safety directions

Estimated effects of interventions on road safety outcomes to 2010

Working Paper 7

Land Transport Safety Authority

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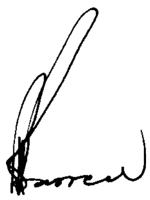
Foreword

This Working Paper is the seventh in a series of technical documents which form part of the LTSA's *Safety Directions* Development Programme. This Programme is creating the tools needed to underpin New Zealand's road safety funding cycle. In this way it contributes to the achievement of the LTSA's statutory objective of undertaking activities that promote safety in land transport at reasonable cost.

Working Paper 7 describes how specific interventions selected for New Zealand's proposed Road Safety Strategy 2010 affect road safety outcomes. These relationships are incorporated into the road safety model described in our previous Working Paper 6. Working Papers 6 and 7 provide useful reference sources to support Road Safety Strategy 2010 consultations.

This and the other Working Papers in the series are being published to stimulate debate within the wider road safety community. We would welcome your input and comments to assist this process and to help us to further improve the quality of our safety findings.



Reg Barrett
Director of Land Transport Safety

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Introduction

This working paper describes the outcomes of the road safety interventions selected for inclusion in New Zealand's proposed *Road Safety Strategy 2010* (NRSC 2000). We present the effect that each intervention will have on reducing the level of road trauma, and we do so for each option[1] by which the proposed strategy may be achieved. We also document the evidence and reasoning behind our estimates.

The information in this paper was used in the mathematical model that predicts road safety outcomes for the proposed strategy (LTSA 2000a). Hence it only covers interventions that will change during the strategy period (*table 1*). Interventions that will not significantly change are not discussed as their effects are already accounted for.

Table 1

Social cost, by intervention (% reduction in Baseline Outcome 2010)

Type of intervention	Option			
	Business as usual 2010	**Enforcement**	**Mixed**	**Engineering**
The road environment				
Standards and rules				
Blackspot treatments	2.1%	2.1%	2.1%	2.1%
Existing construction programme	5%	5%	5%	5%
Expanded constr'n programme			11.7%	18.0%
Trauma management	0.9%	0.9%	0.9%	0.9%
Compliance				
Urban speed management		5.3%	5.3%	3.3%
Open road speed management		19.1%	11.6%	11.6%
Compulsory breath-testing		3.3%	3.3%	3.3%
Restraint-wearing		4.2%	4.2%	2.9%
The vehicle				
Standards and rules				
Light vehicles	15.5%	15.5%	15.5%	15.5%
Heavy vehicles		0.5%	0.5%	0.5%
The road user				
Standards and rules				
Driving age		2.6%		
Stricter licensing conditions	1.1%	1.1%	1.1%	1.1%
Reduced blood alcohol content		4.5%	4.5%	
Zero BAC for young drivers		0.1%		
Legal hours of darkness		0.7%		
Compliance				
Vehicle impoundment	1.9%	1.9%	1.9%	1.9%
Licence suspension	1.5%	1.5%	1.5%	1.5%
Alcohol interlocks		0.6%		
Education		*Included in other interventions*		
Performance assessment		2%	2%	2%
Efficiency gain	9%	9%	9%	9%

1 Three options have been developed for the proposed strategy. These are termed *Enforcement emphasis*, *Mixed*, and *Engineering emphasis*, and are explained in NRSC (2000). Options differ in the mix and intensity of interventions used to achieve the proposed strategy's targets.

Some of the estimates in this paper are robust, others are tentative. The proposed *Road Safety Strategy 2010* is about to enter a phase of public consultation, during which the estimates will be refined and detailed wherever necessary. Consultation will also help identify which interventions merit further attention; and may also reveal data that we will find useful in our analysis.

The road environment

Standards and rules

Blackspot treatments

Estimated reduction in social cost	Enforcement emphasis option	2.1%
	Mixed option	2.1%
	Engineering emphasis option	2.1%

Cause and effect

Blackspots[2] are locations on the road network where crashes are abnormally frequent or severe, and where social cost is in consequence abnormally high. Most blackspots exist because parts of the existing road network were designed many years ago and are deficient by modern standards. But even newer roads sometimes have safety deficiencies that only emerge when they have been in use for some time. Blackspots are generally characterised by a range of deficiencies that include visually deceptive geometry, inadequate stopping or passing sight distance, inadequate lighting, unexpected bends, and excessive forces on vehicles (*table 2*). They often show up as clusters of crashes—but not always: crashes are rare events and it may sometimes take years for a pattern to emerge.

Blackspots are defined in terms of the absolute number and severity of crashes, not risk per vehicle. So for example two physically similar sites might have the same risk, but one might qualify as a blackspot and the other not. Why? Because the one has more traffic, and therefore more crashes; it is no riskier than the other, but it is more suitable for treatment because we are likely to save more casualties for substantially the same remediation cost. In short, we define blackspots in terms of their absolute number and severity of crashes because it is efficient to do so.

Present situation

New Zealand has had a blackspot program for many years, and has been systematically monitoring it since 1989 (*appendix 1*). Under the programme 250 to 300 blackspot sites are selected each year on the basis of their poor crash records—over 3600 to date. Between 1985 and 1998 they have had 4200 fewer crashes than expected, a 28% reduction and a cost saving of over $1 billion.

Future impact

The blackspot programme is scheduled to continue much as before. However, since most existing blackspots have been remedied wherever it was feasible and cost-effective to do so, we expect the number of sites investigated annually to fall by about a quarter. This is inevitable, and reflects the progress we are making: as we remedy the worst sites, the remaining ones are necessarily less rewarding. In

2 This term is sanctified by long usage but could be misleading as not all blackspots are point locations; some are stretches of road and some are best described as areas. Although sometimes called 'black sites', 'black routes', 'hazardous locations' and so on, we call them all blackspots since the same approach applies to all.

theory we could eventually reach a point when it is no longer worth improving the network, but that is very far off. In any case, long before then technological improvements are likely to make it worthwhile to revisit previously treated sites with newer, more effective interventions.

Table 2

Principle design deficiencies and other problems remediable through blackspot treatments

Road geometry	Horizontal and vertical geometry
	Curve radii and transitions
	Longitudinal and cross gradient
Road cross-section	Lane width
	Recovery width for vehicles that stray from carriageway
	Shape of carriageway and side slopes
	Transition to adjacent terrain
Road surface	Slick or uneven surface
Delineation and separation	Centre and edge delineation
	Separation of traffic streams
Intersections and crossings	Form of control
	Layout
	Spacing
	Sightlines
	Pedestrian facilities
Bridges	Single lane and narrow bridges
	Exposed bridge ends
	Approach deficiencies
Roadsides	Hard objects (poles, trees, bridge abutments etc)
	Abrupt changes in ground level
	Sightlines
Illumination	Sunstrike
	Lighting of carriageway
	Light/dark transition
	Headlight dazzle
Stability	Falling debris
	Dropouts
Outside Influences	Natural (animals, vegetation)
	Roadside distractions
	Parked and manoeuvring vehicles
Weather	Wind
	Fog and mist
	Ice
	Snow avalanche

We estimate that we shall treat between 1200 and 2000 sites under the blackspot programme during the strategy period; and as a result there will be 600 to 1000 fewer crashes annually in 2010, a proportional reduction of between 2% to 3.3%. This equates to a proportional reduction in social cost of about 2.1%.[3]

3 Guided by past trends, we estimate that we shall investigate between 150 and 250 sites annually, and that 80% of them will be implemented (cf. *appendix 1*). On the basis of an internal LTSA report in 1997 we also estimate that 0.5 injury and property damage crashes will be prevented annually at each site implemented. We assumed that serious and minor casualties would decline in proportion to the decline in crashes—say, 2.5%. However, since about two thirds of fatal crashes are on open roads but crash reduction sites are primarily urban, the reduction in fatal crashes is likely to be less than the reduction in injury crashes—say, 1.75%.

Table 3

Principal desired safety features in road construction, by (1) main type of crash mitigated, and (2) main type of road where implemented

Motorways	Major urban	Minor urban
Loss-of-control crashes		
■ Construct sealed shoulders to approved standard against median and outside edge ■ Provide physical median barriers ■ Provide audible edgelines and define width ■ Provide roadside clear zones ■ Ensure adequate crossfall and drainage ■ Improve lighting ■ Provide crash attenuators where lanes diverge		■ Sign and delineate all bends with a design speed below 50 km/h ■ Improve skid resistance at bends
Rear-end crashes		
■ Construct sealed shoulders to approved standard against median and outside edge ■ Provide roadside clear zones ■ Improve skid resistance (higher minimum and improved testing)		
Head-on and overtaking crashes		
Intersections		
	■ Control all intersections with traffic signals, signs or roundabouts of consistent and cycle-friendly design, with frequent use of median islands ■ Investigate feasibility of national guidelines for roundabouts ■ Improve lighting, conspicuity and delineation	■ Control all crossroads and busy T- and Y-junctions with signs or roundabouts of consistent and cycle-friendly design ■ Investigate feasibility of national guidelines for roundabouts ■ Improve lighting, conspicuity and delineation
Pedestrians and cyclists		
	■ Provide median refuges where pedestrians are numerous ■ Eliminate unsignalised pedestrian crossings on four-lane roads ■ Provide new, and improve existing, cycle lanes ■ Provide pedestrian guard rails at selected busy locations (for instance at busy intersections near shops)	■ Improve lighting at pedestrian crossings to a consistent standard ■ Provide cycle lanes where space permits and demand warrants ■ Reduce roadway width at pedestrian crossings where it now exceeds 8 m

State highways	Minor open
■ Adopt Austroads standards for horizontal bends ■ Create a more forgiving roadside by sealing shoulders, removing hazards, and reducing roadside slopes ■ Eliminate single-lane and short narrow bridges	■ Provide edgeline treatment and edge-marker posts in accordance with approved practice ■ Construct sealed shoulders wherever traffic volumes warrant ■ Provide roadside clear zones ■ Provide advisory speed signs on all bends where speed should be reduced by 15 km/h or more
■ Expedite four-laning plus medians wherever traffic warrants ■ Widen sealed shoulders ■ Provide roadside clear zones ■ Provide more passing lanes to approved standards	■ Provide centreline delineation on all sealed roads in accordance with approved practice ■ Improve forward visibility wherever practicable
■ Control all side-roads ■ Manage access from abutting properties ■ Provide turn bays where needed ■ Eliminate (or, if impractical, provide hazard signs for) traffic signals in 100 km/h zones ■ Improve lighting to a consistent standard	■ Control all intersections ■ Provide advance warning signs where appropriate

Note: This table shows desired safety features only, and is not intended to be comprehensive or binding. We expect that during the course of the strategy period we shall identify and apply certain treatments that do not appear on this list. Likewise we expect that we will be constrained for financial or technical reasons from applying these treatments across the board.

This reduction assumes that we neither intensify the blackspot programme, nor raise the rate at which sites that we investigate proceed to implementation. If we do either of these, the impact of the blackspot programme would be greater than estimated.

Existing construction programme

Estimated reduction in social cost	Enforcement emphasis option	5%
	Mixed option	5%
	Engineering emphasis option	5%

In analysing the road safety strategy we split road construction into two components: the 'existing' and the 'expanded' programmes. The existing programme is what could be built at the current real level of expenditure.

Cause and effect

New (and reconstructed) roads are nearly always safer than old. So when new roads are built, safety is normally one of the benefits (along with reduced travel time, reduced vehicle operating costs, and possible environmental and amenity costs and benefits).

Present situation

Road Controlling Authorities currently spend about $1.1 billion annually on road construction. This comprises constructing new roads on new alignments, reconstructing existing roads on existing alignments, and retrofitting and maintaining safety and other design features on existing roads.

Future impact

Road Controlling Authorities will by definition maintain their current rate of spending on 'existing road construction' throughout the strategy period. We cannot say at this stage exactly how the money will be spent—that is something to be worked out as part of the strategy itself—but we can identify the main road design features that we would implement wherever it was cost effective to do so (*table 3*). However, desirable as these features are, we accept that it is most unlikely that we will be able to implement them as widely as we would like. They should therefore be seen as an ideal we will aim for, not a target we are committed to achieving.

We estimate that improved effectiveness of the existing construction programme will reduce the social cost of road trauma by 5%.[4] This is probably conservative; Vulcan (1997) estimated that major road construction would reduce the Australian road toll by 10% by 2010. Because of the uncertainty, we propose to undertake more work to refine this estimate.

Expanded construction programme

Estimated reduction in social cost	Enforcement emphasis option	none
	Mixed option	11.7%
	Engineering emphasis option	18.0%

4 From 1996 through 1998 neither road safety outcomes nor road safety expenditure changed significantly, although traffic volume grew by 3.1% per annum. This suggests that improvements in (1) the safety of the road network and (2) the vehicle fleet, plus (3) efficiency gains for enforcement, roughly counteracted the upward pressure of traffic growth on the road toll. Another way of looking at this is that, after accounting for increased vehicle safety and enforcement efficiency, road construction was sufficient to ensure that the road toll did not rise in the face of growing traffic. We assume this will continue. If so, road construction will be such that, in isolation, it would cause a 5% fall in social cost, all other things being equal.

As already stated, we split road construction into two components: the 'existing' and the 'expanded' programmes. The expanded programme consists of road construction that would require an increased real level of expenditure.

Cause and effect

See *Existing construction programme*.

Present situation

See *Existing construction programme*.

Future impact

An expanded road construction programme could produce as much safety benefit as we wanted, provided we were prepared to pay for it. It would comprise the same sorts of treatments as would be undertaken under the existing construction programme, only more of them (*table 3*).

In developing the strategy we defined three options that differ in the relative weight placed on road engineering versus enforcement. In the *Enforcement emphasis* option, road construction is kept at current levels; in other words, there is no 'expanded' construction programme. But in the other options—the *Mixed* and *Engineering emphasis* options—road construction expands to compensate for their lower intensity of enforcement. In other words, in these options the amount of road construction is determined as a residual: it is whatever we need in order to achieve the same safety outcome as under the *Enforcement emphasis* option.

Trauma management

Estimated reduction in social cost	Enforcement emphasis option	0.9%
	Mixed option	0.9%
	Engineering emphasis option	0.9%

Safety standards do not always meet the eye. Roads of identical appearance may differ in their standard of safety because one is well served by emergency, medical and rehabilitation services, and the other is not. Hence we treat trauma management as part of the road environment.

Cause and effect

According to the European Transport Safety Council (ETSC 1997) effective trauma management is characterised by:

- efficient emergency notification
- fast transport of qualified medical personnel
- correct diagnosis at the scene
- stabilisation of the patient
- prompt transport to point of treatment
- extensive rehabilitation services.

Trauma management of this type—in particular, fast, expert medical care—crucially affects the severity of injury and probability of survival. Since the social cost of fatality and permanent disability[5] is very large, improved trauma management can have a significant effect on social cost, even if the proportional reduction in fatality or disability rates is small.

5 NZIER (1999) estimates that in New Zealand about 1.9% of those injured in crashes are never able to return to work, and in the UK about 1.7%.

Present situation

The quality of New Zealand's emergency services (including those for road trauma) appears to be satisfactory by international standards, but could certainly be improved. The Ministry of Health, ACC, the Council of Medical Colleges and other stakeholders have developed a new acute management system to be implemented nationally by the end of 2001 (MoH, 1999). Its key features are:

- five regional networks centred on New Zealand's five main ('tertiary') medical centres,
- patient delivery to the nearest hospital providing appropriate care,
- rescue capability,
- integration of emergency services,
- appropriate emergency transport,
- agreed protocols, guidelines, and standards,
- workforce development and training, and
- telecommunications and emergency response.

Future impact

During the strategy period we shall begin to feel the benefits of the planned new acute management system. In addition, the spread of mobile phones and crash alert systems[6] will reduce response times. We expect these influences to have a significant effect on safety outcomes, though we are not able to quantify it.

We relied on expert judgment to estimate the impact of improved trauma management. Vulcan (1997) estimates that in Australia improved trauma management will reduce the number of fatalities and serious injuries by 10% by 2020. However, most of this reduction is expected to materialise after 2010, so we conservatively assumed a 2% reduction in fatalities, which equates to a 0.9% reduction in social cost.

Compliance

Urban speed management

Estimated reduction in social cost	Enforcement emphasis option	5.3%
	Mixed option	5.3%
	Engineering emphasis option	3.3%

Urban speed management differs markedly from that on open roads: both rely on the same repertoire of interventions but the mix and emphasis is quite different. Hence urban and open road speed enforcement are discussed separately.

Cause and effect

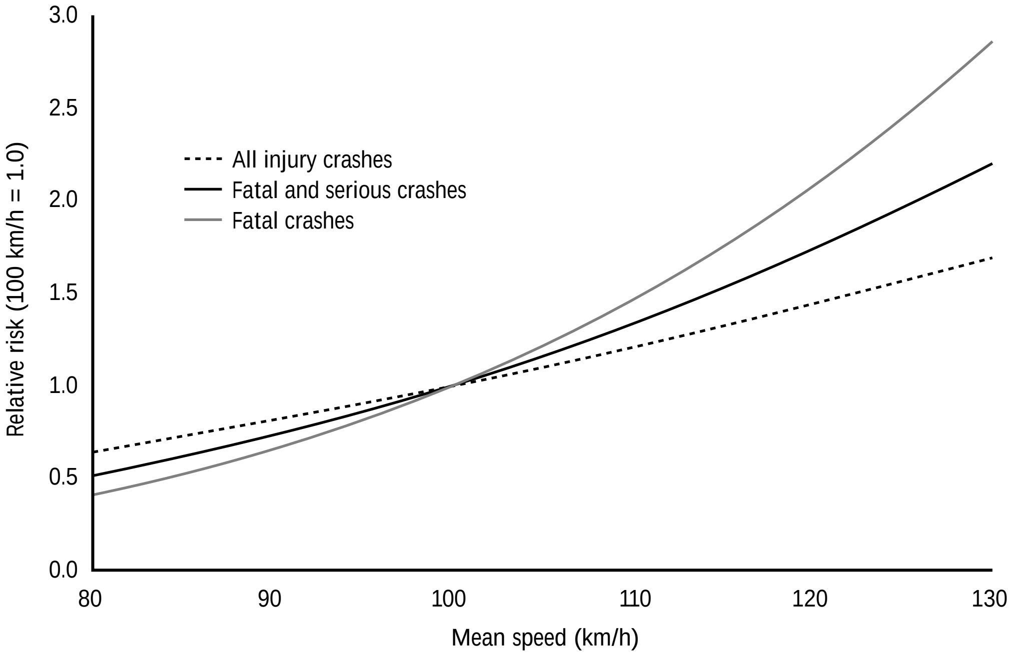
Speed moderation is one of the most effective ways of reducing road trauma.[7] For example, a 1% decrease in mean speed (from 101km/h to 100 km/h, say) causes fatalities to decline by 4% and injuries by 2% (*figure 1*).

6 On-board devices are now available that automatically alert emergency services of a crash, giving location and probable severity. They are becoming common in the United States, and may become so in New Zealand.

7 The link between traffic speed and road trauma is well established. Nilsson (1982) for example proposed a relationship between mean traffic speed and casualties that has since been confirmed by observation. According to Nilsson, the change in the fatality rate is related to the fourth power of the proportional increase in speed, and change in injury rate is related likewise to the square.

Figure 1

The effect of speed on crash risk



Source: Nilsson (1982)

Speed management interventions work best in concert. In general, police surveillance and speed cameras are suited to major urban roads, and traffic calming to minor ones. In this section we discuss police surveillance and speed cameras; traffic calming is dealt with elsewhere as it concerns the standard of physical design of the road environment, not compliance with it.

Present situation

Traffic in New Zealand's urban areas is generally limited to a speed of 50 km/h, though higher speeds are permitted on some main roads. But many drivers exceed the limit by a substantial margin: we estimate that about 15% of drivers exceed 60 km/h on roads with a 50-km/h speed limit. On major urban roads enforcement is conducted by a combination of police patrol and speed cameras. This effort has been considerably strengthened in recent years by a programme of targeted enforcement supported by hard-hitting television advertising.[8] On minor urban roads it is hard to enforce speed limits in the same way because of the length of roads of this type. Instead, speed is best managed by means of traffic calming (*box 1*).

Future impact

Speeds on major urban roads could be brought down by stricter enforcement of the kinds we already employ: stiffer sanctions in the form of demerit points[9] for speed cameras, and a reduced tolerance for exceeding the posted speed limit.[10]

8 In 1995 we implemented an intensified programme of targeted road safety enforcement supported by hard-hitting television advertising. An independent review of the first two years estimated that more than 100 lives and 1000 serious injuries had been saved, equivalent to $611 million in social cost, and delivering a benefit–cost ratio of 28:1.

9 Demerit points are issued to offenders in proportion to the gravity of the offence. If an offender acquires too many points within a specified period, the offender's licence may be suspended.

10 Until recently it was customary for speed camera operators to ticket only those drivers whose speed exceeded both the posted speed limit and the 85th percentile for the traffic stream at that spot, that is, the fastest 15%. In June 2000 tolerances were set to 10 km/h above the posted speed limit. The effect will be to reduce tolerances nearly everywhere and, it is hoped, thereby reduce mean speeds.

With measures of this kind we are confident in the light of other countries' experience that mean speeds on our major urban roads could be brought down from the current 56 km/h to 53 km/h (*Engineering emphasis* option) or 51 km/h ((*Mixed* and *Enforcement emphasis* options).

We relied on Nilsson (1982) (f*igure 1)* to estimate the impact of these speed reductions on road safety outcomes.[11] We conclude that fatalities on major urban roads would decline by 20% to 31%, all injuries by 10% to 17%, and social cost by 3.3% to 5.3%, depending on the reduction in mean traffic speed (*table 4*).[12]

Table 4

Estimated impact of speed management interventions

Intervention	Major urban roads		All open roads		All roads
	Fatalities	**Injuries**	**Fatalities**	**Injuries**	**Soc. cost**
Urban speed management					
Mean speed: 53 km/h	-20%	-10%			-3.3%
Mean speed: 51 km/h	-31%	-17%			-5.3%
Open road speed management					
Mean speed: 99 km/h			-22%	-15%	-11.6%
Mean speed: 93 km/h			-37%	-23%	-19.1%

Source: LTSA.

Open road speed management

Estimated reduction in social cost	Enforcement emphasis option	19.1%
	Mixed option	11.6%
	Engineering emphasis option	11.6%

Cause and effect

See *Urban speed management*.

Present situation

The maximum legal speed on New Zealand roads is 100 km/h. Roads with this legal speed limit are referred to as 'open roads'. Most are found in rural areas, urban motorways being an exception. Many motorists exceed the open road speed limit—in many places about 15% of drivers exceed 115 km/h. The open road speed limit is currently enforced by a combination of police surveillance and mobile speed cameras (*box 1*).

Future impact

Police surveillance and speed cameras remain our speed management tools, and if intensified could significantly reduce mean speeds on our open roads. But to estimate the magnitude of the reduction we must first consider what would happen if we continued present practices unchanged.

11 Nilsson is if anything conservative for urban roads. Kloeden et al (1997) for instance concluded that the 'risk of casualty crash involvement in a 60km/h zone doubles with every 5km/h increase in travelling speed'—an estimate considerably higher than Nilsson's.

12 Although some casualties on minor urban roads might also be saved, to avoid the possibility of double-counting we ignored them since speed management on such roads is mainly by means of traffic calming, and is evaluated elsewhere.

Box 1

Speed management interventions

There are two main approaches to curbing speeding: deterrence and prevention.

Deterrence. Speeders may be detected automatically (say by means of speed cameras) or by means of a physical police presence.

- **Speed cameras.** In New Zealand speed cameras are operated overtly: they are only deployed within designated and signed zones, and no particular attempt is made to conceal them. Consequently drivers are often warned of the presence of a speed camera by oncoming drivers flashing their headlights, especially in the open road environment. (By contrast, in Victoria there are no announced camera zones and cameras are often concealed.)
- **Police patrol.** The police operate mobile radar speed-measuring equipment from patrol cars, and also use roadside equipment with 'chase' cars. Unlike speed cameras, police patrols also detect and deter other kinds of reckless, careless and dangerous driving besides speeding.
- **Intelligent transport systems.** Direct image capture from digital cameras and advanced video imaging are examples of ITS technologies that could greatly improve the efficiency of speed management. They could be introduced into New Zealand within a few years.

Prevention may be achieved through appropriate road design—that is, traffic calming—or (and this is some way off) by means of control devices fitted to the vehicle.

- **Traffic calming.** Traffic speeds may be restrained through the physical design of roads and neighbourhoods (humps, roundabouts, street closures etc.). This practice, known as 'traffic calming', discourages through traffic from using local streets; creates a streetscape that both inhibits fast driving and protects pedestrians and cyclists, who are most at risk; and can also be effective in slowing down traffic where rural highways pass through small settlements. Traffic calming is appropriate for minor urban roads because there are far too many of them for enforcement to be cost-effective. Besides, traffic calming offers aesthetic and amenity benefits as well as safety benefits. We can also view traffic calming in another way. A high design speed encourages fast driving. Traffic calming merely brings design speed into line with the desired, and signed, traffic speed.
- **Vehicle speed limiters** are mandatory on certain specialised commercial vehicles where stability is compromised, but are already used voluntarily on many ordinary commercial vehicles and are expected to become more common.
- **Global positioning systems** (GPSs) can be used either to warn drivers of unsafe speeds or to limit vehicle speed directly. They work by comparing the vehicle's actual speed with a reference safe speed linked to a digital map of the road network. The system would normally be too costly to be justified by crash savings alone, but could be attractive if combined with a GPS that was also used for another purpose such as freight tracking.

Because modern cars are faster and more comfortable to drive, in the absence of countermeasures mean traffic speeds would not just stay where they are—they would creep upwards, and if unchecked would erode safety and raise social cost. They have not done so in New Zealand in recent years only because we have stepped up our speed management effort. Without further preventative measures we predict that mean traffic speeds on open roads will increase by 1% by 2010. This will cause open road fatalities to increase by 4% and injuries by 2% (*figure 1*).

Despite the tendency of speeds to creep upwards, we estimate that it is possible to reduce the mean open road traffic speed to 99 km/h (*Engineering emphasis* and *Mixed* options) or 93 km/h (*Enforcement emphasis* option) through the imposition of a combination of some or all of the following measures.

- **Demerit points.** Demerit points would increase the effectiveness of speed cameras.
- **Lower tolerances.** It is normal to apprehend drivers only if they exceed the posted speed limit by more than a certain tolerance. Tolerances have recently been reduced, though the effects are still to be felt.
- **Lower posted speed limits.** A mean traffic speed of 99 km/h could, we consider, be achieved while retaining the existing 100 km/h open road speed limit; but to achieve mean traffic speeds of 93 km/h the open road speed limit would have to be lowered to 90 km/h.
- **Enhanced surveillance.** We can deter speeding through improved and intensified surveillance. There are various ways to achieve this (*box 1*). A recent example is the setting up of a dedicated Police State Highway Patrol and the dedication of traffic safety officers to strategic enforcement, the effects of which will begin to be felt in 2001.

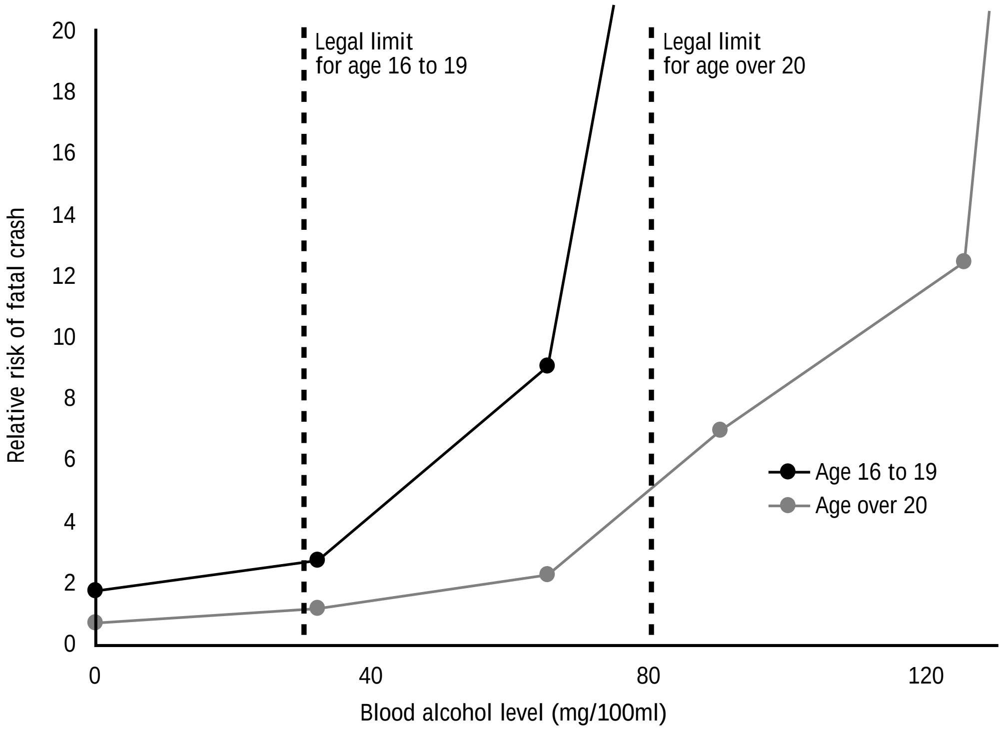
To bring mean speeds down to safer levels we will have to invoke a combination of these interventions. We are confident that speeds can be reduced by at least 1.6 km/h, since this was observed in a recent trial of hidden speed cameras[13], and we believe that similar results could be achieved by other methods of enhanced surveillance. A combination of additional speed enforcement measures, such as demerit points, would further reduce speeds to 99 km/h. To reduce speed further still, to 93km/h, we would need to lower the open road speed limit.

We relied on Nilsson (1982) (*figure 1)* and the results of the covert speed camera trial to estimate the impact of these speed reductions on road safety outcomes. We conclude that fatalities on major open roads would decline by 22% to 37%, serious injuries by 15% to 23%, and social cost by 11.6% to 19.1%, depending on the reduction in mean traffic speed (*table 4*).

13 In the trial, which took place in the central North Island, mean traffic speeds fell by about 1.6 km/h, and injuries by 19%. This is a greater casualty reduction than would be expected by the Nilsson (1982) formula. There are three explanations. First, we found that the fastest driving, who tends to be associated with the severest crashes, was most affected. Second, the cameras were placed on the riskiest parts of the network. Third, besides just reducing speed, drivers may have exercised greater caution generally.

Figure 2

The effect of blood alcohol on relative risk of a fatal crash



Source: Mayhew(1983)

Estimated reduction in social cost	Enforcement emphasis option	3.3%
	Mixed option	3.3%
	Engineering emphasis option	3.3%

Cause and effect

Alcohol consumption greatly raises the risk of crashing. For example, a driver with a blood alcohol content (BAC) of 80 mg per 100 mL (the current legal limit in New Zealand) is about three times as likely to crash as when sober (*figure 2*). The incidence of driving under the influence of alcohol ('drink-driving') can be reduced by stricter enforcement, a lower BAC limit (see *Reduced blood alcohol content*), or a combination. This section deals with one type of enforcement, compulsory breath-testing (CBT)[14].

Present situation

The Police conduct an active CBT programme. It could be strengthened by increasing the number of police hours devoted to CBT, by reducing the BAC limit, or both (*box 2*).

Future impact

We estimated the safety impact of intensified CBT by appealing to Australian experience. On this evidence we estimate that CBT of the Victorian and NSW kind

14 The intervention known as 'compulsory breath-testing' in New Zealand is called 'random breath-testing' in Australia. For simplicity we use the New Zealand terminology throughout.

Box 2

Interventions to combat drink-driving

Most interventions to combat drink-driving concern the procedures and laws by which the Police can first identify, and then apprehend, offenders. These approaches can be characterised as 'casting a wider net'.

- **Compulsory breath-testing** works mainly through deterring potential drink-drivers.
- **A reduced BAC limit** brings more drivers into the 'net' by including those that exceed 50 mg per mL, a level that can be shown to impair driving.
- **A zero BAC limit for young drivers** is justified on the grounds that the effect of drink-driving by novice drivers is exacerbated by their inexperience.
- **Mandatory licence carriage** can assist by making it harder for young drink-drivers to escape penalty if they are breath-tested.

Three interventions deter drink-driving by increasing sanctions and negative consequences.

- **Vehicle impoundment** is a severe penalty that can be imposed on disqualified or unlicensed drivers. Since such drivers are more likely than others to be affected by alcohol, vehicle impoundment is effective in combating drink-driving.
- **Licence suspension** is imposed for serious speeding and drink-driving offences.
- **Alcohol interlocks** are devices that make it difficult for drunk persons to be in charge of a vehicle.

will reduce alcohol-related casualties by 13%.[15] This equates to a 3.3% reduction in social cost. We consider this to be a conservative estimate, as it is based on what has actually been achieved in jurisdictions where the authorities themselves believe that further improvements are possible.

Restraint wearing

Estimated reduction in social cost	Enforcement emphasis option	4.2%
	Mixed option	4.2%
	Engineering emphasis option	2.9%

15 There are two widely used measures of drink-driving performance: the proportion of dead drivers with an excessive BAC, and the proportion of crashes in which alcohol is a contributing factor. The latter is more comprehensive since it covers all crashes, not just those in which the driver dies; but it is affected by subjective judgment, so is less reliable. Under both, New Zealand performs poorly in comparison to Australia. In Victoria in 1995 22% of dead drivers were found to have a BAC over the legal limit; in NSW in 1996 21% of deaths were in alcohol-related crashes. Both findings corroborate each other. On this evidence we estimate that if New Zealand both reduced its legal BAC limit to 50 mg/100 mL, and conducted CBT in a manner similar to Victorian and NSW, it would reduce the proportion of alcohol-related fatalities from 28% to 22% all other things being equal—a 29% reduction.

This reduction results from two interventions—strengthened CBT and a lower BAC limit—whose impact must now be disentangled. Looking first at the BAC limit, Henstridge et al. (1997) found a 8% reduction in fatal crashes and 7% in serious crashes associated with a lowered BAC from 80 to 50mg/100mL in NSW in 1980. This equates to an 18% reduction in alcohol-related fatalities (and, we assume, alcohol-related injury crashes as well). We assumed that the same proportionate reduction would occur in New Zealand. Now if the total reduction from both CBT and a lowered BAC is 29%, and if a lowered BAC contributes 18%, then CBT must contribute 13% (assuming that the interventions combine multiplicatively).

Cause and effect

When a vehicle crashes, it decelerates or accelerates at an extreme rate. Its occupants meanwhile continue to move at the vehicle's previous speed until they are stopped, either by a stationary object (if thrown clear), by the interior of the vehicle (if unrestrained), or by a seatbelt (if restrained). Despite widespread belief to the contrary, it is extremely dangerous to be thrown clear: better to stay inside the vehicle, especially if the interior is padded and fitted with airbags; better still to be restrained by a seatbelt (and if airbags are fitted as well, better yet). Lap-and-shoulder belts provide the most protection of any type of restraint. When correctly fitted and used, they reduce the probability of fatality or serious injury in a crash by 40%, and when combined with airbags, by 46%.

Present situation

It is mandatory to wear seatbelts in New Zealand. About 11% of front-seat[16], and 38% of rear-seat, occupants fail to comply. Given that seatbelts are known to be highly effective in saving lives and preventing injuries, this is not a proud record. Many countries do better (although many more do worse). According to police estimates, every year about 50 people die whose lives would have been saved if they had used the seatbelts available to them.

The advertising and enforcement programme was extended to include restraint use in 1996. The seatbelt component aims to reduce non-wearing rates through powerful advertising in support of continued police enforcement. Advertising aims to persuade non-wearers of the advantages of seatbelts, and remind regular wearers of the need to always use them. Seatbelt enforcement has increased considerably since 1995 through a combination of community and child restraint campaigns and increased issuing of offence notices. The effect of this increase in enforcement has been especially noticeable in parts of Auckland.

Future impact

A nationwide non-wearing rate of 5% is achievable (*Engineering emphasis* option). It has already been reached in some parts of New Zealand and is the average for Victoria, Australia. A rate of 2% (*Mixed* and *Enforcement emphasis* options) would be harder to reach, but not impossible, as we know from the fact that some parts of New Zealand have already done it. Depending on the non-wearing rate, social cost would fall by between 2.9% and 4.2% (*table 5*).

16 Based on LTSA surveys of front-seat adult seatbelt wearing. 17 000 adults were surveyed at 57 rural and 57 urban locations in 1999. The national wearing rate is the number of restrained adults as a proportion of the total (excluding those where seatbelt wearing status was not observed). Note that there is considerable regional variation: some regions such as Taranaki, Wellington and Auckland City have non-wearing rates among the lowest in the world.

Table 5

Estimated impact of speed management interventions

Non-wearing rate	Casualty reduction			Social cost
	Fatality[a]	**Serious injury[b]**	**Minor injury[c]**	
5%	4%	2%	1%	2.9%
2%	6%	3%	1%	4.2%

Notes

(a) We assume that (1) 40% of vehicle occupants who die are unrestrained (according to police records, 30% of occupant fatalities were known to be unrestrained, and we assume a further 10% were unrestrained, that is, one third of those whose restraint status was unknown); (2) 40% of these fatalities would be saved if restrained (Evans 1991); and (3) reducing the non-wearing rate among all occupants would only reduce the rate among the crash-involved by two-thirds as much, since high-risk road-users are known to be more resistant to wearing restraints than others.

(b) We assume (in addition to the above assumptions) that (1) 20% of vehicle occupants who are seriously injured are unrestrained; and (2) 40% of these would avoid serious injury if restrained. We expect the non-wearing rate for serious injuries to be lower than for that for fatalities because non-wearers are more likely to die in a serious crash. Our estimate lies between 11% (the non-wearing rate for the general population) and 40% (non-wearing rate for fatalities).

(c) We assume (in addition to the above assumptions) that (1) 11% of vehicle occupants with minor injuries are unrestrained (estimate based a fortiori on the reasoning applied to serious injuries); and (2) 20% of these would avoid minor injury if restrained. We estimate that restraints are half as effective at reducing minor injuries as major injuries and fatalities.

Source: LTSA.

The vehicle

Standards and rules

Light vehicles

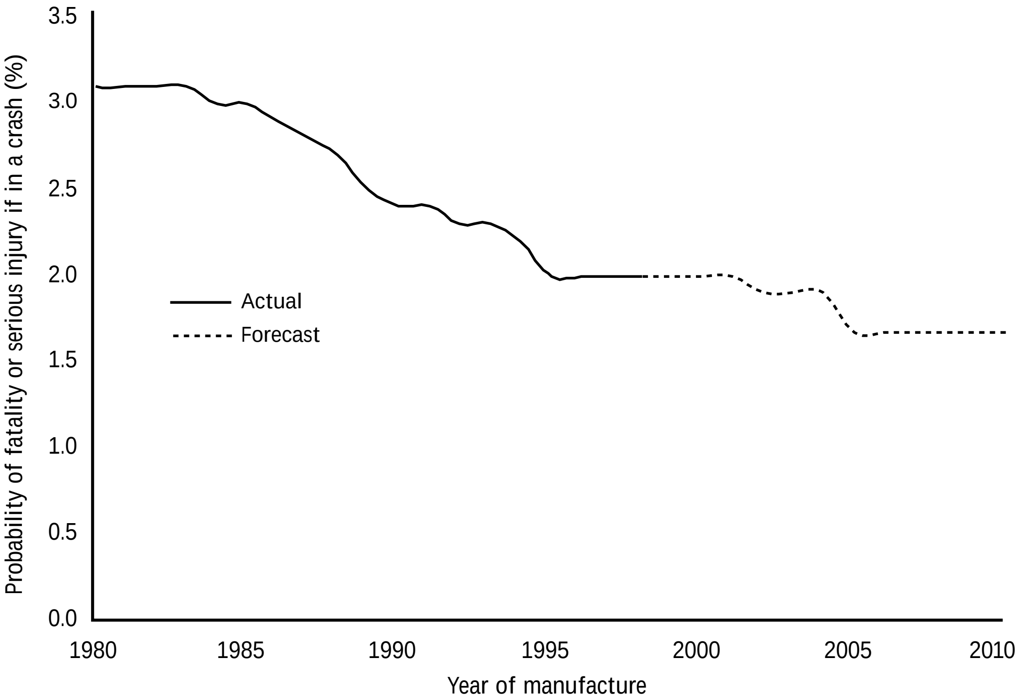
Estimated reduction in social cost	Enforcement emphasis option	15.5%
	Mixed option	15.5%
	Engineering emphasis option	15.5%

Cause and effect

Since the 1960s cars have become steadily safer. A car built in 2010, for instance, is expected to be far safer in a crash as one built in 1980 (*figure 3*). This continues a long trend that started as far back as the 1960s as cars improved in ‘active’ safety—that is, features that help the driver avoid a crash; and ‘passive’ safety—features that protect occupants in the event of a crash (*table 6*). This has happened largely because vehicles are designed and built to exacting safety standards.

Figure 3

Crashworthiness of light vehicles, by year of manufacture



Source: Monash University Accident Research Centre (actual); LTSA (forecast).

To achieve a safer national vehicle fleet, however, it is not enough to make safer cars available; people also have to afford them. This means that if a new safety standard is introduced, it is some years before there are many cars on the road that comply. The speed of take-up depends on how fast the market is growing and how fast existing owners replace their older vehicles. In New Zealand's case it also depends on the age-profile and market share of used imports, which make up a large share of the vehicles supplied to the market. These meet the standards that applied when they were manufactured, and that may no longer be current at the time of import.

Table 6

Principal vehicle safety features to affect safety outcomes to 2010

Active safety	Passive safety
Crash avoidance	Crush zones & safety cages
Anti-lock braking systems	Frontal impact protection
Traction control / 4WD	Side impact protection
Handling and stability	Safety belts
Audible warning devices	Airbags
Lighting and conspicuity	Seats
Adjustability and comfort	Head restraints
Minimising driver distraction	Safer vehicle interiors
	Load restraint
	Fire safety

In the past the composition of the vehicle fleet, and hence the crash fleet, has changed greatly in response to these factors, and we expect it to go on changing. Since forecasting it is a complex matter, we constructed a computerised simulation model for the purpose (*appendix 2*).

Present situation

Although vehicle standards are mostly set overseas, decisions there affect New Zealand since we accept the standards promulgated by the world's leading vehicle safety jurisdictions—the USA, Japan, Europe and Australia—and have done so since 1991. As a result of this policy, New Zealand's vehicle standards are in line with some of the best overseas practice, and consumers have a wide range of models to choose from. As a result, too, of a liberal import policy New Zealand now has a competitive vehicle market with relatively low prices, which encourages consumers to replace their older vehicles with newer, safer ones. The upshot is that the vehicle fleet is being progressively renewed to higher standards of safety.

Future impact

We expect vehicle safety to continue to improve over the coming decade as technological advances that have already been accepted permeate into the national fleet. New frontal impact standards are among the most important, and cars built to these standards are now entering the fleet. Towards the end of the decade we may begin to benefit from specialist crash-avoidance devices; these are still mostly experimental and their impact speculative.[17] These and other benefits come from the family of automated devices collectively known as intelligent transport systems (ITS). Consumers will continue to have access to affordable, safer vehicles as older, less safe vehicles are replaced by newer, safer ones.

We will continue the policy of adopting the leading overseas vehicle safety standards. We will also introduce better ways to ensure that vehicles comply with relevant safety standards and to encourage owners to maintain them in good condition. This is particularly relevant for heavy vehicles, where NZ performs poorly. Another initiative will be to provide information to motorists about vehicle safety.[18] The aim is to encourage better vehicle maintenance and to make the public more aware of the importance of crashworthiness. Market demand may then encourage importers to supply vehicles that exceed the minimum safety standards. The overall aim is to make vehicles entering the fleet safer and more affordable. In this way, by 2010 the fleet will be much safer than it is now, just as it is much safer now than it was ten years ago.

We estimate that improved light vehicle standards will reduce *Baseline 2010* social cost by 15.5%.

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17 Alcohol interlocks, which could be regarded as a crash-avoidance intervention, are treated instead as enhancing compliance with acceptable road user behaviour, and consequently discussed elsewhere in this paper.

18 The LTSA has recently joined ANCAP, the Australian New Car Assessment Programme—an organisation of government transport departments, motoring organisations and clubs. ANCAP tests the crash performance of the vehicle structure and occupant restraint system. The aim is to publicise the safety performance of cars on the market. This is valuable information, as safety performance varies greatly between models, even those in the same price range. Buyers can make more informed decisions, which in turn encourages manufacturers to improve and promote product safety. Experience with equivalent programmes in Sweden and the UK shows that they work: buyers respond to test results, particularly where a model performs poorly; and manufacturers improve their vehicles in response.

Heavy vehicles

Estimated reduction in social cost	Enforcement emphasis option	0.5%
	Mixed option	0.5%
	Engineering emphasis option	0.5%

Cause and effect

When a truck collides with a light vehicle, the truck's greater mass protects its occupants at the expense of other road users. This explains why in about 80% of fatal truck crashes, in New Zealand or elsewhere, the victims are either in smaller vehicles, or are pedestrians, motorcyclists and cyclists. This places a special onus on the authorities to prevent truck crashes. It is not that trucks are usually at fault but that if a crash happens the consequences are likely to be so much more severe.

Present situation

In New Zealand heavy vehicles are involved in about 18% of fatal road crashes—which is high compared with other developed countries.[19] This is not to imply that truck drivers are responsible, however. Despite their problems, heavy vehicles are under-represented in terms of *culpability* in fatal crashes: truck drivers have primary responsibility in less than a third of the fatal crashes in which they are involved. Compared with other affluent countries New Zealand also has an above-average proportion of truck crashes that lead to rollover (29% in 1999). Moreover recent research has found that although most New Zealand trucks are generally stable, a minority contribute disproportionately to crashes (15% of trucks are involved in 40% of 'loss of control' crashes involving rollover).

Future impact

Since most truck crashes are the other driver's fault, much can be done to reduce them by educating ordinary drivers in how to share the road with trucks. But the trucks themselves can also be improved. We are therefore working with the industry to make heavy vehicles safer, for instance by improving their conspicuity and stability.

- **Vehicle stability.** New Zealand has a bad record for rollover crashes. Logging trucks are particularly unstable, having a crash rate over three times the national average. New stability performance measures will therefore be developed for incorporation into a proposed mandatory standard. The aim is to bring underperforming vehicles up to the national average. This will reduce annual social cost by an estimated $11.7 million, or just under 0.4%.
- **Visibility.** In 1998 a code of practice (*Heavy Vehicle Visibility Code*) was produced for making heavy vehicles more visible through improved lighting and the use of reflective material. This code is voluntary. As it is adopted by a growing number of operators it is likely that we will see fewer crashes between small and heavy vehicles.[20]

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19 For instance in the US, where exposure rates are similar to New Zealand, trucks are involved in about 8% of fatal crashes.

20 In the USA, Burger et al. (1985) found that similar measures reduced the night-time crash rate by over 21% and the daytime rate by over 16%.

- **Under-run guards.** Rear, side and front under-run guards on trucks help protect pedestrians, motorcyclists, cyclists, and light vehicle occupants in the event of a collision. Research is in progress into the feasibility and cost-effectiveness of fitting under-run guards on trucks.[21]

Improvements in vehicle stability alone are expected to reduce social cost by 0.4%. We lack detailed data relating to under-run guards and visibility improvements, but conservatively estimate that when these measures are included, heavy vehicle interventions will jointly reduce *Baseline 2010* social cost by 0.5%.

The road user

Standards and rules

Driving age

Estimated reduction in social cost	Enforcement emphasis option	2.6%
	Mixed option	none
	Engineering emphasis option	none

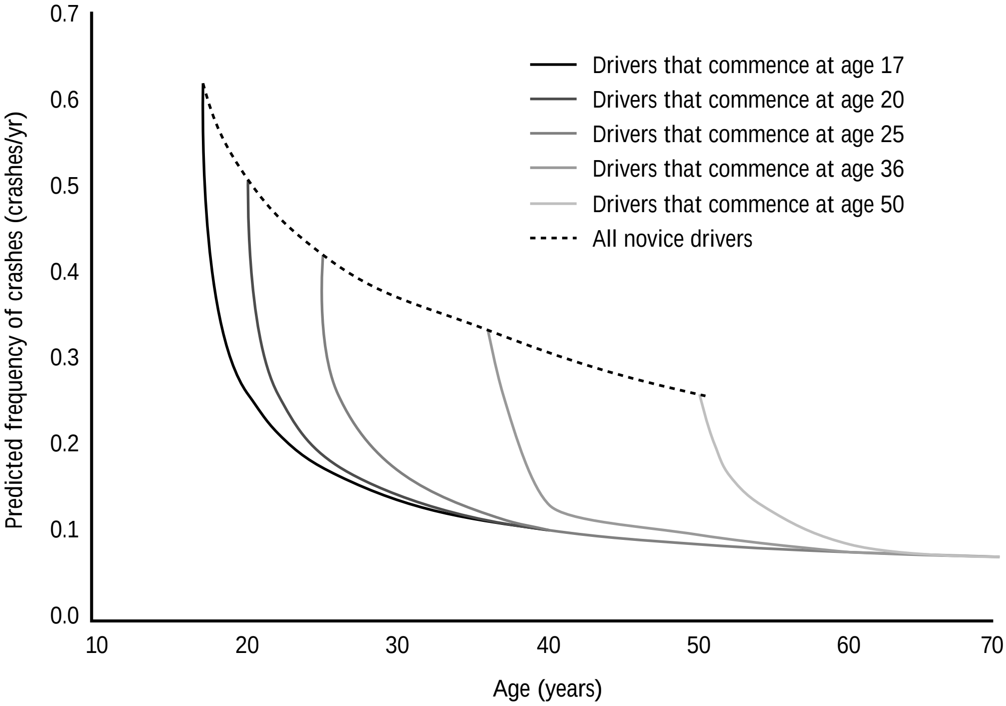
Cause and effect

Young drivers are on average more likely to be involved in crashes than older drivers. Their higher risk is partly due to inexperience and partly to age: young drivers appear to be more prone to take risks (*figure 4*). Whatever the reason for this, we can prevent a disproportionate number of crashes by raising the age at which a person is permitted to drive. This will not eliminate the risk inherent in inexperience (which will only be postponed) but it will eliminate some of the risk inherent in youth. Other interventions can be employed to remedy the problem of inexperience (see *Stricter licensing conditions*).

21 In the UK, DETR (1997) expect front underrun guards to reduce car occupant fatalities in heavy motor vehicle crashes by 12%. This equates to a reduction in social cost of 0.4% in New Zealand, but because a high proportion of our fatal truck crashes are on the open road it is unlikely our benefit would be that high. Note, however, that these conclusions relate only to *front* under-run guards.

Figure 4

The effect of age and inexperience on the risk of crashing



Note: Frequency of crashes is normalised for a mobility level of 7500 miles per driver-year.
Source: Maycock (1991)

Present situation

Young drivers (that is, those aged 15 to 19) are involved in 18% of fatal crashes and 22% of injury crashes. Some of these crashes could be prevented by raising the legal driving age, which in New Zealand is 15 years of age—younger than in most other countries, many of which only permit a person to drive at age 17 or 18.

Future impact

Raising the minimum driving age would eliminate most crashes involving drivers in the affected age groups. But not all. In about 20% of crashes involving drivers under 17 the driver was unlicensed. These drivers are already driving illegally, and would presumably continue to do so. Furthermore, if the minimum driving age were raised to 17, more young people would drive unlicensed. If all licensed drivers under 17 were to cease driving, 80% of crashes by this age-group would be eliminated. But since the incidence of unlicensed driving would rise, we estimate that there would only be 70% fewer crashes.

Stricter licensing conditions

Estimated reduction in social cost	Enforcement emphasis option	1.1%
	Mixed option	1.1%
	Engineering emphasis option	1.1%

Cause and effect

Driver inexperience and youth raise the risk of crashing (*figure 4*). One way to combat this is to impose restrictions on learners and young drivers (who are often the same people) to lessen the likelihood they will find themselves in danger. Such restrictions take many forms but most commonly concern speed, type of road, number and type of passengers, vehicle power, blood alcohol content (BAC), and hours of travel.

Present situation

Learners (including drivers on restricted licences) are involved in 16% of fatal crashes and 19% of injury crashes. Some of these crashes could be prevented by imposing stricter licensing conditions on learners.

Graduated driver licensing. We already impose restrictions on how, where and with whom learners and young drivers can drive. These restrictions—known as the Graduated Driver Licensing Scheme (GDLS)—are gradually eased as the driver acquires experience and demonstrates competence. The GDLS has recently been strengthened, but because the effects are still to be felt they are described next under *Future impact.*

Mandatory licence carriage. Until 1999 only GDLS drivers were required to carry driving licences when driving. This may have allowed some young drink-drivers to escape penalty. Since drivers under 20 are limited to a BAC of 30 mg per 100 mL (stricter than the adult limit of 80 mg) some young drivers may have been encouraged to exceed the BAC limit in the belief that the police would not trouble to check their licences if they were not being carried. Now that all drivers are required to carry licences, this option is no longer open, so we expect to see a reduction in drink-driving by young drivers. Because these effects are still to be felt they are described next under *Future impact.*

Future impact

Graduated driver licensing. The GDLS was strengthened in1999 at the same time that mandatory licence carriage was imposed. An exit test is now required at the end of the restricted period, L-plates are required during the learning phase, and there are harsher penalties for breaches of conditions. On the basis of expert judgment we estimate that the stricter GDLS will reduce crashes by drivers aged 15 to 19 by 5%.

Mandatory licence carriage. To our knowledge no studies have been made of the safety impact of mandatory licence carriage. We therefore estimated its effect in New Zealand as follows. We know that 10% of drivers who exceed the legal BAC limit and who have a crash are under 20. If mandatory carriage reduced this by, say, 10% then alcohol crashes would decline by 1%.

Reduced blood alcohol content

Estimated reduction in social cost	Enforcement emphasis option	4.5%
	Mixed option	4.5%
	Engineering emphasis option	none

Cause and effect

Alcohol consumption greatly raises the risk of crashing (see *Compulsory breath-testing*). The incidence of drink-driving can be reduced by stricter enforcement, a lower BAC limit, or both. This section deals with reducing the BAC limit.

Present situation

Adult drivers in New Zealand are currently limited to a BAC of 80 mg per 100 mL. This is in line with many countries; although many others, including Australia, have a lower limit of 50 mg per 100 mL.

Future impact

We estimated the safety impact of reducing the adult BAC limit to 50 mg per 100mL by appealing to Australian experience. On this evidence we estimate that a reduced BAC will reduce alcohol-related casualties by 18%.[22] This equates to a 4.5% reduction in social cost. We consider this to be a conservative estimate, as it is based on what has actually been achieved in jurisdictions where the authorities themselves believe that further improvements are possible.

Zero BAC for young drivers

Estimated reduction in social cost	Enforcement emphasis option	0.1%
	Mixed option	none
	Engineering emphasis option	none

Cause and effect

See *Reduced blood alcohol content*.

Present situation

In New Zealand young drivers (that is, those under 20) are currently limited to a BAC of 30 mg per 100 mL.

Future impact

If we reduce the legal BAC limit to zero for young drivers, we estimate that the number of crashes involving both young drivers and alcohol will decline by 5%. This will produce a 0.5% reduction in alcohol related crashes, equivalent to a 0.1% reduction in total social cost.

Legal hours of darkness

Estimated reduction in social cost	Enforcement emphasis option	0.7%
	Mixed option	none
	Engineering emphasis option	none

Cause and effect

Research has shown that there are benefits in using headlights at times of poor visibility, for instance around sunset and sunrise (Koornstra et al., 1997).

Present situation

Unless conditions of visibility are impaired (for instance during heavy rain) drivers are currently required to have their headlights on only during the hours of darkness as defined by law: from half an hour after sunset until half an hour before sunrise.[23] This definition could be readily extended.

22 See *Compulsory breath-testing* and associated footnotes.

23 There is also a visibility criterion in the Road Code (LTSA, 2000b: p75): 'You must turn on your vehicle's headlights...at any...time when you cannot see clearly a person or vehicle 100 metres away.'

Future impact

We could extend the legal definition of 'hours of darkness' by an hour at each end of the day. During these two extra hours of twilight drivers would be required to drive with headlights. We estimated the benefit by reference to (1) the number of multi-vehicle crashes during the affected period (except those involving motorcycles, which already tend to use headlights during the day); (2) the proportion of crashes avoided, as determined by a formula developed by Koornstra et al. (1997); and (3) the proportion of vehicles that already turn on their lights before the legal hours of darkness.

Compliance

Vehicle impoundment

Estimated reduction in social cost	Enforcement emphasis option	1.9%
	Mixed option	1.9%
	Engineering emphasis option	1.9%

Cause and effect

Vehicle impoundment is a sanction normally imposed on unlicensed and disqualified drivers who are found to be driving. Impoundment works in various ways. The mere threat deters many potential offenders from driving while unlicensed or disqualified. But if they do continue to drive, either they are caught, in which case impoundment takes them off the road, or they are not, in which case they are likely to drive less and with greater caution. All these outcomes will improve road safety.

Present situation

Until recently vehicle impoundment was not normally used in New Zealand, but a law has now been enacted under which vehicles may be impounded in some circumstances if their drivers are found to be unlicensed or disqualified. Its effect is yet to be fully felt or evaluated.

Future impact

We estimated the impact of vehicle impoundment as follows. First, we established the number of casualties from crashes involving disqualified and unlicensed drivers (*table 7*). Next, we estimated from New Zealand data the proportion of disqualified drivers that would be subject to impoundment, and assumed that a similar proportion of unlicensed drivers would be similarly affected. Then, on the basis of overseas research, we estimated the reductions in crash rate due to specific deterrence, and reduced the number of casualties accordingly. Lastly, we made informed judgments as to the impact of general deterrence on disqualified and unlicensed drivers who are not punished by impoundment.

Table 7

Casualties, by alcohol involvement and licence status, 1997-98

Licence status of driver	Fatality: Alcohol-affected	Fatality: Not alc.-affected	Fatality: Total	Injury: Alcohol-affected	Injury: Not alc.-affected	Injury: Total
Without impoundment						
Disqualified	26	12	38	231	160	391
Unlicensed	24	40	64	294	792	1 086
Other	197	606	803	2 195	13 546	15 741
Total	247	658	905	2 720	14 498	17 218
Estimated reduction due to impoundment[a]						
Disqualified	7	3	10	58	40	98
Unlicensed	4	6	10	44	119	163
Total	10	9	19	102	159	261
Percentage reduction	4.1%	1.4%		3.7%	1.1%	

Note:

(a) We estimate that one in four disqualified drivers will be directly affected by impoundment. There are at any one time about 30 000 disqualified drivers in New Zealand, or about one driver in 80. Every year about 8000 are caught driving while disqualified, many more than once. These drivers would suffer impoundment. If this many are actually being caught, many more are probably offending, perhaps as many as half. This suggests that disqualification is being widely flouted. Other sources corroborate this. For instance, we find that in 1997/98 11% of fatal crashes and 9% of injury crashes involved disqualified or unlicensed drivers—a large proportion given that they should not have been driving in the first place.

In the absence of data on the extent of unlicensed driving, we assumed that impoundment would affect the same proportion of unlicensed drivers as disqualified drivers.

On the evidence of a Californian study (DeYoung 1999) we estimate that impoundment will cause disqualified drivers to have 38% fewer crashes, and unlicensed drivers 25% fewer crashes, than they would have had otherwise. We recognise that this estimate is uncertain due to differences in the social and legal environments of New Zealand and California, and in the details of the impoundment laws in both places.

Drivers whose vehicles would be impounded are subject to specific deterrence. Thus a quarter of crashes involving disqualified and unlicensed drivers would decline by 38% and 25% respectively.

Disqualified and unlicensed drivers whose vehicles are not impounded are subject to general deterrence. These drivers also have crashes, but because general deterrence is normally weaker than specific, their crash rate will not fall as much as the others; but will affect many more drivers—about three-quarters of those disqualified and unlicensed.

We estimate that the combined effect of specific and general deterrence will be to reduce crashes by all disqualified and unlicensed drivers on average by 25% and 15% respectively. Since most crashes by disqualified drivers involve alcohol, the estimate is applied to alcohol and non-alcohol crashes separately.

Source: LTSA.

Licence suspension

Estimated reduction in social cost	Enforcement emphasis option	1.5%
	Mixed option	1.5%
	Engineering emphasis option	1.5%

Cause and effect

Mandatory roadside licence suspension, like vehicle impoundment, is a sanction with general and specific deterrent effects.[24] International research (for instance Stigmastat 1989) has shown roadside licence suspension to be effective in reducing alcohol related crashes and drink-drive court cases.

Present situation

New Zealand has recently introduced mandatory roadside licence suspension for (1) driving with over double the BAC limit, (2) refusing to take a blood test, or (3) exceeding the speed limit by more than 50km/h. Because the full effects are still to be felt they are described next under *Future impact*.

Future impact

Drink-driving
We estimate that about 40% of alcohol-affected drivers involved in fatal crashes, and 20% of those involved in injury crashes, were driving with over double the BAC limit at the time.[25] We also estimate that licence suspension would reduce the incidence of such crashes by 20%.[26] Hence it would reduce the number of fatal and injury crashes involving alcohol by 8% and 4% respectively. This equates to a 1.5% reduction in social cost.

Speeding
We are unable to estimate the impact of licence suspension on the incidence of speeding. Conservatively, we have omitted it.

Alcohol interlocks

Estimated reduction in social cost	Enforcement emphasis option	0.6%
	Mixed option	none
	Engineering emphasis option	none

Cause and effect

Alcohol ignition interlocks are devices to prevent a vehicle's engine starting unless the driver provides a breath sample with an acceptable (possibly zero) alcohol content. Because they are costly and irksome, alcohol interlocks are

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24 Licences may also be suspended for medical and administrative reasons. The present discussion relates only to suspension as a sanction for certain serious drink-driving and speeding offences that are stipulated under section 95 of the Land Transport Act 1998.

25 Crash records show that about 50% of dead alcohol-affected drivers in New Zealand were driving with over double the BAC limit at the time of their deaths. Since drivers with a high BAC are more likely to die, we adjusted this proportion downward to 40% to reflect the proportion of alcohol-affected drivers who are involved in fatal crashes and who are driving with over double the BAC limit at the time.

26 In NSW, JSCRS (1989) predicted that licence suspension would reduce alcohol-related crashes by between 10% and 30%.

normally only imposed on recidivist[27] drink-drivers. Parts of the United States, Canada and Australia currently have legally-sanctioned alcohol interlock programmes.

Present situation

New Zealand does not currently have an interlock programme.

Future impact

To our knowledge no studies have been made of the safety impact of alcohol interlocks. We therefore estimated its effect in New Zealand as follows. We assume that if interlocks were introduced in New Zealand, recidivist drink-drivers would be required to have them installed for a period of one year after conviction. Interlocks (assuming they are not bypassed) would thus prevent crashes involving a recidivist drink-driver within one year of conviction. We do not know the number of casualties in such crashes, but we do know the number of casualties in crashes involving a driver who was both disqualified and affected by alcohol; and the latter provides a basis for estimating the former (*table 8*).

Table 8

Casualties in crashes involving alcohol-affected drivers, 1997-98

Licence status of driver	Severity	
	Fatality	**Injury**
Without alcohol interlocks		
Disqualified	26	231
Not disqualified	221	2489
Total	**247**	**2720**
Estimated reduction due to alcohol interlocks[a]		
Disqualified	7	58
Percentage reduction	2.5%[b]	2.0%

Note: (a) We estimate that one in four drivers who were both disqualified and affected by alcohol are recidivists, and would therefore be affected by alcohol interlocks. (b) This equates to 0.75% of all fatalities, which is similar to Vulcan's (1997) estimate of 1% for Australia. Vulcan's estimate is slightly higher than ours, probably because he assumed that interlocks would be fitted to all convicted drink-drivers's cars, whereas we assume they would be fitted only to those with two or more convictions.
Source: LTSA.

27 Depending on the offence in question, a recidivist may be defined in law as a person convicted of multiple offences within a specified period. For example, under the Land Transport Act 1998 a driver is designated a repeat offender if (1) he or she is convicted of drink-driving two or more times within five years, and (2) at least one conviction involves a 'high' alcohol level or the driver refuses to give a blood specimen.

Other factors

Education

Cause and effect

Education runs through everything we do. It consists of activities that inform and support changes in road safety behaviour. Without education, most road safety interventions would be harder to introduce and their effectiveness much diminished. For instance, a law to require cyclists to wear helmets is best introduced after a lengthy period of educating the public in their value; and speeding, drink-driving and other unsafe driving practices are best combated by combining enforcement with public education in the form of media advertising.

Present situation

We normally think of education as something that happens in school. But road safety education consists of a range of activities, most of which have adult audiences and do not take place in schools. In expenditure terms the most important components of the LTSA's education programme are advertising and community programmes.

Future impact

The LTSA's existing education programmes will continue throughout the strategy period. We do not expect the content and delivery of education to change much, but the resources devoted to them will increase in proportion to road safety expenditure as a whole. The effects of education have already been included in the other interventions assessed (see *Table 1*).

Performance assessment

Estimated reduction in social cost	Enforcement emphasis option	2%
	Mixed option	2%
	Engineering emphasis option	2%

Cause and effect

'Performance assessment' describes an approach to achieving compliance that stresses incentives rather than punishment. Its aim is to make the road transport industry and road users more responsible for the management of their own safety performance. Under a performance assessment regime, participants with a good record of compliance are offered an incentive: they are subjected to less scrutiny than those with a poor record. This reduces the burden of compliance, and may be other economic advantages. For instance, a fleet operator with a good safety record would certainly avoid much of the expense of getting its vehicles frequently certified, and might furthermore be granted certain operating concessions with economic value. Meanwhile road users with a poor record are subjected to intensified scrutiny. Enforcement still has a role, but is only invoked where incentives fail. Incentives take the form of a reduced compliance burden and other economic advantages.

Performance assessment' is a form of self-management. Industry participants as far as possible carry out their own management checks to maintain safe operation and compliance with regulations. The regulator's function is mainly to monitor safe performance and to target remedial action. This is efficient. Instead of imposing a one-size-fits-all compliance procedure that necessarily caters for the worst offenders, we leave it to industry participants and road users to decide how best to achieve the safety standards we set. Since they know their own business better than we do, they can do it more effectively and cheaply than we can. This is advantageous to them, as it avoids the inconvenience and cost of being subjected to outside monitoring; and it is advantageous to the rest of us because in the end we all benefit from more effective compliance.

Present situation

The current system subjects everyone to more or less the same checks, which is costly and provides little incentive to perform well since the chance of getting caught is normally small.

Future impact

During the strategy period the LTSA will gradually introduce procedures that accord with ‘performance assessment’ as described above. One aspect of this is the Safety Management System (SMS) that will apply to road controlling authorities. The SMS sets out

- standards of practice for traffic management and road engineering
- appropriate staff expertise and procedures
- a management structure
- a system of regular audits
- rules for disclosure of information on road conditions and performance
- a procedure for developing a safety strategy, identifying problems and proposing solutions.

There is no formal way to estimate the impact of the SMS, let alone that of other aspects of improved performance assessment. This is because they cannot be separately identified but are manifest as improved efficiency[28] for many other road safety interventions. We therefore based our estimate on expert knowledge. We conclude that the SMS alone would reduce *Baseline 2010* social cost by 2%. Conservatively we have not attempted to estimate the impact of other forms of improved performance assessment.

Efficiency gain

Estimated reduction in social cost	Enforcement emphasis option	9%
	Mixed option	9%
	Engineering emphasis option	9%

Cause and effect

When a road safety intervention becomes more efficient it produces the same outcome with fewer resources. This happens in various ways.

- **Learning.** With the passage of time we are learning to get more from the resources at our disposal.

28 Note that this is in addition to the ‘efficiency gain’ described in the next section. It is evaluated separately because it relates to a particular intervention, the SMS, that is still to be introduced. In this respect it differs from the efficiency gain that arises from the extrapolation of an existing trend.

- **Road safety management.** Better management practices and analysis tools allow us to place resources where they have the more impact, and to use them more productively once there.
- **Improved technology.** There can be no doubt that enforcement devices and safe road construction methods are advancing steadily.
- **Behavioural change.** Road users may be increasingly internalising safe behaviours, that is, they behave safely not because they are forced to but because they choose to.

Present situation

Although hard to prove, we believe that New Zealand's road safety interventions are in general becoming more efficient. We find, for instance, that safety improves during periods even when no additional resources are devoted to it (see for instance *footnote 4*). Efficiency gains are not the only possible reason for this, but they are certainly consistent with it. Moreover, we can identify examples of efficiency gains associated with particular interventions, even if we cannot quantify them without more study.

Future impact

We expect most if not all interventions to become more efficient. Much of the improvement will, we think, stem from better targeting and allocation of resources.[29] Although we are unable to attribute these and other efficiency gains to individual interventions, we have estimated their safety outcome in aggregate: efficiency will improve by 1% per annum at the beginning of the strategy period, declining gradually to half that value zero at the end. This amounts to a cumulative 9% efficiency increase over the strategy period, which implies an equal proportional reduction in *Baseline 2010* social cost by 2010.

We recognise that this estimate is very uncertain. Hence it can be regarded as a margin that we will strive to reach in excess of the outcomes predicted for individual interventions predicted elsewhere in this paper. In short, it is a spur to achievement.

29 Vulcan (1997), for instance, expects that by 2020 Australia will reduce the proportion of dead drivers over the legal alcohol limit from 22% to 15% by conducting breath-testing in 'a very intelligent manner'. If replicated in New Zealand, this would reduce social cost by 5% more than we have estimated.

Appendix 1

The blackspot programme

Description

In 1985 a programme was set up to investigate blackspots and to recommend low-cost engineering remedies; and in 1989 the LTSA began systematically monitoring its effects and consolidating the results. The physical characteristics of the site before treatment, and the nature of the treatment itself, were documented and matched to crash data before and after treatment. Between 250 and 300 sites are investigated under the programme annually, normally because they have a record of crashes of the same type at the same approximate location (*table 9*). The mix of site types has remained largely unchanged since the programme began: about half are at intersections, a third on routes, and most of the rest mid-block; a few relate to areas

Table 9

Sites investigated under the blackspot programme, by type

	Local Authority Roads				State Highways			
Year	**Area**	**Inter-section**	**Mid-block**	**Route**	**Inter-section**	**Mid-block**	**Route**	**Total**
1985				1	39	7	57	104
1986		4		5	7	8	4	28
1987		72	11	14	37	21	49	204
1988		114	9	64	62	35	34	318
1989	2	172	29	99	64	36	55	457
1990	3	63	5	36	30	16	30	183
1991	5	77	22	81	68	31	35	319
1992	5	166	19	149	46	48	40	473
1993	1	39	8	58	70	24	58	258
1994		77	8	35	79	39	68	306
1995	7	92	10	76	45	23	36	289
1996		105	12	18	77	29	15	256
1997	1	104	13	29	42	36	25	250
1998	2	68	13	49	48	38	10	228
Total	**26**	**1 153**	**159**	**714**	**714**	**391**	**516**	**3 673**

We expect the blackspot programme to be scaled back somewhat during the strategy period to between 150 and 250 additional investigated sites annually. This is because by then many of the most suitable sites will have been treated. Still, we estimate that only about two-thirds of the sites have as yet been fully implemented. This suggests that there is plenty of work in the pipeline, with more to come.

Findings

Under the programme 250 to 300 blackspots are investigated each year—over 3600 as of 1998. In the period 1985 to 1998 they have had 4200 fewer crashes than we would otherwise expect[30] , a 28% reduction and a cost saving of approximately $1 billion.

As expected, the rate of reduction is tapering off—from 35% in 1994 to 29% in 1999—as the riskiest sites are treated. Non-intersection sites deliver the biggest gains, followed by intersection sites, then route sites (*table 10*).

Table 10

Average reduction in crash rate at treated sites, by type and year

	1994	1999
Location		
Intersection	38.8%	40.4%
Non-intersection	56.9%	59.2%
Route	27.8%	18.3%
Road type		
Open road	n/a	36.0%
Urban	n/a	24.2%
Road controlling authority		
State Highway	41.7%	*33.4%*
Local Body	29.8%	*25.0%*
Engineering region		
Auckland	35.0%	25.7%
Wellington	33.3%	29.9%
Christchurch	40.0%	39.1%
All sites combined	**34.7%**	**28.6%**

Note: Area sites are excluded as there are too few for statistical accuracy.

Rates of crash reduction range from a high of 49% for 'chevrons at bends' to a low of 18% for pedestrian refuges (*table 11*).

Table 11

Average reduction in crash rate at treated sites, by type

Treatment		Reduction	Sites	Year
Right turn bays and marking		33%	37	1994
Pedestrian facilities	Pedestrian refuge	18%[a]	18	1994
	Bulbous kerbs	37%[a]	33	1994
Flush medians		19%	40	1995
Shoulder improvements	Straights	37%	41	1995
	Bends	43%	15	1995
Roundabouts		36%	42	1995
Traffic signals		35%	14	1995
Resealing		39%	76	1996
Chevrons at bend		49%	103	1996
Lighting		33%	231	1997

Note: (a) Pedestrian crashes only.

30 Nationwide, road crashes have been on a downward trend for several years now, but crashes at designated, treated blackspots have fallen more than elsewhere. We allowed for national and regional trends when estimating the reduction due to blackspot treatment.

Appendix 2

Modelling light vehicle safety

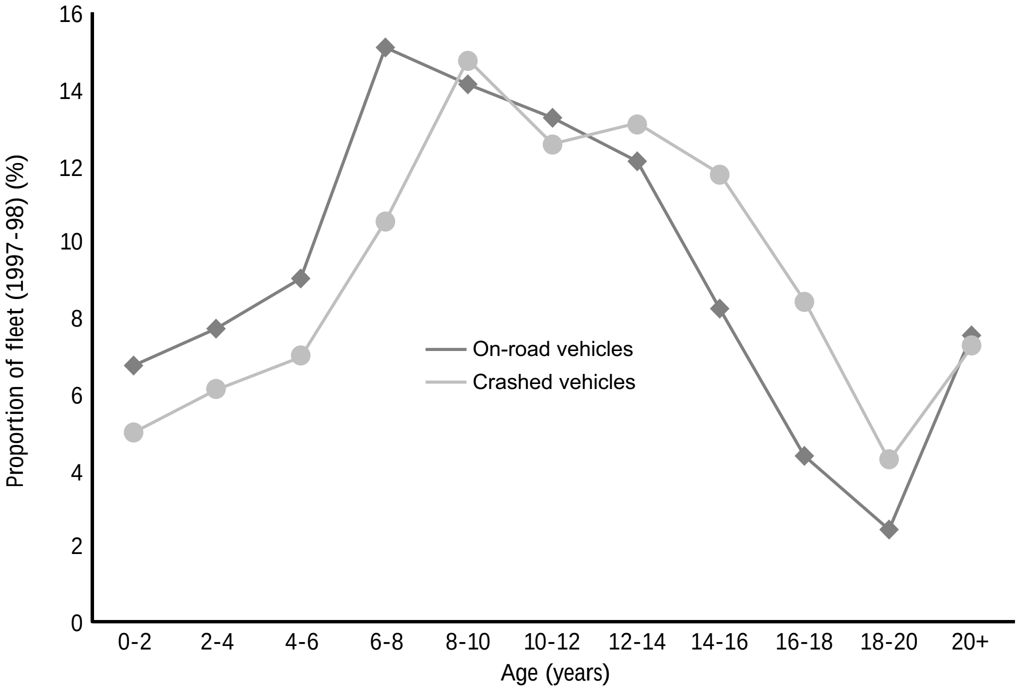
The impact of vehicle standards depends on the nature and timing of the standards themselves, and on the rate at which they are adopted into the national vehicle fleet. Because of their complexity we built a computerised model to handle the required computations. The model first forecasts the age profile of vehicles involved in crashes. It then links this forecast to another: one describing when new standards will be introduced and what effect they have in raising the crash-avoidance and crashworthiness of vehicles built to those standards. The result is an overall safety outcome that allows for the fact that vehicles are getting safer and the composition of the national fleet is changing.

The age profile of crashed vehicles

Current crashed vehicle fleet
The first step is to characterise the age profile of crashed vehicles, that is, all vehicles that were involved in crashes that resulted in death or serious injury (*figure 5*). This information comes from the LTSA's database of road crashes.

Figure 5

Age composition of the vehicle fleet: crashed versus all vehicles



Source: LTSA

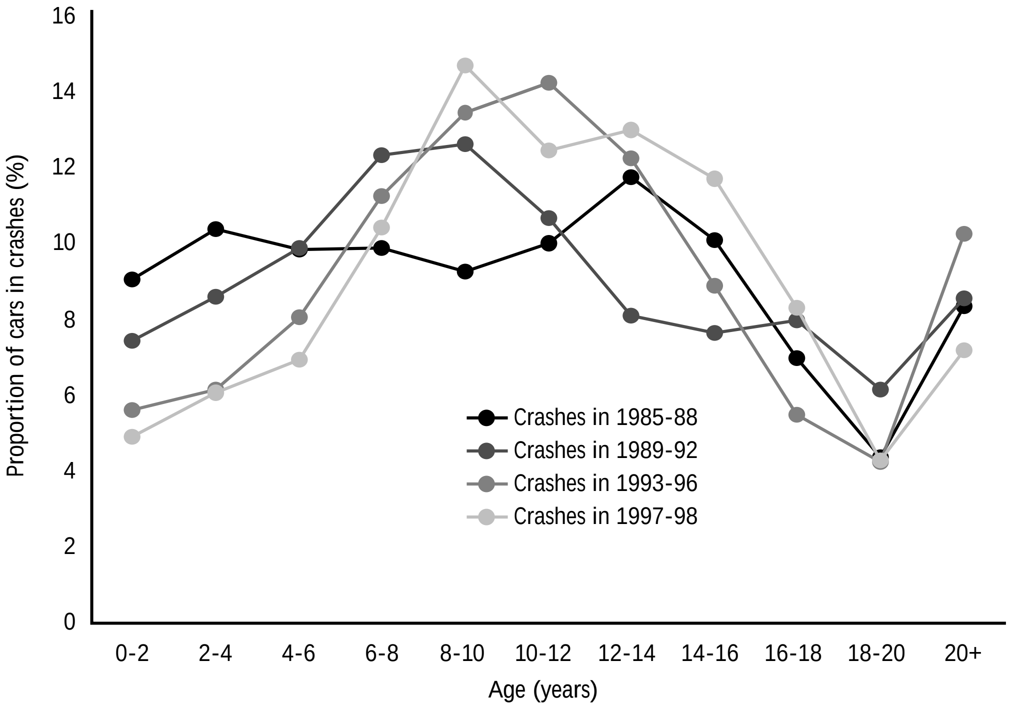
Future crashed vehicle fleet
The age composition of crashed vehicles is changing through time (*figure 6*). From being relatively 'flat' in 1985-88, it has become increasingly skewed towards 'middle-aged' cars—those between 5 and 15 years old. This reflects the

changing composition of the total national fleet, which is being influenced by imports of used vehicles, most of which are 5 or more years old.

Using the model we forecast the age profile of crashed vehicles (*figure 6*). The model is analogous to the 'cohort-survival' models widely used by demographers to forecast the size and composition of human populations: just as people are born or immigrate, and ultimately die, so vehicles are manufactured or imported, and ultimately scrapped. The model systematically applies mathematical rules to allow for the number of vehicles of a given age that are scrapped or imported. The resulting total number of vehicles is then 'aged' one year, and the process repeated.

Figure 6

Age of crashed vehicles, by year



Source: LTSA.

Timing and impact of vehicle standards

Crashworthiness

Cars manufactured in 2010 will protect their occupants better in the event of a crash than those manufactured currently. We estimate that this improved crashworthiness will reduce the incidence of fatalities and serious injuries among vehicle occupants in the event of a crash by about 33% (*table 12*).[31]

Crash avoidance

Crash avoidance affects not just vehicle occupants but pedestrians, cyclists and motorcyclists. We therefore expressed its impacts in terms of reductions in the social cost of all road users (*table 12*).

31 Since no crash can be prevented more than once, the effects of safety features combine multiplicatively as follows: 1 - [(1 - 0.05) x (1 - 0.13) x (1 - 0.12) x (1 - 0.08)] = 0.33.

Table 12

Impact in 2010 of improved vehicle safety features

Safety feature	Reduction	
	Occupants killed and seriously injured	**Social cost of all road users**
Crashworthiness[a]		
Side impact	5%	
Frontal impact	13%	
Offset frontal impact	12%	
Further occupant protection	8%	
Crash avoidance[b]		
Improved crash avoidance standards		1.0%
Other programmes (including ITS)		1.7%

Source: (a) Monash university Accident Research Centre estimates; (b) LTSA estimates

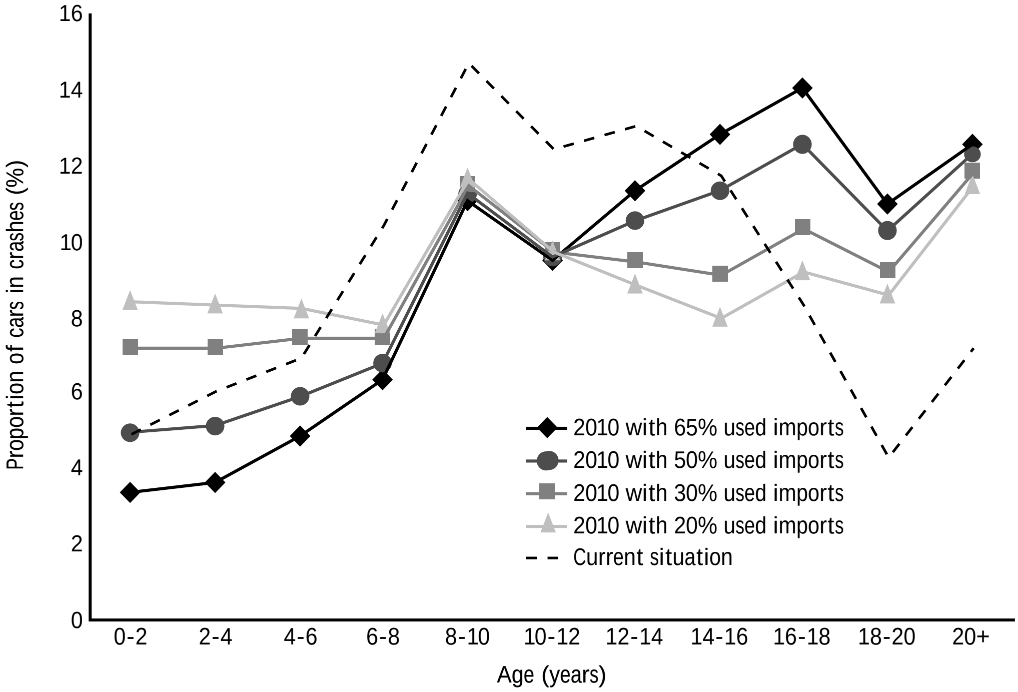
Overall safety impact

The model forecasts the number of crashed vehicles in each age category in 2010. We provide estimates of age-specific risk for vehicles in 2010. The model then weights the age profile by the age-specific risk profile to produce an estimate of overall safety impact.

The forecast age profile of crashed vehicles is sensitive to the market share of used imports, which can only be guessed at (*figure 7*). However, we found that this has relatively little effect on safety outcomes. This is because the availability of used imports has two effects, one of which tends to reduce vehicle safety and one to increase it. Safety is reduced to the extent that used imports substitute for new; but safety is increased to the extent that used imports cause owners to scrap their old vehicles.

Figure 7

Effect of used imports on age composition of crashed vehicles in 2010



Source: LTSA

Appendix 3

Fatigue management

We did not model the impact of fatigue management as its impact is expected to be small and uncertain. We discuss it here because we believe fatigue to be a serious road safety problem that deserves attention, even if we are currently unable to mitigate it significantly.

Cause and effect

Driver fatigue is commonly equated with falling asleep at the wheel. But that is the extreme case; driving can be impaired by fatigue well before the point of falling asleep. Fatigue is known to reduce vigilance and reaction speed. Consequently the fatigued driver is more likely to get into a dangerous situation and to be slower to correct it.

There are several approaches to combating fatigue. One is to detect the signs of fatigue and alert drivers. But despite continuing research we are far from having a practical and reliable device to do this. Another approach, widely practiced in New Zealand and overseas, is to prohibit commercial drivers from spending excessive periods behind the wheel, and to require that they receive adequate rest periods (though ensuring compliance is another matter). But it is generally accepted that similar restrictions cannot be placed on private drivers, let alone enforced. Instead, publicity and educational campaigns can warn drivers of the danger of fatigue and can present safe driving practices. Lastly, since fatigue-related crashes often involve alcohol or speed as well, they can be tackled indirectly by combating drink-driving and speeding.

Present situation

Fatigue is a greater problem than the mere numbers suggest. According to crash records, fatigue is implicated in about 8% of fatal crashes and 5% of injury crashes. But the records are largely based on the reporting police officer's judgment, so the actual prevalence of fatigue is likely to be higher; and as the awareness and understanding of driver fatigue improves, the reported prevalence of fatigue may rise.

Commercial vehicles
Although implicated in few crashes, fatigue is an important issue for commercial drivers. Currently they are restricted by law in the hours they drive and breaks they take. A review of the regulations is currently under way, and improved management practices are being investigated.

Private vehicles
Currently, fatigue among private motorists is tackled directly through publicity and educational campaigns, and indirectly through combating drink-driving and speeding.

Future impact

Commercial vehicles

The policing of driving hours will eventually be helped by replacing manual logbooks with electronic recording devices that ease the compliance burden and are harder to falsify. However, New Zealand has no plans to introduce electronic logbooks, which in any case are still experimental. Likewise, devices to detect drowsiness are still experimental and will remain so for years. We have no data on the effectiveness of such interventions.

Private vehicles

Since it is impractical to impose restrictions on driving hours for the private motorist, the main way to combat fatigue in this group is through combating drink-driving and speeding, which are discussed elsewhere. Increased publicity and education may also help, but we are unable to quantify their effect. We therefore make no specific allowance for reducing fatigue-related crashes.

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