the highest VKT of all categories, then this category has a relative risk factor of 2.

Relative risk factors represent the relative probability of occurrence of an accident as a function of exposure on a particular road category relative to the lowest risk category.

Discussion and conclusions

This study has focussed on the identification and acquisition of crash and road inventory data for Queensland. The two databases for the period 1995 to 1999 have been linked together using the unique crash number and provide an integrated data set which is being used to relate the frequency, severity and nature of accidents to the physical and geometric features of roads characteristics. Models are being developed that would relate relative accident risk to road features. These include surface type, number of lanes, functional class, shoulder width, speed zone, divided/undivided, and horizontal and vertical alignment features. The Queensland Main Roads district 9 based around Townsville has been used as an example study area and the feasibility of this approach has been established in an Honours thesis project.

Table 4 **Accident frequency per kilometre of road**

FEATURE	Class Description	1996	1997	1998	1999	Average
SURFACE TYPE						
	Sealed, dry	0.1866	0.5894	0.5766	0.5578	0.4776
	Sealed, wet	0.2674	0.8631	0.9997	1.1253	0.8139
	Unsealed, dry		0.2553	0.2535	0.2917	0.2668
	Unsealed wet		0.0524	0.0760	0.0720	0.0668
DIVIDED/UNDEVIDED						
	Divided	0.4485	0.4206	0.4280	0.4236	0.4302
	Undivided	7.3274	6.2745	6.1414	6.2426	6.4965
SPEED-ZONE						
	<60 km/hr	51.2635	22.7127	25.2373	64.8570	41.0176
	60 km/hr	24.9257	11.7818	10.7992	7.0138	13.6301
	70 km/hr	9.6457	4.6348	5.9125	2.4720	5.6662
	80 km/hr	3.5361	1.4877	1.5436	1.1975	1.9412
	90 km/hr		6.7141	3.8060	1.1374	3.8859
	100 km/hr	0.8454	0.2301	0.1747	0.1535	0.3509
	110 km/hr	0.7974	0.5483	0.3565	0.2090	0.4778
LEFT SHOULDER WIDTH						
	0-1 m	0.4032	0.3373	0.3024	0.2871	0.2660
	1-2 m	0.6297	0.5971	0.5727	0.5654	0.4730
	2-3 m	2.6687	2.6288	2.9847	2.9404	2.2445
	>3 m	4.7123	5.3044	5.1526	4.1383	3.8615
RIGHT SHOULDER WIDTH						
	0-1 m	0.4143	0.3457	0.3203	0.3013	0.2763
	1-2 m	0.6293	0.6051	0.5588	0.5549	0.4696
	2-3 m	2.5631	2.8133	2.9420	2.6561	2.1949
	>3 m	2.5501	2.3946	2.4071	2.1425	1.8988
NUMBER OF LANES						
	One	0.0615	0.05786	0.0567	0.06085	0.0474
	Two	0.3517	0.35764	0.3426	0.3400	0.2784
	Three	3.0433	3.2973	3.3782	3.0383	2.5514
	Four or more	0.4716	0.46181	0.5523	0.4910	0.3953
	Not stated	0.1751	0.05899	0.0597	0.0421	0.0672

The study is primarily aimed at establishing the higher risk factors in rural areas due to poorer road standards. Quantitative models would provide insights into why rural areas experience disproportional high rates of accidents and fatalities. Another aspect of this study is aimed at developing relationships between enforcement and driver behaviour and attitude. It has been observed that the incidence of drink driving, violation of seat-belt restraint, and other traffic violations are more common with drivers in rural areas. The thesis that lower levels of enforcement in rural areas may be responsible for this behaviour will be tested quantitatively.

This paper presents the results achieved to-date in a much larger on-going study. It documents the work carried out to establish the feasibility of the proposed research methodology and the achievements in the identification, acquisition and linking of the databases essential in this larger study. It is, therefore, inappropriate to draw definite conclusions from the analysis presented.

Acknowledgements

The establishment of feasibility of the approach for determining the effect of geometric standards on road safety described in this paper has been supported by the Centre for Accident Research and Road Safety Queensland.

References

1. Abdel-Aty, M A and Radwan, A E (2000), Modeling traffic accident occurrence and involvement, *Accident Analysis and Prevention*, vol. 32, no. 5 pp 633-42
2. Armour, M, Carter R E, Cinquegrana, C S, and Griffith, J R (1989), *Study of single vehicle rural accidents*, Road and Roadsides Report (vol. 2), Vic Roads, Victoria, Australia
3. Asfa (2000), Safer and more comfortable, *La Lettre de l'ISTED*, No. 19, Nov. 2000, p. 2
4. Chudworth, C J and Stewart, D (1990), A remedy for accidents at bends, *Traffic Engineering and Control*, vol. 31, no. 2, pp 88-93
5. Gaudry, M and Vernier, K (2000), The road, risk, uncertainty and speed, in *Structural Road Models: The International Drag Family*, Elsevier Science Publishers, Amsterdam, Netherlands, pp 225-36.
6. Hasson, P (2000) Design as an element in a comprehensive rural road safety strategy, *2nd International Symposium on Highway Geometric Design*, Road and Transportation Research Association, Cologne, Germany, pp 145-157
7. Henderson, M J (1995) Towards an action plan for rural road safety: A report of the Wodonga seminar, Federal Office of Road Safety, Canberra, 1995.
8. Jamroz, K, Krystek, R and Michalski, L (1998), Selected aspects of road safety in Polish road design practice, *Transportation Research Circular* 8:1-9, Transportation Research Board, Washington DC, USA.
9. Ogden, K W (1996) *Safer Roads: A Guide to Road Safety Engineering*, Avebury Technical, Hants, England.
10. Parliamentary Travelsafe Committee (1999) Rural road safety in Queensland, *Issues Paper No. 4* Brisbane, Queensland 8pp
11. Rankine, B (2000) A statistical analysis of road accidents in Northern district, B.E. Honours thesis, School of Engineering, James Cook University Australia
12. Robertson, S A and Goodwin, P B (1987) *Driver stress and the process of highway design*, National Technical Information Service Springfield VA 22161
13. Robinson, J B L, and Smith G A (1999), The 1999 Canadian Geometric Design Guide: Road safety initiatives, *2nd International Symposium on Highway Geometric Design*, Road and Transportation Research Association, Cologne, Germany, pp 49-56
14. Talens, H (2000), Design aspects for sustainable safe roads, in *Proc. Traffic Safety on Two Continents*, Malmo, Sweden, Swedish National Road and Transport Research Institute, pp 127-40
15. Wegman, F C M and Slop M (1998), Safety effects of road design standards in Europe, *Transportation Research Circular* 39:1-10 , Transportation Research Board, Washington DC, USA.