DEVELOPMENT OF A STRATEGY FOR IMPROVING ROAD SAFETY

Alan Nicholson
University of Canterbury
New Zealand

RESUMO
Este artigo discute os aspectos de saúde pública e os custos sócio-econômicos de acidentes rodoviários e a necessidade de uma estratégia para melhorar a segurança rodoviária. Após a descrição dos principais requerimentos para tal estratégia, o artigo discute a necessidade de uma abordagem sistêmica que considere o usuário, o veículo e os fatores ambientais e o uso de métodos de redução e prevenção de acidentes. Constata-se que existe um nível considerável de incerteza na efetividade das medidas preventivas e que estudos de avaliação säo necessários. O artigo, então, descreve experiências na Nova Zelândia na melhoria da segurança rodoviária e conclui-se que é possível uma redução substancial nos acidentes e nos custos sociais com uma estratégia apropriada considerando o usuário, o veículo e os fatores ambientais.

ABSTRACT
This paper discusses the public health aspects and socio-economic costs of road accidents, and the need for a strategy for improving road safety. After describing the main requirements of such a strategy, the paper discusses the need for a systematic approach addressing user, vehicle and environment factors, and the use of accident reduction and prevention methods. It is argued that there is considerable uncertainty over the effectiveness of accident countermeasures, and that evaluation studies are required. The paper then describes experience in New Zealand in improving road safety, and concludes that with an appropriate strategy addressing user, vehicle and environment factors, a substantial reduction in accidents and the social costs is possible.

1. INTRODUCTION

A recent World Health Organisation report states “road traffic injuries are a major but neglected public health challenge that requires concerted efforts for effective and sustainable prevention” and “of all the systems with which people have to deal every day, road traffic systems are the most complex and most dangerous” (Peden et al., 2004). This is consistent with experience in the UK, where the deaths per hour of exposure for road accidents is about 25, 10 and 5 times that for in-home, construction and mining accidents, respectively (Wells, 1996). Road transport accounts for about 37.7% of accidental deaths in the UK, compared to only 3.3% for workplace accidents (Evans, 1994). Only activities such as deep-sea fishing and adventurous recreational activities (e.g. rock climbing, hang gliding), in which only a small proportion of the population participate, have a higher fatal accident rate (Wells, 1996).

Peden et al. (2004) estimate that currently 1.2 million people are killed (and as many as 50 million are injured) in road crashes worldwide each year, compared to about 1.0 million in 1990. The road accident death rate (per 100,000 inhabitants) varies considerably between countries, with the highest rates being found in some Latin American countries. Brazil has a much higher rate than highly motorized ‘western’ countries (Table 1), especially for males.

Table 1: Road Accident Deaths per 100,000 Inhabitants

Country	Males & Females	Males	Females
Australia	8.6	12.4	5.0
Brazil	24.0	36.9	10.0
New Zealand	12.7	16.7	8.6
UK	5.3	7.9	3.1
USA	14.7	20.5	9.6

Peden et al. (2004) estimate that the death rate worldwide has increased from about 1.0 million (or about 20%) since 1990, and suggest the number of deaths and injuries worldwide will increase by about 65% over the next 20 years, unless there is a new commitment to prevention. Highly motorized 'western' countries have, however, seen substantial reductions in their road accident deaths and injuries in recent decades. For instance, in the UK, which currently has the lowest death rate in the world, the death rate reduced by about 50% between 1960 and 1995, during which period the death rate in Brazil increased by about 400%.

Peden et al. (2004) also estimate the global social cost is about US$520 billion annually and note that despite this, there is little funding for research on road safety compared to other diseases. According to Hartunian et al. (1980), the economic cost of road accidents in the USA exceeded the economic cost of coronary heart disease, and was about two thirds the economic cost of cancer (the economic cost excludes any allowance for pain, grief and suffering). Peden et al. (2004) note that despite the high social cost of road traffic crashes, they attract "less mass media attention than other, less frequent types of tragedy". This has been noted previously by Evans (1994) and Nicholson (2002), who found that 'low frequency, major consequence' events (e.g. rail and air crashes) get more attention than 'high frequency, minor consequence' events (e.g. road crashes), despite the higher expected annual social cost for the latter.

This paper discusses the need for a strategy for improving road safety, the fundamental issues to be addressed in developing a strategy, the role of accident reduction and prevention, and the need for evaluation of accident reduction and prevention measures. The paper then describes the development of the New Zealand (NZ) road safety strategy and the results achieved so far.

2. THE NEED FOR A COMPREHENSIVE STRATEGY

One of the first countries to address its road safety problem in a systematic and concerted manner was the UK, where legislation in 1974 placed a statutory responsibility for road safety on local government (the road controlling authorities). Subsequent legislation in 1984 required each local authority to "prepare and carry out a programme of measures designed to promote road safety". These legislative changes led to the Institution of Highways and Transportation developing guidelines for improving highway safety (IHT, 1986).

These guidelines proposed the following goal: "to reduce the overall number and severity of accidents by road engineering and management through:

- the application of cost effective measures on existing roads as a basis for accident reduction, and
- the application of safety principles in the provision, improvement and maintenance of roads as a means of accident prevention."

The guidelines distinguished between 'accident reduction' (a reactive process aimed at treating locations where accidents have been occurring relatively frequently) and 'accident prevention' (a pro-active process aimed at avoiding the creation of hazards where accidents might occur relatively frequently in the future). These two approaches are discussed later.

The IHT guidelines also emphasised the need for a comprehensive strategy involving:

- defining overall objectives and setting quantified targets;

- determining what financial and staff resources are required and ensuring those requirements are met;
- identifying what data are required and ensuring they are available;
- establishing appropriate procedures for the analysis and interpretation of the data, and the development of effective remedies and a programme of works;
- implementing that programme and monitoring the effects, and checking that the overall objectives and specific targets are being achieved.

The main advantage of having quantified targets (for fatality and injury reduction, say) is that they place an onus on road controlling authorities to either meet the targets or have good, acceptable reasons for failing. While the cost of implementing remedial treatments is often low, the cost of preparatory work is often high relative to the implementation cost. In addition, the preparatory work is time-consuming and requires specialist skills, with the IHT (1986) stating "the technique of accident investigation and the design of remedial measures require specialist engineering expertise of a high order". The IHT recommended the establishment of specialist accident investigation teams, giving economies of scale and improved effectiveness through the pooling of expertise, and a staffing level of one engineer (or highly skilled technician) for every 400-1000 injury accidents in the road controlling authority's area each year.

One of the key requirements is a good accident data-base, which can be used for:

- investigating and assessing sites and situations amenable to accident reduction by cost-effective remedial treatment;
- assessing the safety implications of new highway and traffic management schemes;
- monitoring the results of accident reduction and prevention programmes.

The IHT (1986) gives an extensive list of the data required for thorough accident investigation. Given the difficulties involved in collecting accident data (e.g. Police having insufficient time or training), very few (if any) countries collect all the data items in the IHT list.

In nearly all countries, only a fraction of accidents (e.g. those involving a vehicle and injury) are required to be reported. In addition, only a fraction of accidents that should be reported are reported. Consequently, accidents records can amount to a small sample of all accidents. The problem of a small sample size is aggravated by the high probability of bias, due to systematic variation in the reporting rate with variation in such factors as accident location, accident severity and user class.

The technical procedures for analysing the data, identifying effective remedies, developing a programme of works, and monitoring the effects (to check that the overall objectives and specific targets are being achieved) are discussed later.

3. BASIC PRINCIPLES

Haddon (1968) suggested one can intervene to reduce accident costs during the pre-crash, the crash and the post-crash phases. The purpose of pre-crash phase interventions is to reduce the probability of a crash occurring. Examples of such interventions include changing mode split (to reduce the exposure to road accidents), driver education and Police enforcement, and improving vehicle roadworthiness and road alignment design. The purpose of crash phase interventions is to reduce the probability of injury given that a crash has occurred. Examples of such interventions include ensuring occupant restraints are used, improving the performance of occupant restraints, and improving the roadside (so drivers can regain control of vehicles before hitting solid objects). The purpose of post-crash phase interventions is to reduce the probability of death or permanent impairment given a crash has occurred and injury has resulted. Examples of such interventions include educating users in first-aid skills, designing vehicle fuel systems to reduce the risk of fire, and improving ambulance services.

Haddon also suggested the target of interventions could be the user, the vehicle or the road environment. This led to a nine-cell matrix (commonly called the Haddon matrix), for classifying interventions according to the phase and the type of factor they address.

During the 1970's, a number of in-depth investigations of road accidents were undertaken, to identify the factors involved in accidents (Sabey and Staughton, 1975; Treat et al., 1980; Sabey, 1983). These studies involved identifying and categorising the factors as road environment (E), user (U) and vehicle (V) factors, with combinations of different types of factor giving another four categories (EU, EV, UV and EUV). The results are shown in Table 2.

The studies concluded that user-factors are involved in between 92.6 and 94.9% of all accidents. The major area of difference was the proportion of accidents involving only user factors (57.1% to 76.5%) and the proportion of accidents involving a combination of user and environment factors (16.0% to 26.4%), indicating some doubt over user and environment interaction.

Table 2: Percentage of Accidents Involving Different Types of Factors

Types of Factors Involved	Treat	Sabey	Sabey & Staughton
E	3.3	2.0	2.5
U	57.1	76.5	65.0
V	2.4	3.0	2.5
EU	26.4	16.0	24.0
EV	1.2	0.1	0.3
UV	6.2	2.0	4.5
UVE	2.9	0.3	1.4
E+EU+EV+UVE	33.8	18.4	28.2
U+EU+UV+UVE	92.6	94.8	94.9
V+EV+UV+UVE	12.7	5.4	8.7

The results of the studies seemed to indicate that the greatest potential for reducing accidents lay in changing user behaviour. Thus, the failure of a user to cope with the demands of the road environment was generally deemed to be user error, with road controlling authorities being absolved of responsibility for the vast majority of accidents, and little attention being given to addressing vehicle and road environment factors.

Hauer (1987) suggests it is human nature to seek the cause of a crash in the events immediately preceding it, the result being a bias towards blaming the driver. For example, if a traffic signal turns amber (or yellow) as a vehicle approaches and:

- a vehicle crashes into the rear of a decelerating vehicle in front, or;
- a vehicle crosses the limit line after the signal turns red and collides with a vehicle on the intersecting road;

driver error would probably be deemed the 'cause' of the accident. Traffic engineers are unlikely to be blamed for using signals to control the intersection or using inappropriate signal settings.

Vehicle and road environment factors got more attention after Sabey and Taylor (1980) suggested the potential savings of proven remedial actions addressing environment, user and vehicle factors were 20%, 33.3% and 25%, respectively. This trend was reinforced after a review of road safety policy in the UK (Department of Transport, 1987) concluded annual road traffic injuries could be reduced by 30%, with 80% of the reduction coming from the 'indirect approach' (i.e. addressing road environment and vehicle factors) and only 20% from the 'direct approach' (i.e. addressing user factors). In many developed countries, it is recognised that changes to the road environment, so users can cope better with the demand it places on them, are probably very cost-effective and practicable. Such countries now follow a more balanced approach to safety improvement, involving addressing all three types of factors.

4. ACCIDENT REDUCTION

Accident reduction programmes can take several forms:

- single site plans, involving treating sites (intersections or short lengths of road) where many accidents are clustered (i.e. 'black-spots');
- route action plans, involving treating substantial lengths of road where many accidents are clustered (i.e. 'black-routes');
- area action plans, involving treating areas with many accidents dispersed over the area (i.e. 'black-areas');
- mass action plans, involving the application of a known remedy (e.g. anti-skid surfacing for wet-road accidents) to locations with enough accidents susceptible to that remedy.

According to the IHT (1986), the plans differ with respect to the expected accident reduction and the economic return (measured by the ratio of the first-year accident cost saving to the cost of implementation), as shown in Table 3. It should be noted that the amount of analytical work and implementation cost both tend to increase from site to route to area plans.

Table 3: Expected Effects of Alternative Plan Types

Plan Type	Expected Accident Reduction	Expected Economic Return
Site	33%	> 50%
Route	15%	> 40%
Area	10%	10% - 25%
Mass Action	15%	<40%

The information in Table 3 suggests that to get the best return on road safety expenditure, one should focus on single site plans, but Nicholson (1989) suggested the choice of plan type (site, route or area) should depend upon the spatial distribution of accidents. Choosing a site plan when accidents are highly dispersed, or an area plan when accidents are highly clustered at points, will probably result in a poor economic return. Shaikh and Nicholson (1993) found that accidents are much more dispersed in NZ, where only 3-6% of accidents occur at locations with five or more accidents in five years, than in the UK, where 15-29% of accidents occur at locations with five or more accidents in three years (Table 4). This led Nicholson (1995) to suggest that less emphasis should be placed on site plans and more emphasis should be placed on route and area plans in NZ.

Table 4: Proportions of Accidents in Various Group Sizes

Accident Group Size	Proportion of Accidents in Such Groups	
	United Kingdom (3 yrs)	New Zealand (5 yrs)
1	35% - 51%	50% - 57%
2	16% - 25%	25% - 29%
3	4% - 17%	10% - 11%
4	5% - 10%	4% - 6%
5+	15% -29%	3% - 6%

Nicholson (1989) also suggested that if one starts with site plans and these are effective, accidents will become less clustered at points. It may then be possible to identify routes, along which there are many accidents even though there are no ‘black-spots’. If such routes are treated effectively, there will be a further reduction in the level of accident clustering. It may then be necessary to adopt a higher level of aggregation (areas, say) in order to detect entities warranting accident reduction. That is, accident reduction treatment, if effective, will change the spatial distribution of accidents. One might expect to progress from site plans to route plans to area plans; the problem is to identify when best to change from one plan type to the next.

It should be noted that if accident prevention is not being done well, site or route clusters might be created. Hence, one must carefully examine the spatial distribution of accidents, and should not assume that because one has progressed from site plans to route plans, say, that there will never again be a need for site plans.

Development of an accident reduction programme entails three tasks:

- identification (of ‘black-spots’, ‘black-routes’, ‘black-areas’ or sites with sufficient susceptible accidents);
- diagnosis (not required for mass action plans);
- selection (not required for mass action plans).

Identification entails analysing accident data, to find hazardous locations having a well above average accident occurrence (or an identifiable pattern of accidents). This stage acts as a screen, to reduce drastically the number of locations subjected to diagnosis and selection.

Diagnosis entails analysing the symptoms of an accident problem (i.e. the factors involved in accident occurrence), to identify how those factors operate and synthesise a package of actions (i.e. remedial treatment), to reduce the probability of accidents occurring. Selection involves:

- deciding on the best treatment at each location, taking account of the cost and benefit of each alternative treatment;
- deciding on the best programme of work, taking account of the costs and benefits of the best treatments, and the budget constraint.

It should be noted that identifying a location as hazardous does not mean it will be treated, as it is necessary to find a treatment that is economically attractive. That is, one selects locations for investigation, and from that set of locations, selects locations for treatment.

There are three main criteria for identifying hazardous locations:

- the number of accidents (during some observation period);
- the rate of accidents (per exposure during some observation period);

- the number and rate of accidents (during some observation period).

Locations are selected for investigation if the number and/or rate of accidents exceed some arbitrary thresholds.

The number of accidents is the commonly used criterion in NZ and elsewhere, despite the IHT (1986) suggesting it is unwise to rely solely on the number or rate of accidents, as:

- the number of accidents criterion on its own will lead to location selection biased towards high volume roads having relatively many accidents;
- the rate of accidents criterion on its own will lead to location selection biased towards low volume roads having relatively few accidents.

The number and rate of accidents criterion is the best, as it gives locations with a high 'risk' (or accidents per exposure) and a high number of accidents that may be avoided (i.e. large benefits).

The identification of unusually hazardous locations is subject to two types of error:

- a truly hazardous location not being selected for detailed examination;
- a truly non-hazardous location being selected for detailed examination.

The consequence of the first error type is that opportunities for reducing accidents are missed, while the consequence of the second error type is that limited resources for diagnosis and selection are wasted. The probability of the first error type can be reduced (or increased) by reducing (or increasing) the threshold number and/or rate of accidents, but the probability of the second error type will be increased (or decreased). Nicholson (1988) has shown that both types of error can be reduced by increasing the observation period, and a five year period is generally about optimum from the viewpoint of statistical reliability (Nicholson, 1986 and 1987).

One may have two locations, one of which has many more accidents during the period of interest, but those accidents are of numerous different types, and the other of which has fewer accidents, but they are of only one or two types. It may be difficult to identify a suitable treatment for the first location, but relatively easy for the second location. If locations are selected for investigation based on the total numbers of accidents, the first location may be selected while the second is not, and both locations may not be treated, even though there may be a very cost-effective treatment for the second location. The probability of this can be reduced by selecting locations for investigation based on the numbers of particular types of accidents.

6. ACCIDENT PREVENTION

It is commonly said that "prevention is better than a cure", and accident prevention (commonly called safety auditing), which seeks to ensure the application of safety principles in the provision, improvement and maintenance of roads (to avoid the creation of hazards) is an excellent complement to accident reduction (to cure existing hazards).

Formal safety auditing commenced with the IHT (1990) guidelines, which suggested that the main requirements of safety auditing are:

- a systematic organisation of auditing at discrete stages in the planning, design and construction of a road project;
- a close liaison between the project designers and the safety auditors;
- a well defined auditing procedure covering when and how audits are done;
- a well defined procedure for implementing the results of the audits.

The IHT suggested safety auditing can be done at four stages in the development of a project:

- during feasibility/initial design (consider route choice, standards, network effects, junction locations and types of control, etc.);
- on completion of preliminary design (assess horizontal and vertical alignments, sightlines, junction layouts, etc.);
- on completion of detailed design, and prior to preparation of the contract documents (assess detailed layouts, markings, signs, signals, lighting, etc.);
- just before opening (auditor, designer, contractor and traffic police should carefully examine the road during both day and night, while driving, cycling and walking).

The IHT suggested that the auditing effort might well reduce as the project size reduces (e.g. audit at all four stages for very large projects and only at the final stage for very small projects).

The key issues to be resolved regarding the administrative arrangements for safety auditing are:

- who does the audit (the original design team, a second design team, or a team of safety specialists);
- if an independent audit team, whether they recommend or require changes;
- if they merely recommend changes, who decides whether to implement them.

One should seek to identify a potential problem before it becomes expensive to rectify, and minimise the risk of accidents on the whole network (not just on the new or improved road). Safety audit and other scheme objectives may conflict and may be difficult to reconcile. Hence, both the auditors and decision-makers should prepare formal reports, documenting the reasons for their recommendations and decisions, respectively. Safety auditing commonly involves using checklists, the form of which depends on the type of works. While checklists are very useful for ensuring consideration of all common factors, one should beware of relying entirely on checklists, as lateral thinking is important.

7. EVALUATION

Road safety is "a field in which myth and personal solutions abound … without a tradition of scientific rigour … difficulty distinguishing between scientific findings and propaganda … anyone can don the mantle of 'expert' … many citizens are convinced they have the 'answer' … articulate lobbyists, not always with proper qualifications but often with the best intentions, press for measures which are frequently not well founded" (Trinca et al., 1988).

There is much uncertainty regarding the effectiveness of accident reduction and prevention treatments, despite the many evaluation studies done over several decades (Jorgensen and Associates, 1978). The problem stems partly from the effectiveness of a treatment varying with the circumstances of its application. There has also been a lack of understanding of the importance of careful experimental design and data interpretation in evaluation studies. Hauer (1987) concludes that "factual knowledge about the relationship between roadway geometry and safety is quite limited, sometimes contradictory and often insufficient". He also notes that decisions relating to safety are often determined by political considerations (e.g. being seen to do something, rather than doing something effective).

Hauer (1987) suggested separating "the function of initiating, implementing and operating a program from the function of measuring its impact on society", to avoid potential conflicts of interest. This would increase study objectivity and reduce publication bias arising from organisations not publishing embarrassing results (publication bias would still exist because of a tendency for editors to reject papers not reporting a statistically significant effect). Hauer also suggested “practising professionals do not have the time or ability to do research” and that “one can not build professional knowledge without establishing a premeditated organizational setup for that purpose”. It was with these issues and concerns in mind that the NZ Accident Investigation Monitoring System (AIMS) was developed and implemented.

The purpose of AIMS is (Kraus, 1991; Nicholson, 2000):
(1) to evaluate the overall effectiveness of the accident reduction programme;
(2) to identify the effectiveness of particular types of accident reduction treatment;
(3) to identify the most effective treatments and the situations where they work best;
(4) to enhance the accuracy of future predictions of treatment effectiveness.
The AIMS relies upon co-operation between the Land Transport Safety Authority (LTSA) and each Road Controlling Authority (RCA).

Firstly, the LTSA supplies each RCA with information about accidents on their roads. Each RCA then identifies the apparently hazardous locations in their areas, diagnoses the problems at those locations, identifies potential treatments, and selects the most appropriate treatment. Each RCA then sends details of each location (including the problem diagnosis and selected treatment) to the LTSA. This triggers the monitoring process, with the LTSA entering the data into the AIMS database. After implementation, each RCA advises the LTSA of the treatment completion date, and the LTSA analyses the accident data for five years before and after implementation, to estimate the effectiveness of each treatment. If the RCA subsequently modifies the treatment or implements another treatment, they inform the LTSA, so that the accident data can be interpreted accordingly. If the LTSA finds, from its analysis of accident data for a treated site, that the treatment has aggravated the original accident problem, then it informs the RCA, which can modify the treatment.

The AIMS database contains information for about 4000 treated sites, with about 66%, 33% and 1% being for site, route and area treatments, respectively, with about 43% and 57% for State Highways and Local Authority roads, respectively. Based upon the approximately 2500 sites for which five years of post-treatment data are available, the LTSA estimates that the overall average accident reduction has been about 29% (LTSA, 2001). The LTSA has also produced estimates of the mean effectiveness for ten common types of treatment: right-turn lanes; pedestrian refuges and bulbous kerbs; flush medians; shoulder improvements; roundabouts and traffic signals; pavement reseals; curve warning signs; road lighting improvements; throat and fishtail islands; guardrails. Detailed results for each treatment have been sent to every RCA for use in future treatment selection.

8. NZ SAFETY STRATEGY DEVELOPMENT

The NZ accident reduction programme commenced in earnest in 1985, at which time there were about 750 deaths and 18,900 injuries from road accidents reported annually. The focus initially was almost entirely upon treating sites, but there has been an increasing emphasis on route treatments, as recommended by Nicholson (1995). There is effectively a statutory obligation for the State Road Authority, but not Local Authorities, to employ accident reduction. A very high level of Local Authority participation has been achieved through financial incentives, with Transfund NZ, which funds all State Highway work and about 50% of work on Local Authority roads, making funds available specifically for accident reduction work. As noted above, the LTSA estimate of the accident reduction at the treated locations is about 29%.

Accident prevention (or safety auditing) commenced in earnest in 1993, with the safety audit being conducted by a team of safety specialists, who are independent from the original designers. The audit team submits a written report with recommendations for changes considered necessary, with the client (the RCA) rather than the original designers, deciding whether they should be implemented. If the audit team's recommendations are not implemented, the RCA prepares a written report explaining why they were not implemented, so that the process is fully documented.

There have been several studies into the benefits of safety auditing. One study of design stage audits in Australia (Austroads, 2002) found that:

- the benefit/cost ratio for implementing audit team packages of recommendations ranged from 3 to 242, with a mean of 36 (i.e. all audits produced worthwhile results);
- the benefit/cost ratio for implementing individual audit team recommendations ranged from 0.06 to 2600 (i.e. some individual recommendations were not worthwhile, while some were extraordinarily worthwhile);
- the majority (65%) of recommendations cost less than about US$750 to implement, and 85% of these had benefit/cost ratios greater than 10.

Road safety auditing has been voluntary until recently, but based on these findings, Transfund NZ has made road safety auditing mandatory for most new projects from July 2004.

In parallel with these increasing accident reduction and prevention efforts, which were focussed on road environment factors, the NZ Government embarked upon the development of a National Road Safety Plan, aimed at involving key organisations outside the transport sector (including the Departments of Health, Justice, Labour, Education and Youth Affairs, plus the Accident Compensation Corporation and Alcoholic Liquor Advisory Council) in promoting road safety. The initial plan (Ministry of Transport, 1991) defined objectives and set targets, as well as the coordination of ideas, resources and activities across all sectors, both locally and nationally. The plan covered driver education and enforcement (i.e. user factors), vehicle standards and licensing (i.e. vehicle factors), and accident reduction and prevention. The plan and targets were revised in 1995 and 2000, with the latest version being finalised in 2003 (LTSA, 2003). Whereas the earlier plans focussed on reducing the number of deaths and injuries, such changes are now seen as a means of achieving a much broader goal, namely the reduction of the annual social cost of accidents from about NZ$3.0 billion in 2002 to $2.2 billion in 2010.

Since 1985, the annual number of fatalities and injuries has reduced about 45% to 400 and about 25% to 13,900 respectively. This has been achieved despite rapidly increasing vehicle ownership and use, and it has been estimated (LTSA, 2003) that in the absence of the road safety improvement strategy, fatalities would have increased to about 900 annually in 2002. This implies a saving of about 3000 deaths and NZ$7 billion in social costs during the period 1990-2002 (excluding the social costs of injuries). This has been achieved via a mixture of engineering, education and enforcement measures. While it is difficult to identify the effects of each type of measure separately, it seems likely that they have contributed fairly equally.

The LTSA is currently encouraging each RCA to develop and adopt the Safety Management System (SMS) approach. This is primarily an administrative process to assist decision-makers to select "effective strategies to improve the efficiency and safety of the transportation system" (Depue, 2003). Such a system can provide a broad framework within which the technical processes of accident reduction and prevention fit. The 1991 Intermodal Surface Transportation Efficiency Act required each state in the USA to have an SMS, but Depue found that while in 1994 all states had work plans to do this, only about half had an SMS in place in 2001. This might be due to such systems being made optional by the 1995 National Highway System Designation Act, suggesting that progress on improving road safety depends upon the clarity and strength of signals given to each RCA by the Central (or Federal) Government.

Development of a road safety strategy for a country should take account of the legal situation within that country. A 'no fault' accident insurance scheme operates in NZ, and those involved in accidents are unable to sue for damages, except where recognised standards of good practice are not met. Making no effort to identify and treat hazardous locations, or prevent their creation, thus renders one vulnerable to legal proceedings. There is thus a strong incentive for each RCA and practising engineer to ensure they comply with recognised standards of good practice.

9. CONCLUSION

The deaths and injuries from road accidents, and the massive social costs, are increasing worldwide. The increase is occurring primarily in low-middle income countries, including Brazil and other Latin American countries, with reductions being experienced in motorized 'western' countries.

These reductions have been achieved through the adoption of comprehensive strategies, based on well-established basic principles (i.e. addressing user, vehicle and environment factors in the pre-crash, crash and post-crash phases of accidents). The adoption of a two-prong approach, involving accident reduction (to address existing hazards) and accident prevention (to avoid creating new hazards) has proven to be very efficient (i.e. the benefits far exceed the costs) and effective (i.e. substantially improved safety has been achieved).

This two-prong approach has been pioneered in the UK, and has been closely followed by other countries, including Australia and NZ, all of which have achieved major improvements in road safety in the last 20 years. It is likely that the adoption of a similar approach in those countries with increasing road accidents (including Brazil) would result in reversal of that trend. If this is not done, a serious public health problem (i.e. road accident deaths and injuries) is likely to become more severe.

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Endereço correspondência:
Alan Nicholson,
Department of Civil Engineering, University of Canterbury
Private Bag 4800, Christchurch, New Zealand
Phone: 64-3-364-2233
Fax: 64-3-364-2758
Email: alan.nicholson@canterbury.ac.nz
Website: http://www.civil.canterbury.ac.nz/