

**School journey safety:
a comparative study of
engineering devices**

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School journey safety: a comparative study of engineering devices

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Executive Summary

Introduction

The aim of this research, carried out in 2004, is to improve safety for children on their home to school journey. This is to be achieved by comparing the effectiveness of engineering safety devices used both in New Zealand and overseas, and to provide a framework for the development of a comprehensive toolbox to assist engineering practitioners and the community in selecting appropriate devices. Land Transport Safety Authority (LTSA) crash data indicate that approximately 40% of child pedestrian injuries occur on the home-to-school journey. This report focuses upon engineering devices that can be used as part of an integrated approach to providing safe trips for schoolchildren.

This study was in four stages.

Stage 1: A literature review drawing on sources both from New Zealand and abroad.

Stage 2: A survey on road controlling authorities (RCAs) (both national and international) on the effectiveness of engineering devices used.

Stage 3: Key themes from the literature review and the survey information were analysed.

Stage 4: A framework for a toolbox was developed. When completed, the toolbox will draw together best practice in a form that can be easily used by practitioners.

Literature review

The aim of the literature review was to give an overview of the published information of engineering devices which are currently used to improve safety for children on their home-to-school journey in New Zealand and overseas. The main body of literature available that deals with engineering measures which are specifically for improving safety for the home-to-school journey, has been considered in conjunction with the various safe routes to school type programmes in different countries, and evaluation of them. From the literature it has been possible to list most of the different types of engineering devices used, although very little literature was available on the evaluation of such devices.

Important results found in the literature include:

- Traffic calming, low-speed roads, speed humps, raised surfaces, and centralised crossing places are the most effective treatments for improving traffic safety.
- Providing wide footpaths with greater protection from roadside vehicles together with regular maintenance and removal of footpath obstructions and overgrown foliage helps to address children's feelings of being unsafe, and promotes pedestrian use.
- Projects involving cyclepaths, tracks, and markings do not show clearly which measures have produced significant improvements; differences that are statistically significant range from safety being made much worse to considerably improved safety.

- Slowing the traffic speed in the near vicinity of children and where children congregate has been shown to have marked benefits, often with both a reduction of incidents and a reduction in the severity of injuries. Speed limit signs need to be accompanied by other traffic management treatments.
- Warning devices, such as flashing amber lights located at crossing places in front of schools, have a notable safety improvement impact. However variable message signs, although having some effect on slowing speeds, were not as effective as physical traffic calming measures, or had as much impact as children being present on the roadside; with the impact of the sign diminishing over time.
- Focusing on perceived problems raised by school-age children and their parents helped to identify problem areas or areas of concern. However, it is equally important to investigate crash data.
- At railway level crossings, very little has been done to warn pedestrians, especially children, of approaching trains. Trespassing on railway corridors is a serious safety concern.
- Increasing school bus conspicuity, improving vehicle design and the roading environment, and introducing consistent national audits are needed. School bus-related fatalities are more likely to occur in the afternoon and involve children who have just left the bus.
- Designing a road environment that recognises children's capabilities as well as their limitations will inherently provide a safer place for children. Best performing countries in terms of keeping children safe in traffic have supportive, active and progressive legislation.

Survey of engineering devices

To establish the type and effectiveness of engineering devices currently used to improve safety for children on their home-to-school journey, two questionnaires were prepared and circulated in New Zealand and overseas. The type 'A' questionnaire was intended for RCA traffic engineers and road safety officers, and was designed to pick up on their role for implementing safety improvements and knowledge of their road network.

The type 'B' questionnaire was intended for major stakeholders such as policy and standards organisations, police and other injury prevention groups interested in improving safety for children.

The most common findings from the survey of engineering devices are that:

- Use of visibility-enhancing devices is increasing;
- Other devices considered effective in improving safety include:
 - school patrols,
 - signalised crossings,
 - speed zones,
 - pedestrian (zebra) crossings,
 - kea crossings,
 - footpaths,

- pedestrian refuge islands, and
- special markings and road narrowings;
- Use of slow speed treatments in residential areas is increasing overseas;
- Stakeholders favoured devices that controlled motorists.

The two parts of this report provide a picture of the state of traffic engineering safety devices around schools both in New Zealand and in other countries.

Analysis of key themes

The comparison of engineering safety devices used showed some significant differences between the types of devices used in New Zealand and those which are used overseas. The most significant difference between the situation in New Zealand and that overseas is the lack of emphasis in New Zealand on the benefits of slowing vehicle speeds at locations where children congregate. The benefits of reducing speeds and having school speed zones is well documented overseas. This form of treatment is starting to be used in New Zealand, and relevant guidelines are now being developed.

Traffic management and calming

Other significant treatments that have been found to be very effective in improving safety on the school journey is the implementation of traffic management or traffic calming measures. These area-wide types of treatment are often combined with safe route to school type programmes. The combination of engineering, education, and enforcement is a common feature in 'best performing' countries with regards to children's safety on the roads. The evaluation of the effectiveness of engineering measures, once they have been implemented, is an important feature in the best performing countries. Safety problems identified by the children, combined with investigation of crash data has been the most effective way of identifying where engineering safety improvements should to be targeted.

Signalised mid-block pedestrian crossings

There are some conflicting views with regards to the safety of signalised mid-block pedestrian crossings, and the authors of this study suggest further evaluation and analysis of crash data are needed. Much of the literature reviewed has focused on the effectiveness of providing additional warning devices, such as flashing lights, to highlight the presence of a pedestrian crossing. Some attention has been drawn to the need for better visibility of children, with recommendations for reflective conspicuity aids that can be worn by children.

Safe places to cross roads

The literature and survey results have shown that the type and form of a safe place to cross the road is dependent on the use of the crossing and the environment in which the crossing is placed. The complexity of these factors, combined with the uncertainty of whether crossing places are installed to current safety standards, makes comparison between the types of crossings inconclusive. This research has highlighted that there are no 'quick fixes' for provision of a safe crossing place, and additional warning devices need to be tailored specifically to each individual site.

Safety treatments for railway level crossings

Information on the merits of providing warning and safety treatments aimed at pedestrians at railway level crossings appears to be lacking. Safety devices at railway level crossings appear to be primarily aimed at motorists, with very little to warn pedestrians, and especially children, of approaching trains. The limitations children have in identifying the direction sounds are coming from is also a problem in detecting approaching trains, and this problem is exacerbated where there are multiple tracks. The problem of people walking along or crossing railway tracks appears to be worldwide, with some countries recognising the need for fencing the railway corridor as well as enforcing existing regulations. New Zealand studies have clearly shown that trespassing is an endemic problem where crossing facilities are inappropriately placed, unattractive, or result in a much longer travel journey.

Safety with school buses

School bus safety is a common concern worldwide. Some countries extensively use programmes that focus on children’s behaviour on the bus. The New Zealand literature is currently focused on providing better warning signs on school buses, especially when they are stationary. The authors could not find any information on compliance with the New Zealand Road code whereby motorists are required to slow to 20 km/h when passing a stationary school bus. Additionally, the authors consider that the safety benefits of having school buses that are easily and readily identifiable should be investigated.

Legislation

The literature shows that the best performing countries had a supportive legislative framework and the political will to provide the necessary facilities, programmes, and funding that are required to keep children safe. In these countries the legal responsibility for child/vehicle crashes was placed primarily on the motorists.

Comparison of effectiveness of engineering devices

Comparison of devices – Close to schools	Considered effectiveness		Comments
	NZ	Overseas	
Pedestrian crossings (zebra)	Moderate to High	Moderate	High non-compliance in NZ. Not over multi-laned roads, effectiveness reduced by snow.
Warning devices – crossing places	Signs Moderate (NZ, O/seas) – colour change trend. Fluoro disks: Moderate to High (NZ). Flashing lights: Low to Moderate (NZ), Moderate (O/seas).		
School patrols, Crossing guards	High	High	May be paid by municipalities (o/seas).
Kea crossings	Moderate to High		High non-compliance for installation, and drivers.
School zones, Reduced speed zones	Few in NZ, however rated High. Reported accident reduction of 3.85% for every km/h reduction in speed limit. School zones used in most o/seas countries, can be a problem with compliance to reduced speed.		

Comparison of devices – Home-to-School Journey	Considered effectiveness		Comments
	NZ	Overseas	
Traffic calming	Most effective way of improving safety close to school and residential areas. Not appropriate for high volume main roads.		
Speed humps	Moderate to High	High	Reduce the number of child injuries in residential streets.
Kerb extensions (road narrowings)	Moderate to High		Rated High in both urban and rural areas. O/seas – most effective when combined with no stopping parking restrictions.
Pedestrian refuge islands	Moderate to High		Extensively used in NZ. Increase driver awareness, best when combined with kerb extensions (o/seas).
Raised platforms	Moderate		O/seas – also used as part of pedestrian crossings.

Other devices	Comments from NZ and overseas
Conspicuity aids for children	Safety jackets: High (NZ). Sashes/dangles: Recommended (o/seas). Visibility of child pedestrians and cyclists: major safety concern; O/seas view: more can be done in this area.
Railway level crossings	Problem worldwide. Most warning devices aimed at motorists, not pedestrians. Safety gates, mazes, limit lines on footpaths, fences and warning lights used o/seas.
Buses	Recessed bus bays: Moderate (NZ). Most crashes occur in afternoon when a child has just alighted from a bus.
School safety programmes	Safety programmes are a growing area of safety opportunity, with programmes often resulting in engineering safety devices being installed.

Influence of cost

Cost is an important factor in the choice of an appropriate engineering safety device. Supportive legislation and a willingness to fund engineering safety improvements have a direct influence in the best examples of other countries' actions in terms of children's safety in traffic.

Gaps in knowledge

The literature review has identified some important gaps in knowledge that the authors believe are worthy of further investigation. These include:

- safety measures for pedestrians crossing railway lines,
- mid-block crossings – the need is for a controlled study including concerns with non-compliance and severity of injury,
- pedestrian safety audits – guidelines focusing on safety for pedestrians, and the need for audits to be taken from the child's perspective of pedestrian safety,
- long-term evaluation study of safety in school catchment areas,
- bus safety,
- conspicuity of school buses, and
- legislation – a legal framework and political will to address safety issues for children on the school journey.

Developing the toolbox

This literature review and survey covers some very important information. So that the findings from the literature review and survey of engineering devices are useful (to practitioners and the community), the knowledge needs to be transferred into a practical guide or toolbox.

A framework for developing a toolbox together with suggestions for a decision-making process has been provided. A toolbox of the type suggested could only be fully developed through consultation and testing on real-world situations. The authors believe that there are significant improvements to be made and strongly recommend future development.

The suggested process is in the form of a flowchart which highlights the need to match the device to the individual situation, and to make reference to national and local policies, standards, and guidelines.

Conclusions

- No one 'magic bullet' or 'quick fix' can be applied.
- Devices need to be tailored for individual situations and user groups.
- Addition of complementary devices and design detail enhances safety gains.
- Differences between urban and rural impact of devices should be recognised.
- A document providing a range of best practice engineering treatments is needed in New Zealand.
- Development of best practice guidelines needs to incorporate findings in the literature.

Recommendations

The information researched in this report is recommended as the first step in providing a practical tool for traffic engineering professionals, RCAs, and the community. By providing accurate and relevant information to all parties informed decisions on 'best practice' methods can be made. Adopting such an approach will improve safety for children on their home to school journey.

The recommendations are that:

- The development of a toolbox to aid practitioners and the community to improve child pedestrian safety should be further developed, and that key stakeholders be involved during its development.
- The toolbox should provide:
 - a process for identifying individual needs for specific environments,
 - a fit with national standards, guidelines and policies,
 - a guide of 'best practice' devices appropriate to address real and perceived problems (as a matrix).
- The gaps in knowledge identified in this research are addressed.
- A long-term study is initiated to evaluate area-wide effectiveness of devices used to improve safety on the home-to-school journey.

Abstract

This research, carried out in 2004, is to improve safety for children on their home to school journey. The effectiveness of engineering safety devices used both in New Zealand and other countries is compared, and a framework for the development of a comprehensive toolbox is provided to assist engineering practitioners and the community in selecting appropriate devices. Land Transport Safety Authority New Zealand (LTSA) crash data indicates that approximately 40% of child pedestrian injuries occur on the home-to-school journey. This report focuses upon engineering devices that can be used as part of an integrated approach to providing safe trips for schoolchildren.

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1. Introduction

The safe passage of children to and from school is extremely important. This study undertaken in 2004 investigates some of the measures, both in New Zealand and internationally, that aim to make the road environment safer for school students, and focuses primarily on younger school-aged children between five and twelve years. The two reasons for this are: they are the most vulnerable road users, and they will be the most ill-suited for engineering devices that are targeted at the wider population.

As with other groups in the community, school students use a range of modes of transport to complete their journeys. There are, however, some important differences. School children are among the most vulnerable road users regardless of mode taken. Critically, they lack the skills and cognitive abilities to consistently make safe decisions about their travel. Their small size means that they are harder for other road users to see, and children find it more difficult to see the potential danger.

Engineering a safer environment through the implementation of physical devices is only part of the solution in providing the safest possible trip for students. Enforcement and education of students and other road users also have to be part of a wider safety plan. Physical measures can only achieve so much in providing a safe environment for travel to school. The students still need to interact with the system, and to achieve a safe outcome they must be taught the safe use of traffic devices, be that waiting for cars to stop at a zebra crossing, or the meanings of symbols at a signalised intersection. Other transport users have to understand, respect, and obey the restraints imposed on them to provide safe trips to school for children.

There has been some debate about the relative merits of education programmes compared with investment in additional engineering devices. Schieber & Vegega (2002) report that 'it is becoming increasingly clear to the injury research community that merely learning about traffic has no certain bearing on a child's street crossing behaviour'. However, children must learn to interact with vehicles safely and understand the rules governing behaviour around traffic. Neither educational programmes in isolation, nor engineering measures alone, will produce safe school journeys.

When deciding on traffic engineering measures, as part of a wider traffic safety plan, special care has to be taken in choosing the correct type of engineering measure. No one solution will be suitable for application at all schools; some engineering devices will work where traffic volumes are high, while other devices may offer more appropriate solutions in low volume areas. This report does not aim to provide a unique solution for engineering school safety; rather its aim is to show the range of measures available and their relative effectiveness and potential disadvantages.

The report is divided into four stages.

- The first is a literature review drawing from sources both nationally and internationally.

- The second stage investigates how the engineering devices are used through a survey of road controlling authorities (RCAs) and road safety stakeholders.
- The third stage brings together the key issues from the literature review and the survey information.
- The fourth stage forms the basis of a toolbox that is intended to provide a best practice guideline drawing from both the scientific literature and information on real-world implementation of road safety devices.

This document is intended to be used by traffic engineers, RCAs and schools. The authors have aimed to make the information self contained, and have only introduced technical terms when necessary and with explanation. A glossary of the types of devices referred to in this report is provided.

2. Literature review

2.1 Understanding travel modes

The mode of travel is the type of transport that the traveller uses. The mode might be walking, as a passenger in a car or bus, or cycling (Figure 2.1). Travellers may also use a combination of modes to complete their trip. When designing engineering devices for the areas around schools it is important to take into consideration the types of modes that the students will use in getting to school. As the modes have different engineering requirements, providing a safe area for students who use any mode must be a priority.

Social, environmental, and health reasons may influence why one mode to and from school might be preferred, so engineering devices that are used in the school area should take this into account. Since the primary focus of this literature review is safety of the school journey, the environmental and health concerns that are raised by mode of transport will be laid aside.

There has been a dramatic change in the way that students travel to and from school. Increasingly children are reliant upon private motor vehicles, rather than other modes of transport like walking and cycling. This change can be seen in the results of the Land Transport Safety Authority 1997/98-travel survey (LTSA 2000). The graph in Figure 2.2 shows that a significant shift occurred from walking and other modes to passenger, but overall the number of trips in rural areas has dropped, with a population move to cities.

Figure 2.3 shows that in cities for children aged from 5 to 12, all travel modes have increased, i.e. more trips overall, with the increase being in passenger trips.



Figure 2.1 Modes of travel include buses, cars, and walking school buses.

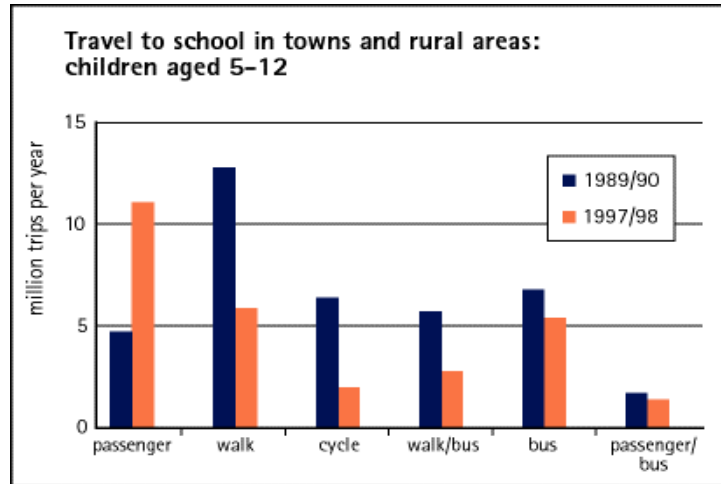


Figure 2.2 Travel to schools in rural areas, towns, and communities undertaken by children aged 5 to 12 years (Land Transport NZ 2000).

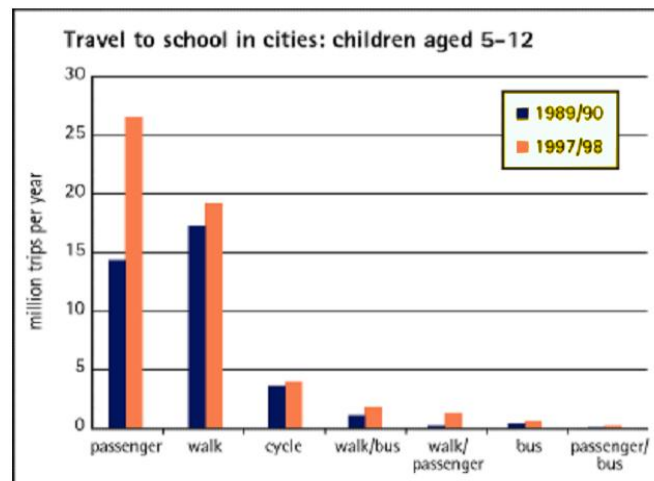


Figure 2.3 Travel to schools in cities undertaken by children aged 5 to 12 years (Land Transport NZ 2000).

Figure 2.4 shows the percentage of trips by different travel modes for 1990 and 1997. The change in travel behaviour has been significant, and has changed the demand on the area outside schools. As the number of students who travel as passengers in private cars increases, the traffic volume around schools will increase in the critical pre- and post-school periods, and the demand for parking near the school will be much higher. The increase in students travelling as passengers greatly increases the amount of space that their transport demands.

Figure 2.5 shows that young people are the most vulnerable users of transport, and this is independent of the type of mode that is used. However, the most vulnerable users are not necessarily the youngest, as Jensen & Hummer (2002) state:

Actual risk per trip, hour or km that children experience reveals that the risk among older children is highest for any individualised mode of transport despite the fact that older children have better skills. Older children sustain more injuries due to longer travel time and higher speeds, which result in increased travel on major roads, and to lower adherence to responsible social values than young children.

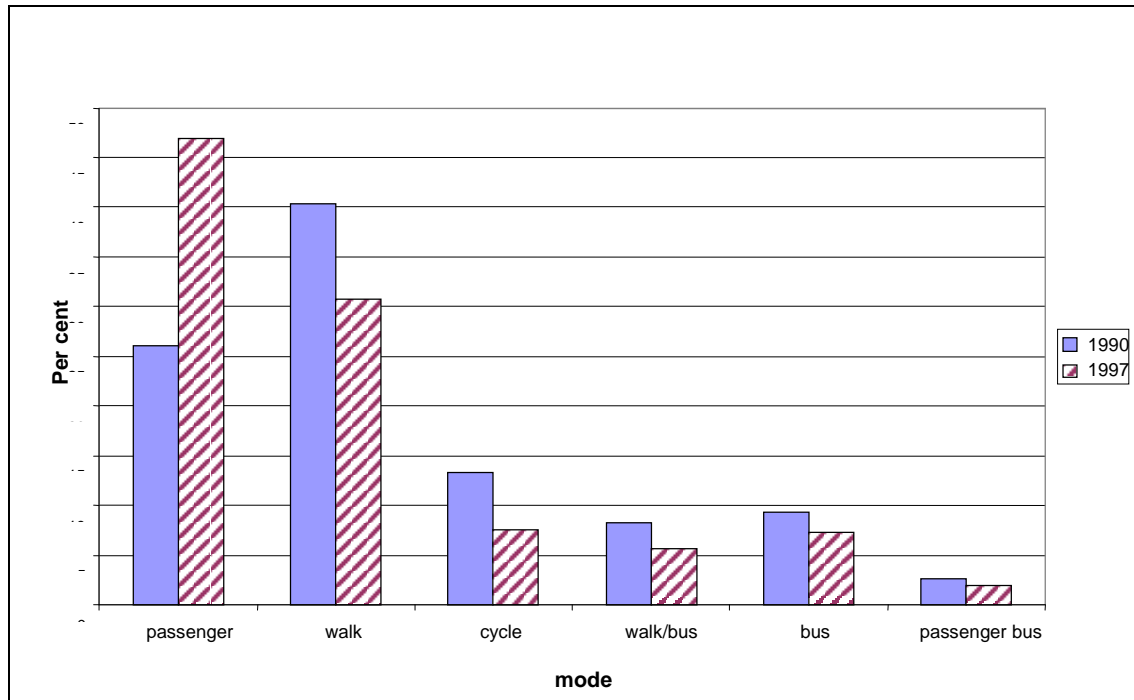


Figure 2.4 Percentage trips taken using different travel modes (LTSA 2000).

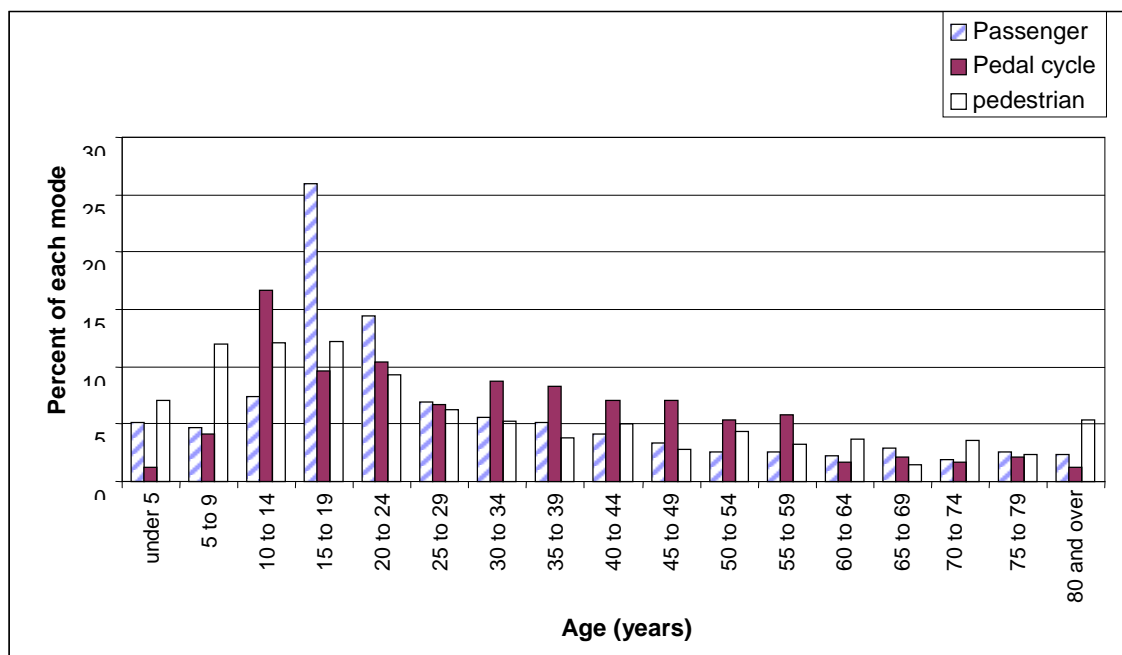


Figure 2.5 Proportion of injuries (%) for the different age groups as passenger, when cycling or when walking.

The journey from school to home occurs at a time of day when there is a marked increase in the amount of traffic and in the number of accidents occurring. The impact of a variety of different road users using the roads at the same time leads to an increased danger has been explored in Charlton et al. (2002).

This section will provide a brief overview of the different modes that are used in the school journey and some of the engineering requirements for each mode.

2.2 Individual modes

2.2.1 Pedestrians

As the travel data shows in Figure 2.4, walking is now the second most common mode for children to get to and from school. It is also the simplest of all the modes of transport, and is part of the school journey when using other modes of travel; for example, walking to a waiting private vehicle or to a bus stop.

Pedestrians in general are the most vulnerable road users. Combined with the reduced cognitive abilities of children (Mainroads WA 2004a), pedestrians require special attention in the design of safe areas in and around schools. As Figure 2.6 shows, there is a dramatic increase in the number of pedestrian injuries between 1500 and 1600 hours. This critical post-school period is when nearly half of the child pedestrian accidents occur, and providing safe passage for children is paramount.

Davies (1999) reports that in Great Britain 95% of all pedestrian casualties occur in urban roads which have speed limits of 40 mph (64 km/h) or less. The conclusions that he draws from studies into pedestrian crash data are that 30 mph (48 km/h) and greater speed zones are too high for pedestrian safety, and that it is wrong to assume that children will act as responsibly around traffic as adults do. Davies also highlights common factors that have been identified in research into the causes of pedestrian accidents. These include:

- the ordinariness of the circumstances leading to the accident,
- the drivers almost always consider the pedestrians to be at fault,
- vehicle or road defects were rarely a significant cause or contributory factor,
- consumption of alcohol by drivers and pedestrians, and
- masking of pedestrians by parked or stationary vehicles.

The most common way for pedestrians to be protected is to provide footpaths. It is essential that footpaths are provided around schools. Intersections of different modes of travel (i.e. roads and footpaths) are where many of the accidents occur (Cairney 2000a). Providing safe-crossing places is of primary importance and much of the literature (and this report) is devoted to providing crossing places that are efficient and safe for pedestrians.

Any increases in the number of students who walk to and from school have positive repercussions in other areas. As these benefits are outside the direct scope of this project they will only be mentioned in passing. Such positive outcomes include improved public

health and fitness of the students, and lessened impact on the environment compared to motor vehicle transport. These may be the other reasons that a strong emphasis on walking is given at a particular school, or at a governmental level.

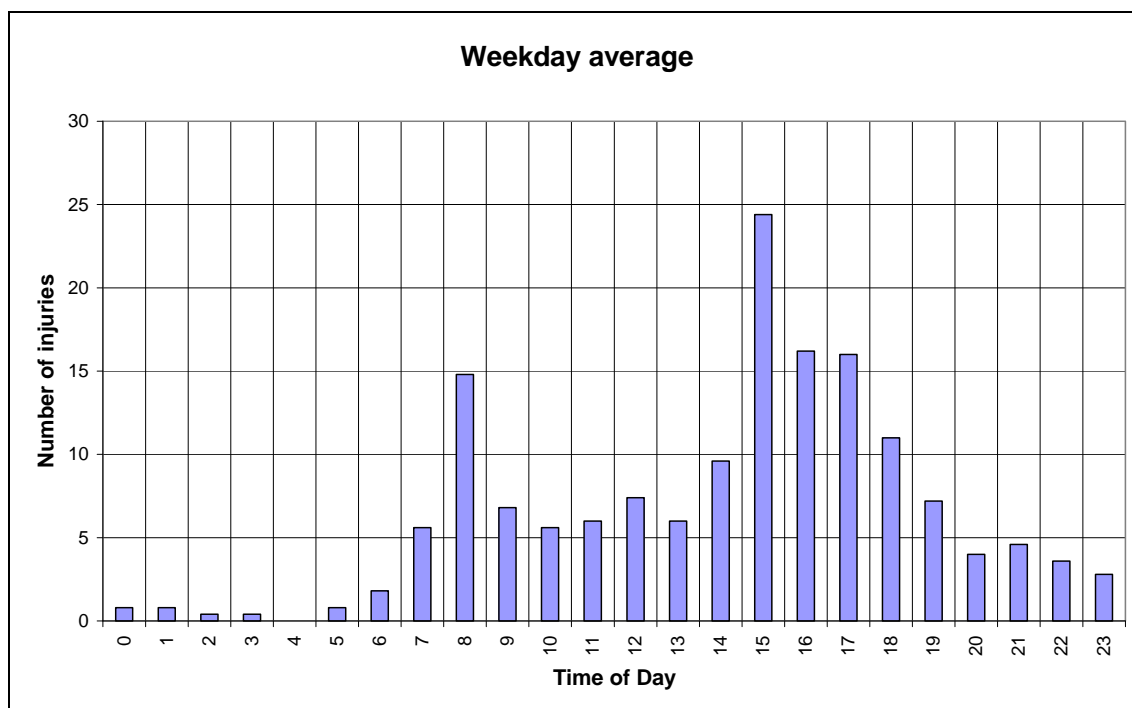


Figure 2.6 Pedestrian injuries by time of day for 2002 (from Land Transport NZ data for 2002).

2.2.2 Cyclists

Cycling, while still one of the most popular ways for students to get to school, especially older children, has however seen somewhat of a decline in popularity as Figure 2.4 shows. Cycling provides many of the benefits of walking, such as exercise for the participant and no vehicle emissions, while increasing the range of travel. Cycling takes up relatively little space, although secure bike storage needs to be provided at the school.

Cycling may not be suitable for younger children. However, if cycle training and support programmes are in place, older primary school children can safely ride to school. Cycle trains, similar to walking school buses, are being trialled overseas in which students are accompanied by an adult on the trip to and from school (McLeod 2002).

As Figure 2.7 shows, the largest group of cyclists injured in 2003 were the 10- to 14-year-olds. Although the number in this group who ride is large, it is still of great concern that the hospitalised injuries to these cyclists are so high.

Concerns about safety may be one of the causes of the decline in the popularity of cycling. If this is the case, then encouraging young people to use cycling as a mode of transport requires adequate provision of cycling facilities. Cycling facilities include dedicated cycle lanes and safe crossing places on roads where the traffic is heavy.

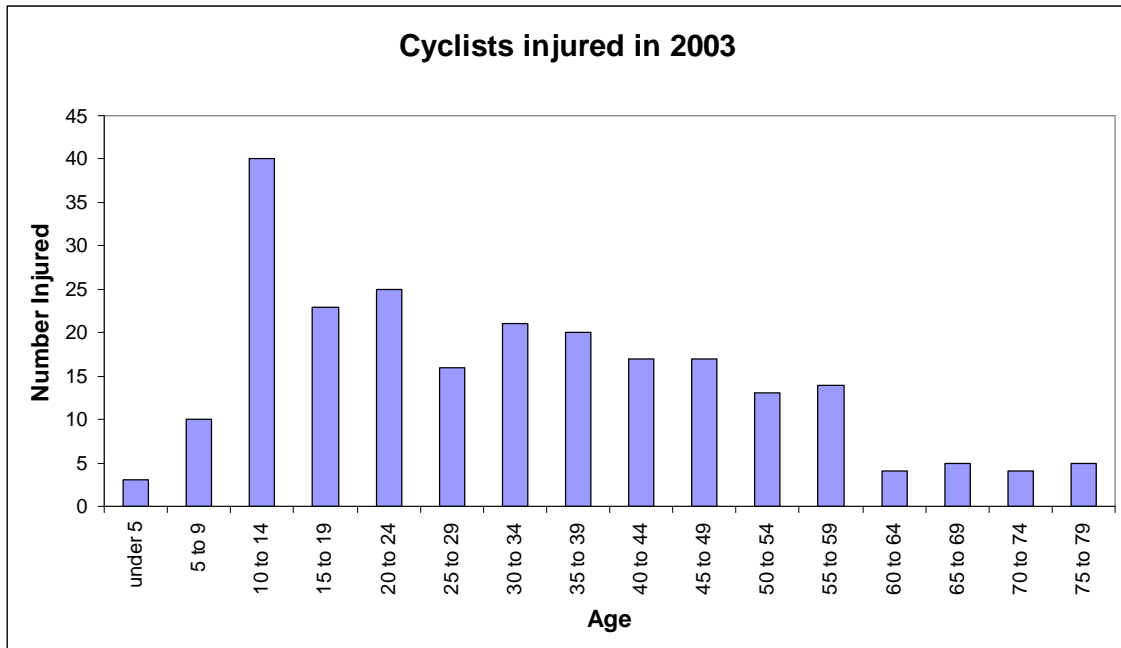


Figure 2.7 Cyclist injuries by age in 2003 (from Land Transport NZ data for 2003).

The facts that the cognitive skills of primary school children are not fully developed, and young children also have little knowledge of road traffic laws, must be recognised when considering cycling to school. For these reasons children of primary-school age should only ride on or near roads with supervision until they have the skills and knowledge to do so alone. Generally, the appropriate facility for primary school children is an off-road path or a 'quiet' residential street (Austroads 1999a).

2.2.3 Car passengers

The most common mode of completing a school journey now is as a passenger in a private motor vehicle. Passengers in cars have to get to the cars outside schools and parking can be a problem. The number of cars that are waiting to pick up children place a substantial traffic load on the roads surrounding the schools, increasing the danger to other road users. The concentration of vehicles around the school can create high volumes over a short period of time and lead to traffic jams.

Older high school children are significantly over-represented in the injuries sustained by passengers in a private motor vehicle, as shown in Figure 2.8. The primary cause of this may be the number of vehicles driven by young drivers, who are among the highest risk takers on the road. Figure 2.8 also shows the 10- to 14-year age group as having a greater than average representation in the injuries sustained by passengers, and this may be related to the number of young drivers driving cars with passengers.

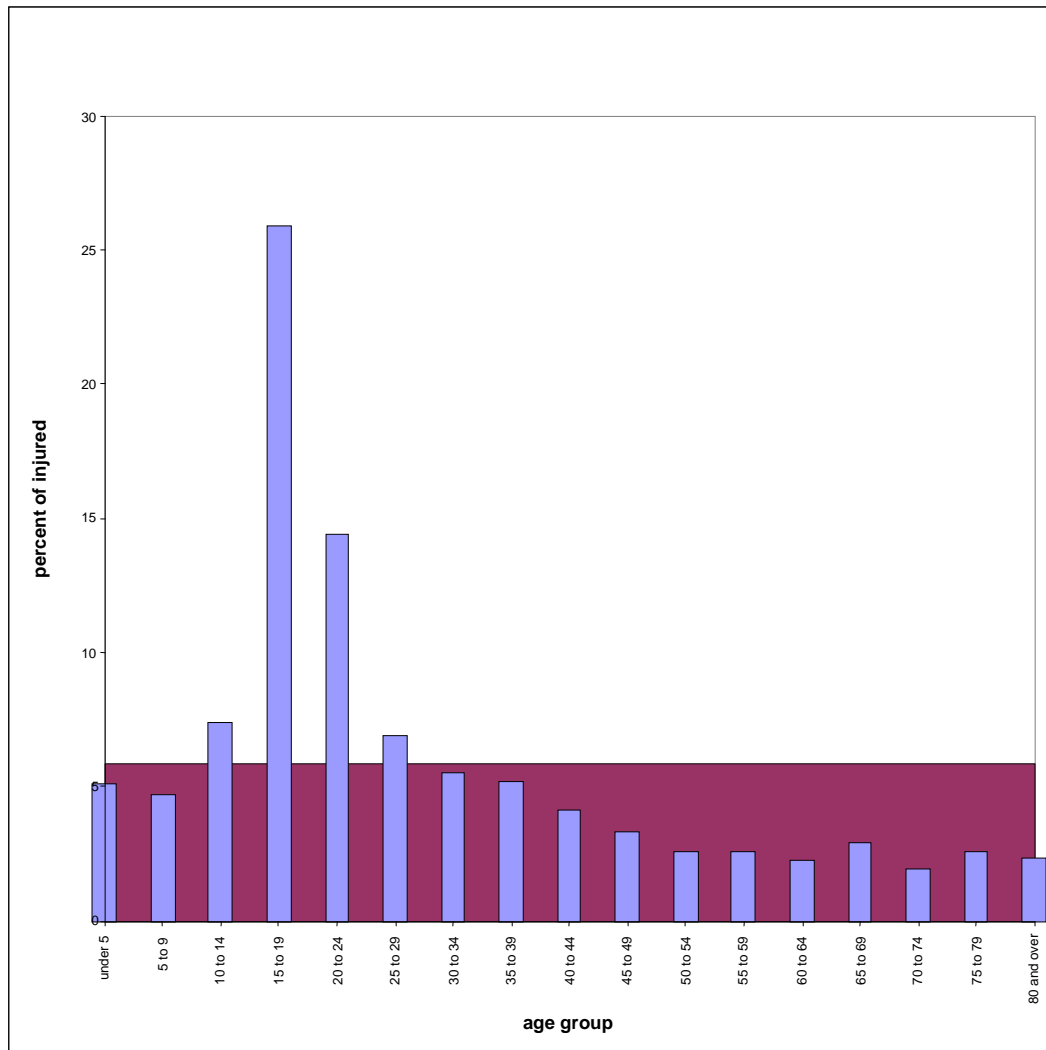


Figure 2.8 Passenger injuries by age occurring in 2002 (from Land Transport NZ data for 2002).

2.2.4 Bus passengers

Buses continue to be a common form of school transport, especially in rural areas, and much attention has been focused on school bus safety. School buses require only a small amount of space at the school gates compared to the number of students that are transported. Buses can transport students long distances, and are therefore suitable in areas that are sparsely populated.

Buses are also used in urban areas, and as well older children are likely to use non-school buses as part of their journey if such a bus service operates. However, some traffic calming features that might be used around schools, such as steep speed humps, may be unsuitable for buses.

Crashes associated with school buses accounted for 15% of the child fatalities between 1992 and 2001 (inclusive), and only 2.3% of the other injuries were related to school transport (LTSA 2002b). This is disproportionately high considering the number of passengers on these buses. Most of the injuries that occur on New Zealand school buses

are in the afternoon, and are after the students have left the bus and are crossing the road. School buses and bus stops are discussed in more detail in Sections 2.3.8 and 2.3.9.

2.2.5 Trains

Trains are used by a small number of students as part of their school journey. Travel by train will nearly always be part of a wider inter-modal trip. Other modes that might be included in this trip are cycling, walking, and as a passenger in a private motor vehicle. Trains are used by only urban students because, outside Auckland and Wellington, commuter trains are non-existent.

This report will deal with trains only as far as crossing railway lines and 'trespassing' on railway lines presents a problem to pedestrians (see Section 2.3.1.6). Accidents that occur while using this mode are rare.

2.2.6 Other modes of transport

Other modes of transport available for students include skateboards, in-line skates, scooters, and motorised scooters. Many schools do not permit students to use these forms of travel to school, and very little information about such alternative modes was found in the literature reviewed.

Motorised scooter use for school journeys was surveyed in Italy, and the proportion of students losing control of their scooters prompted the Education Minister to introduce a road safety programme in schools (Newbold 2002).

2.3 Devices to improve safety on the journey to school

Much of the attention in the literature has been focused on the area directly in front of the school. The main concentration of students is around these school access points. Various traffic treatments have been used according to the volume and speed restriction of the traffic on the surrounding roads. The school frontage may also include other traffic engineering measures designed to get the children across the road safely, as well as to provide a safe road environment with bus bays, and drop-off and pick-up points for students who are driven to school. This section examines the literature available on engineering devices that aim to improve safety for schoolchildren, both close to school and on the home-to-school journey.

The literature review has also looked at different engineering features that are used in the immediate vicinity of schools and on the home-to-school journey. These engineering features included:

- safe crossing places,
- traffic calming,
- school zone restrictions,
- footpaths/cyclepaths,
- parking,

- intersections,
- warnings (including variable message signs),
- bus stops,
- bus safety, and
- security.

Many of the issues that are raised in the area surrounding the schools are also applicable to the wider school-to-home journey. The engineering devices that are used in front of schools can be considered in the context of the wider home-to-school journey depending on the mode of transport taken. Wherever practical the review will separate the literature into the following two sections:

- close to school, and
- home-to-school journey.

However, as an overlap occurs in some instances where the information is relevant to both the close-to-school situation as well as the home-to school-journey, it is recommended that each part be read in conjunction with the other.

Pedestrian transport is the most obvious mode that requires the application of engineering devices along the entire route. Cycling is not recommended for young students, or where no special provisions for safety have been provided. Pedestrians, cyclists, and others need safe crossing places throughout the course of their travel. Students travelling in private motor vehicles and buses need a safe roading network, and safe pick-up and set-down areas provided for them at the school.

2.3.1 Safe crossing places

One of the main features of a child's home-to-school journey is crossing the road, in particular the road on which the school is fronted. A number of different types of engineering features can be used in providing safe crossing places for students. This literature review has identified the following different classes of crossings that are used in different traffic situations:

- uncontrolled crossings – where the motorist has priority over pedestrians,
- controlled crossings – where pedestrians have priority over motorists,
- mid-block signalised crossings,
- intersection signals, and
- grade separations.

Uncontrolled crossings

Uncontrolled crossings are the simplest type of crossing. No priority is given to pedestrians, and the pedestrians cross when there is a gap in the traffic. This requires the pedestrian, in this case a child, to make a difficult judgement about the suitability of crossing. Consequently, this type of crossing measure is only appropriate on roads where the vehicular traffic volume is low.

Children lack the cognitive skills to accurately choose gaps in traffic in which they can safely cross (Austroads 1995). Consequently, they adopt crossing strategies that rely less on interactions with the stream of traffic and waiting for a break in the traffic. However, other studies (Hoffage et al. 2003) have identified that children are not prepared to wait for a gap any longer than adults are, despite their limits. It is therefore vital to the safety of children that adequate crossing facilities are provided for them where the road is busy.

Uncontrolled crossings can be made safer by funnelling the pedestrians to cross at a single point (Cairney 2000c). This allows drivers to be more aware of the potential for children crossing, and allows engineering devices to be implemented that make the crossing point safer. The engineering measures can be applied either individually or in conjunction with each other. The simplest and most effective engineering device is to restrict the parking around an uncontrolled crossing point to increase the sight lines of both the pedestrian and the driver. The most common engineering devices used are pedestrian refuges and kerb extensions. Flat-top road humps, as shown in Figure 2.9, are also in use, but mostly restricted to central business districts.



Figure 2.9 Flat-top road humps (platforms).

Pedestrian refuges are raised islands that divide the traffic in the centre of the road (often located within a painted flush median). Refuge islands allow for pedestrians to safely stop in the centre of the road and cross it in two parts. Pedestrian refuges have the additional advantage of increasing the awareness of the drivers that pedestrians may be crossing at that point. Some disagreement was noted in the literature as to the effectiveness of refuge islands. One study cited in Cairney (2000a) found that they were

among the safest devices (between a one-third and one-fifth reduction in accidents depending on road type), while another study cited in the same source found that they led to an increase in accidents. Refuges without kerb extensions (see next paragraph) have actually resulted in a reported increase in accidents and even with kerb extensions the safety gains may be minor (Cairney 2000a).

Kerb extensions (footpath extensions) are extended areas of the footpath that extend out to the line of the edge of the lane, eliminating parking space at that point. Pedestrian and vehicular inter-visibility is improved, as pedestrians are closer to the line of the traffic while still on the kerb. The kerb extension also reduces the crossing distance needed to cross the road. These are widely used, especially in conjunction with other crossing measures. Kerb extensions on their own have been linked with a 27% reduction in the number of accidents at a site (Cairney 2000a).

Platforms (flat-top road humps) are raised sections of the road on which traffic still has priority. Consequently platform crossings are sometimes the source of confusion and their use as a crossing is discouraged. Flat-top road humps increase the visibility of the crossing, and signal a change in the carriageway and driving conditions. Evidence is given in Cairney (2000a) that raised pedestrian platforms are very effective. However, that study also found that it was not clear if the reduction in crash rates were attributable to these measures or to a wider traffic plan.

Pedestrian fencing can be used to channel pedestrians away from dangerous crossing points. Fencing also has the advantage of consolidating the crossing points to one position on the road. Cairney (2000a) reports up to a 21% reduction of pedestrian crashes following their installation.

All these uncontrolled crossing measures can be used as road calming treatments as discussed in Section 2.3.2.

Summary: Designing crossing places around schools needs particular attention to the cognitive abilities of the pedestrians, and the behaviour that the pedestrians will display when crossing (Cairney 2000a). This means that crossing strategies employed by primary school students are different compared to those used by secondary students. Crossing devices that are most applicable for use by primary school children are often disregarded by older students, for example zebra crossings.

The safest crossing device for secondary school students may be achieved by providing a *raised median* with kerb extensions to divide the crossing task in half, whereas the safest crossing for primary school children will be at a supervised crossing.

Initiatives such as *walking school buses* would probably have very low use if they were implemented in secondary schools, but are suitable for primary schools. Secondary school students also tend to travel longer distances to their schools as the schools have larger catchment areas.

Pedestrian fencing can also be used to improve the funnelling towards safe crossing points (Gadd 2001).

Jensen & Hummer (2002) suggest that the zoning, location, and type of school (primary, intermediate, etc.) are vital considerations, as the length of the trip to and from school is a major obstacle to sustainable and safe journeys.

Controlled crossings

A controlled crossing is one where the pedestrian has the right of way, and the traffic is expected to yield, but the crossing does not use traffic signals. The two types are zebra crossings and kea crossings.

Zebra crossings, which are also known simply as pedestrian crossings, are areas of the roadway that are painted with white lines to give a striped appearance. This indicates that, if a pedestrian is waiting to use the crossing, then the approaching traffic is required to stop. Pedestrian crossings are signposted with orange lights or disks on black and white striped poles, and a diamond painted on the road approaching the crossing. Zebra crossings may be used with some (or all) of the uncontrolled crossing elements to increase the visibility of the pedestrians. Cairney (2000a) reports that research in Australia shows no reduction in the number of crashes at sites where zebra crossings are installed. However, there is a 30% reduction in the total number of accidents for the pedestrian network. This reduction may be attributable to the funnelling effect that draws more pedestrians to cross at the crossing. The safety effectiveness of zebra crossings is not clear-cut (Cairney 2000a).

Wombat crossings, i.e. zebra crossings on raised platforms with a 40 km/h speed limit, are being used around schools in Australia, where Cairney (2000a) reported a 8% reduction in pedestrian crashes. Cairney also reported that using kerb extensions with pedestrian crossings led to a 44% reduction in the number of accidents at a site.

A case-control study in Auckland (Roberts 1994) showed that 14% of all child pedestrian injuries occurred on pedestrian crossings, and that the safety of pedestrian crossings must be urgently addressed. The Roberts study concluded that while crossing on a pedestrian crossing may be safer than crossing elsewhere on the road, the results suggest that there is further scope for improving the safety of pedestrian crossings. Other studies in New Zealand by both LTSA (2002) and local authorities (GHD Ltd 2001) have shown a high non-compliance rate with the standards and guidelines set out for installation of marked (zebra) pedestrian crossings. This non-compliance does not seem to have been taken into account in the evaluation of the safety of pedestrian crossings.

Several studies that are cited in Cairney (2000a) show that school crossings (including patrol crossings) significantly reduce the crash rate. The risk for children crossing at a school crossing was approximately one quarter of the risk associated with crossing at a zebra crossing at the same time of day. The data to make a firm conclusion is insufficient, but school crossings seem to be the safest places for young children to cross. It is also reasonable to assume that similar results will hold for the Kea crossings which are being implemented around schools. However as Kea crossings are being implemented in New Zealand only, no international research is available to confirm this.

Kea crossings (school crossing points) are used exclusively by schools in New Zealand. Kea crossings are similar to school patrol crossings, except they do not use zebra crossing markings. They are set out with 'hold lines' painted on the carriageway to indicate where the vehicle should stop when requested, and they have built-out curbs. Kea crossings are only operational when the warning flags are in place and the hand-held signs are extended showing that children need to cross. At other times, pedestrians have no priority, but act as uncontrolled crossing points, and so do not disrupt normal traffic flow.

Kea crossings are used in 50 km/h zones but they can be implemented in higher speed areas with the permission of the LTSA (LTSA 2002c), and have been implemented in 70 km/h speed zones (LTSA 2002a).

Kea crossings are new in New Zealand, and no comprehensive studies of their effectiveness are available yet. Also, as only a small number of accidents have occurred on them, assessing their effectiveness adequately is very difficult. Even so, anecdotal reports of the expected safety improvements from kea crossings are recorded (Vialoux 2002).

Mid-block signalised crossings

Signalised crossings are crossing points where the traffic is stopped at a mid-block point (see Figure 2.10). All signalised crossings in New Zealand are operated by pedestrians, so that when a pedestrian wishes to cross they press a button that changes the traffic signals. When the traffic has been stopped the pedestrian signals are changed and the pedestrians are allowed to cross.

Cairney (2000a) cites British reports from the late 1970s in which no reduction in the crash rate was recorded where pedestrian operated signals have been installed, except when further work has been done on the site, such as installing guardrails and anti-skid surfaces. Also an increase in the number of crashes occurred within 50 m of the new signals. Later studies showed signalised mid-block crossings in a more positive light. Although still having a higher crash rate than at intersection signals, mid-block crossings were especially effective on high volume roads. It is hard to compare the effectiveness of signalised crossings given the dearth of crash data and the inherent differences in the sites and applications of the crossings, so the effectiveness of signalised crossings is not clear (Cairney 2000a).

Some new developments in signalised crossings have been implemented in Britain, such as the **puffin crossing**. The puffin crossing uses pressure sensors to monitor the pedestrians waiting, and then monitors them crossing the road. When pedestrians walk up to the puffin crossing, the crossing detects their presence and changes the signals to a pedestrian phase (Cairney 2000b). As the pedestrians cross the road, the crossing checks their progress, and does not change the traffic control signal until the pedestrians have reached the other side. There are some concerns about the reliability of such systems, especially the infrared sensors with the sensors not picking up the pedestrians in nearly 10% of cases (Cairney 2000a).

The **pelican crossing** is much the same as the traditional signalised crossing except during the flashing red pedestrian phase. During this phase the traffic control signals flash yellow, and drivers are allowed to proceed through the crossing with caution. The pelican-type crossing reduces the waiting time of the traffic during the pedestrian cycle.



Figure 2.10 Mid-block signalised crossing.

Possible countermeasures to the problem of driver and pedestrian disobedience to their respective signals can be found in the recommendations of Cairney (2000b). These include longer yellow or all red times for the signals, and stronger pedestrian warnings. Also suggested is removing the mid-block pedestrian signals, and replacing them with double pelican crossings with a refuge in the centre of the road. By dividing the crossing task in two, safety outcomes should be improved. Also by changing the signals to a pedestrian crossing both pedestrians and drivers take a larger share of the responsibility of crossing more safely, rather than relying exclusively on the signals. Addressing pedestrian disregard of signals through the use of enforcement is also suggested as a solution to the high accident rate associated with pedestrian-operated signals (Cairney 2000b).

Intersection signals

Signals are often used at intersections to control traffic. When there are pedestrian flows through these intersections, pedestrian signals are frequently added to the traffic cycle. The pedestrian cycle either remains on (used only in very high pedestrian flow areas), or

the pedestrian activates it by pressing a button. In some jurisdictions the red pedestrian signal is extinguished until the pedestrian demand is registered (Austroads 2003).

Though the evidence that installing signals at intersections reduces the pedestrian crash rate is not conclusive (Cairney 2000a), the risks associated with crossing at intersections that have signalised crossings are thought to be low. Studies into the type of accidents that occur at intersection signals show injuries are comparatively minor as most are caused by turning cars (Cairney 2000b). These accidents are much less severe. When pedestrians and vehicles obey the signals on the intersection the crash rate is very low (Cairney 2000c).

One of the primary problems of signalised intersection crossings is the low compliance rate for both pedestrians and vehicles. Sisiopiku (2003) concluded that the low rate of compliance for vehicles turning at intersections made pedestrians less likely to follow the signals. She also notes that compliance is especially an issue in low traffic situations. It is the free-running cars, and the lead cars of platoons, that are most likely to be involved in accidents with pedestrians (Cairney 2000c).

In an attempt to reduce the high non-compliance rates, Roberts (1994) recommends greater police enforcement of pedestrian crossing regulations, with video surveillance used to deter drivers from driving through the red lights, and high penalties for drivers who infringe the crossing regulations.

Grade separation

Grade separation physically removes pedestrians from the road crossing so they cross at a different level. Its form is usually a tunnel under the roadway or a footbridge over it. Cairney (2000a) cites a study that suggests that subways are preferred to over-bridges. Even so, Cairney also argues that issues of personal safety would tip the balance towards overbridges as subways are widely considered by the public to be areas where personal safety may be compromised.

Cairney (2000a) confirms that grade separation is an effective crossing facility resulting in an adjusted crash reduction rate of 28%. However, grade separation is very expensive, and only suitable where both the traffic and pedestrian flows are very high, or both the traffic flow and the traffic speed are very high.

Crossing railway lines

The literature review refers to trains as 'fast, quiet and deadly', so that providing safe and appropriate crossing facilities over railway lines is essential. 'Trespassing' on the railway corridor and crossing at inappropriate places are ongoing problems, and railway lines pose additional problems with regards to safety if the facilities provided are not convenient to use.

Close to school: In the literature reviewed the crossing of railway lines appeared to be more related to the home-to-school journey than to the area close to the school or in front of the school gate.

Home-to-school journey: In Western Australia over the past ten years 31 people were killed, and another 460 were injured, at crashes at railway crossings (Mainroads 2004b). The cost to the community in Western Australia was nearly \$40 million. It was found that pedestrians and cyclists ignore signs and signals, bypass gates, mazes, and fences, and cross railway crossings while the boom gates are down and a train is approaching (Mainroads 2004b).

In New Zealand, pedestrian/train collisions occur both at level crossings, and in 'trespass' situations at places remote from the crossings. A New Zealand study by Waitakere City Council found a major trespassing problem with a high percentage of the general public. These included commuters, school children, the elderly, and shoppers ignoring a grade-separated footbridge and choosing to illegally cross the tracks elsewhere (Figure 2.11). Holes were cut in fences along the railway line, and the installation of 'cut-proof' fences did not alleviate the problem, as pedestrians continued to find ways to cross or walk along the railway tracks. Although an education programme reduced the number of illegal crossings by approximately 24%, this programme was still not enough to prevent the trespass situation (Cuthbert 1998). The trespass problem highlights the importance of providing pedestrian facilities at railway crossings, and the need to make these facilities attractive and easy-to-use.



Figure 2.11 Pedestrian facilities such as a grade-separated bridge at this railway crossing are ignored and instead trespassing carries on.

Canadian regulations, through the Railway Safety Act (RSA) of 1989 and the subsequent amendments in 1999, and the Canadian Transport Agency (CTA), together with Transport Canada, recognise the problems with trespassing on railway lines, and have developed a trespassing prevention policy (Transport Canada 2004). This policy sets out the

responsibilities for the prevention of trespassing, and covers the legal situation. It provides a systematic framework for a positive approach to the prevention of trespassing, and the provision for the safety of the public and personnel, as well as protection of property and the environment. Transport Canada in their 'Direction 2006' provides a strategy aimed at reducing collisions on railway grade crossings by 50% over a 10-year period.

Double railway tracks, with trains travelling in both directions, exacerbate the safety problems, and quieter and electrified trains further increase the potential danger to pedestrians. It would appear that, to address the safety problems of crossing multiple tracks, greater warning of approaching trains from either direction is required both visually and aurally. An Australian study has looked at the prospects for improving the conspicuity of trains at passive (uncontrolled) railway crossings, and in particular has focused on the provision of strobe multicoloured lights on the engine to provide improved daytime warning of an approaching train (Cairney 2003). Transport Canada require engine whistling at all public crossings, except where this may be exempted in specially prescribed situations. Where relief from whistling is sought, adequate crossing warning systems are required to be in place (Transport Canada 2004).

Both New Zealand (LTSA 2000) and Australia (Austroads 1995) have guidelines for engineering works at railway crossings, including:

- grade-separated crossings,
- public road crossings,
- pedestrian crossings at stations remote from the vehicular crossings,
- stand-alone pedestrian crossings (remote from stations or vehicular level crossings), and
- unauthorised crossings.

The guidelines point out that at at-grade crossings, the footpath needs to be to the level of the top of the rail tracks, limit lines should be provided to show where pedestrians need to wait to cross, and warning signs should be provided. Supplementary signage and physical guidance measures may be required to define the intended pedestrian path, and to direct pedestrians (Figure 2.12). This may require the following treatments particularly where heavy pedestrian traffic occurs:

- guard fences along the approach footways to ensure that pedestrians use the footway rather than the roadway,
- pedestrian mazes to direct pedestrians to look for trains before crossing and ensure they cross at a particular location, and
- remotely controlled pedestrian gates or boom barriers to prohibit crossing when trains are approaching or proceeding through the crossing.

Where multiple tracks are to be crossed, mazes should be provided to direct pedestrians and cyclists to look towards the direction of an approaching train. Also stated is that all devices should be detectable by those pedestrians with some form of visual or aural impairment. Night-time lighting of all crossings should be provided.



Figure 2.12 An at-grade rail/pedestrian crossing with poor pedestrian facilities.

Safety audits of railway lines concerning pedestrian safety would appear to be necessary. They should establish where pedestrians cross away from the road crossings in a trespass situation, and highlight the areas of specific concern regarding pedestrians, including school children. As part of the audit process the auditor should walk and drive the track in both day-time and night-time conditions. The current situation in New Zealand, where increased use of the railway tracks (including duplication of lines and electrification) is planned, places some urgency on railway companies and RCAs to develop a well-based method of safety auditing and subsequent implementation of the audit results.

Figure 2.12 is an example of a new at-grade rail crossing which has severely restricted sight lines for pedestrians and a pedestrian barrier in only one direction. No warning barriers are provided for pedestrians walking against the traffic flow.

2.3.2 Traffic calming

Traffic calming is the application of measures to reduce the speed of vehicles and increase the awareness of pedestrians. A wide variety of devices can be used to slow the traffic flows and make drivers more aware of other road users. The most common traffic-calming measures are physical, but increasingly psychological measures are also being considered.

Physical measures used in traffic calming can be divided into three categories (Austroads 1988b), and include:

- Vertical deflections of the road surface, such as
 - speed humps,
 - speed tables,

- road closures,
- rumble strips,
- raised junctions,
- Horizontal deflections, such as
 - chicanes,
 - cycle tracks,
 - mini roundabouts;
- Roadside cues, such as
 - pinch points,
 - kerb extensions,
 - median islands,
 - road narrowing,
 - road paving,
 - paved shoulders,
 - gates,
 - speed monitoring trailers.

The fundamental issue that arises with traffic-calming measures is the conflict between the different road-user groups. In an area where traffic calming is to be introduced, the needs of normal vehicular traffic, pedestrians, cyclists, and emergency vehicles all have to be considered. These needs are often at odds with each other. Davies (1999) notes that the traffic calming measures used in the UK, with its reliance on physical countermeasures, has received some criticism. The critics of the British approach point to a lack of attention to aesthetics, driver behaviour, transport system integration, and environmental consequences.

The ultimate in traffic calming measures is road closure, but this has some very negative impacts (ITE 2004). Although a closed road is excellent for the needs of pedestrians, it is to the detriment of every other road-user group. Most importantly, it reduces the access of emergency vehicles. Unless the road closure is accompanied by a reduction in the number of private vehicles, say by an improved public transport system, then the traffic problem will merely be diverted to a different part of the roading system (Ewing 1999).

Vertical deflections, such as speed humps, are the most effective in slowing vehicle speeds, typically by 20 to 25% (ITE 2004). Speed humps also have the effect of decreasing the traffic volume if an alternative route is available. Speed humps have fallen from favour overseas due to the negative impact that they have, especially on the response times of emergency vehicles. The approximate delay to emergency vehicles has been reported to be between three and five seconds for fire trucks, and up to ten seconds for an ambulance with a patient aboard (ITE 2004). When considering engineering devices on higher order roads, special care must be taken to ensure that the needs of emergency response vehicles are taken into consideration. This often will be achieved by not putting traffic-calming devices on routes that are considered to be primary response

routes. A high number of these primary response routes still will be those on which schools are located, and for which speed-limiting physical measures should have been implemented. Noise, vibration, limits on on-street parking, and residents' resistance are all factors that have limited the implementation of speed humps.

Speed humps seem to reduce the number of child injuries. In one recent article, speed humps in the neighbourhood reduced the incidence of hospitalised injuries to children by as much as 60% if the speed hump is in the street where the child lives (Tester et al. 2004).

The evaluation shows that introducing low-speed roads, traffic calming systems, raised intersections, and various types of roadside cues are the initiatives that have resulted in the most benefit in terms of traffic safety. Thus the recommendation is to focus on this type of speed-reducing measure, as well as the means of control at intersections (Atkins 2002).

In the Netherlands the Delft Woonerf concept was applied, in which cars are allowed but have to travel through designated areas at walking pace. Streets were re-designed to reduce rates of injury and maximum speeds were lowered to reduce the severity of any accidents. Research in the 1970s showed that drivers were not taking the needs of child pedestrians into account however. Consequently there was a shift in focus towards the needs of children. In 1977, 30 km/h speed limits were implemented on many residential roads. These low speed zones seem to have had positive effects on general road safety and are favoured by residents for reducing traffic speed and volume. School journey safety thus becomes part of a wider approach to improve safety for the whole community (Davis 1996).

Further information about integrated pedestrian networks is available in the Land Transport NZ Pedestrian Planning Design Guide (LTNZ in press 2006).

2.3.3 School zone restrictions

In many countries the speed limit is reduced around schools, particularly during the critical pre- and post-school periods. The aim of this is to reduce the speed at which the traffic passes a school during the periods when the density of children is highest. In Australia, for instance, school zones operate between 0730 and 0900 hours in the morning and 1430 and 1600 hours in the afternoon, and applies for all schools, both secondary and primary. The speed limits for these zones are:

- 60 km/h school zone – within 80 km/h and above 90 km/h speed zones, and
- 40 km/h school zone – within 50, 60, and 70 km/h speed zones (Mainroads 2004a).

In New South Wales, Northern Territory, Queensland, Tasmania, and Victoria, the most commonly installed school speed zone in the urban area has a speed limit of 40 km/h. In South Australia, the speed limit at school zones is further reduced to 25 km/h where a traffic-control device is applied.

Davies (1999) cites Webster & Mackie (1996) who found an accident reduction of around 3.85% for every km/h in reduced speed limit. They also found that the introduction of

20 mph (32 km/h) zones was highly successful in reducing vehicle speeds and casualties, and this has reduced the accident frequency of child pedestrian accidents by 70%.

Speed is the critical factor in determining the severity of the injuries sustained by pedestrians involved in a crash. Cairney (2000a) cites a study in which the average probability of a pedestrian being killed by a vehicle travelling at an average speed of 48 km/h was 19%. If the vehicle's speed had been reduced to 40 km/h the probability would be reduced by over 60% to just 6%.

There are problems of compliance with the speed limit in a school zone. The speed limit will probably not be adhered to, but some reduction in the speed of the vehicles and an increased awareness of the presence of children in the area will happen. There is also evidence that school zones reduce the speed of the traffic in that area at all times, not only during the signposted hours (Lee 2000).

One possible solution to the low levels of compliance is to minimise the time of operation for the reduced speed limit. One possible explanation for the low levels of compliance that have been experienced elsewhere is that the signposted speed is only needed when the density of children is at its greatest.

New Zealand has introduced 40 km/h school speed zones in some areas, and has significantly limited the time period when the speed reduction is in operation. Limiting the operation times has the advantage of ensuring that the low speed limit is sufficiently rare for the drivers to take notice of it, and drivers can see that the lowered speed limit is justified by the school children present.



Figure 2.13 School zone signs in operation outside Fairhall School, Blenheim, as an example of an advance automated warning device. NB footpaths should also be provided.

An important part of the introduction of school speed zones is the introduction of adequate warning devices. These devices can be static advisory signs, or advance automated warning devices (such as the sign shown in Figure 2.13). The literature discussing the implementation and effectiveness of the warning devices is outlined in Section 2.3.7.

2.3.4 Footpaths / Cyclepaths

A fundamental for safety of school children is that footpaths are provided on roads fronting schools, and that footpaths on the home-to-school routes are continuous with good pedestrian linkages.

Close to school

Little literature was available that specifically dealt with footpaths and cyclepaths located close to school or at the school frontage, apart from a mention that these areas needed attention in safety audits. The literature that was reviewed deals mainly with footpaths and cyclepaths in general. Details of this review are included in the following section, 'Home-to-school journey'.

Home-to-school journey

Austrroads (2002) provides recommended footpath and cyclepath widths for different situations depending on the location and purpose of the anticipated demand for those facilities. In developing a pedestrian network, five key elements need to be considered in strategies developed to address these issues before promoting pedestrian use (Dravitzki et al. 2003). The key elements include:

- directness,
- continuity,
- safe street crossings,
- visual interest and amenities, and
- security.

An OECD report cites legislation in Belgium and the Netherlands that requires minimum pavement widths of 1.5 m (including accommodation for the placement of lamp posts, traffic signs, and post boxes), a width of 2 m for one-way cyclepaths and 3 m for two-way cycle paths, to facilitate circulation of pedestrians and cyclists in urban areas (McMahon 2004).

A Danish study identified poor visibility conditions, cars driving too close to cyclists, high vehicle speeds, high traffic volumes, and large numbers of heavy vehicles, as causes for children and parents feeling unsafe when walking or cycling to school (Jensen & Hummer 2002). Strategies to address these problems included:

- clearing vegetation,
- relocating road signs,
- relocating fixed objects,
- road marking and/or installing traffic islands at junctions,
- provision of cycle lanes or cycle tracks, and
- provision of wider paved road shoulders.

Further strategies to promote pedestrian use (Dravitzki et al. 2003) include:

- footpath widening,
- improvements to pedestrian security,
- creation of attractive streets with a focus on urban design and landscaping,
- regular street cleaning,
- removal of footpath obstructions (such as parked cars, advertising boards outside shops, and street furniture),
- removal of overgrown foliage, and
- traffic-free walks and green parks.

Safety audits

The literature suggests that all facilities which include pedestrian facilities should be audited for safety, focusing specifically on pedestrian safety. This audit should include compliance with the standards recommended for children, and mobility impaired, and hearing- or sight-impaired people.

Austrroads (1995) provides a safety audit checklist which identifies the pertinent safety issues which are inclusive of pedestrian needs. Through this process, pedestrian safety effectively becomes an 'explicit' factor at all levels of the design process, as opposed to being an 'implicit' consideration. The guidelines state that the auditor must walk the site or route, day and night, for each stage of the audit. The Austrroads guide advises auditors to continually revise and improve the checklist that they use. Young pedestrians are included as one of the five pedestrian categories in the audit process (Austrroads 1995).

The young pedestrians' audit checklist includes:

- Can parking be managed to maximise sightlines?
- Will any street furniture or landscaping obstruct vision of, and visibility to, the young pedestrian?
- Are school gates appropriately located, and is fencing used to guide the children to a crossing point?
- Are footpaths provided, and are these continuous through the scheme?
- In a local traffic area, are appropriate devices being used to slow down the traffic?

Another safety audit checklist (Mainroads 2004c) which is available for dual-use (pedestrian and cycle) paths includes the following topics:

- landscaping,
- reticulation,
- parking,
- conflict between users,
- design speed,
- overtaking,
- widths,
- edges,

- kerbs,
- intersections
 - location
 - warning
 - control
 - layout
 - visibility, sight distances
 - intersections with roads
- signs and lighting,
- traffic signals,
- fences, guardrails, chicanes, and
- pavement.

The Pedestrian Planning Design Guide, being developed by LTSA, includes a walkability audit process which deals with the attractiveness, convenience, and practicality of walking routes (Dravitzki et al. 2003). Supplementing this audit process should be an audit that specifically focuses on pedestrian safety, especially around pedestrian-generating areas such as schools.

Safety audits that are specifically developed for young pedestrians and young cyclists, and undertaking these audits, are essential components in improving the safety for schoolchildren on their home-to-school journey. This is especially so with the current focus in New Zealand on walking school buses (where groups of children walk to and from school, accompanied by an adult) and the development of Safe Routes to School type programmes. These programmes have identified the wish of children to walk or cycle to school. Safety audits of the routes and the implementation of the audit recommendations should be undertaken before walking is encouraged. Also it is important that local authorities include footpath and cyclepath linkages as part of their resource consent approval process for new 'greenfields' developments, and for redevelopment of areas.

2.3.5 Parking

Parked cars can impact on the safety of child pedestrians by obscuring the vision a motorist has of children waiting to cross the road, and can restrict the vision for the child to the vehicles travelling along the road. The congestion along the school frontage at school start and finish times by parents or care-givers dropping off and picking up students impacts on the safety of children. Illegal parking, and parking in such a way that children need to cross the road, is also a safety concern.

Close to school

At the school frontage the parking demand differs between the morning drop-off period for students and the afternoon pick-up time. The morning activity comprises primarily of short-term parking to allow students to disembark, while in the afternoon a longer term parking situation occurs as parents arrive at the school before the school finish time to wait for the children.

Brisbane City Council cites a safe school travel scheme whereby the Council and the Main Roads department jointly fund physical works at the school frontage. These works include internal car parks, indented bus bays, and passenger drop-off zones, and have been found to be a constructive way of improving school safety. The Brisbane City Council and 81% of the schools considered it to be effective or very effective. Suggested improvements included more support from road safety officers, greater Adopt-a Cop support, and enforcement of the two-minute passenger zones at the drop-off area (Lee 2000).

Surveys of primary schools in the Auckland area suggested a ratio of one vehicle per three students require parking at the school frontage at schools start and finish times. With this current level of demand for parking by parents, schools would never be able to provide parking to accommodate the demand. Therefore good drop-off/pick-up facilities, with supervision of the parking operation, appear to be essential; and having or working towards the provision of alternative modes of transport to school will be needed to reduce the number of vehicles parking along the school frontage.

Home-to-school journey

On the home-to-school journey, Roberts (1994) found, in the case-control study conducted in Auckland, that parked vehicles impact on the safety of children crossing roads. The results of the study showed that a high density of on-street parking was associated with a greatly increased risk of child pedestrian injury. The risk of injury at sites with the highest density of on-street parking was over three times that of sites with the lowest density. Parked vehicles are likely to increase the risk of pedestrian injury by obscuring the driver's view of the child as he/she enters the roadway. Davies (1999) found that the masking of pedestrians by parked or stationary vehicles was one of the common factors identified as being a cause for pedestrian accidents in 'built-up' areas.

From a pedestrian perspective, parking should be designated so as not to interfere with sight distance between vehicle drivers and pedestrians. To ensure this, most state regulations prohibit parking within certain distances from pedestrian crossings. Other statutory parking prohibitions such as at intersections, pedestrian crossings, and public transport stops also assist in providing adequate sight distance between vehicles and pedestrians (Austroads 1995).

2.3.6 Intersections

On children's home-to-school journeys they are likely to cross a number of intersections with varying degrees of complexity, and differing levels of safety incorporated in the design. Intersections encountered will range from crossing minor local side roads to major high volume signalised intersections, and the literature review has examined the safety aspects for each. This review can be found in Section 2.3.1 Safe Crossing Places, and will not be repeated here. This section of the report will primarily deal with the literature found for left-turn islands and slip lanes at signalised intersections, and suggested management of intersections to address high vehicle speeds and driver non-compliance with give-way signs.

The *type of intersection* can impact on safety for children. Intersections which have the least demand on driver attention (such as a 'T' intersection) will be inherently safer for pedestrians than complex intersections such as roundabouts, and cross or multi-leg intersections.

Austrroads (1988) sets out the different types of intersections, as detailed below. However, it does not specifically reference the impact of each type on pedestrian safety. Where pedestrian safety has been mentioned, certain observations are offered.

'T' intersections are one of the simplest and safest forms of intersection treatment as potential vehicle conflict movements are minimised. 'Y' intersections, where the intersection angle is less than 70 degrees, are likely to present safety problems for pedestrians as driver visibility may be restricted, undesirable high speed turning movements may occur, and driver priority may not be obvious.

Cross intersections increase the potential for vehicle conflict movements, and generally pedestrian crossing places over the main road should be located away from the intersection. The installation of kerb extensions on a minor side road, and the installation of a splitter island on a more significant side road can assist the crossing of that side road. Cross roads can also be reconfigured into a staggered 'T'. However, while this separates the potential vehicle conflicts, it does not improve the situation for pedestrian safety (Austrroads 1988).

Roundabouts generally provide a safer and more efficient operation for motorists, but because of the increased need for drivers to be focused on vehicle movements, they are generally not considered to be safe places for pedestrians and cyclists to cross. Austrroads (1995) recommend a separation distance from the exit of a roundabout to a crossing facility of at least two car lengths (approximately 12 m).

Signalised intersections provide controlled traffic movements, and reduce the potential for crashes by separating conflicting traffic movements. Signalised intersections generally provide good facilities for pedestrians (especially vulnerable road users such as children). Refer to Section 2.3.1.3.

Multi-leg intersections (five or more approaches) have the potential to cause driver confusion, and the potential for crashes because of the high number of conflicting movements. This type of intersection usually requires large areas of pavement. Generally multi-leg intersections are not pedestrian-friendly.

Austrroads recommends that where left-turn islands are provided at an intersection they should be large enough to accommodate the signal and traffic signalling equipment, provide adequate standing area for pedestrians, and be long enough to ensure that the approach end of the island is at least 3 m in advance of the stop line. Crosswalk lines should only be used at left-turn slip lanes where the crossing is controlled by separate pedestrian signal displays because these form part of signalised pedestrian crossings and children's crossings where pedestrians are allocated exclusive right-of-way periods. Their use at other locations where right-of-way is not explicitly allocated by signal or flags may

cause confusion, and give pedestrians a false sense of security, leading to accidents (Austroads 1995).

The current authors note that, where a signalised intersection is located in the vicinity of a school, it is essential that left-turn islands are large enough to accommodate the large number of students who will be using the facility, especially at school closing times. Adult supervision is also recommended in left-turn slip lanes where the stream of left-turning traffic is continuous.

Reconstruction of intersections, or the re-marking of give way or stop lines, are recommended as possible engineering treatments to address problems with high vehicle speeds, poor sight conditions, high volumes of traffic, and a few vehicles and drivers not respecting give-way signs. 'Y' junctions can be reconfigured and reconstructed to 'T' junctions, and more appropriate road markings can be used to improve children's feelings of being unsafe at intersections (Jensen & Hummer 2002).

2.3.7 Warning devices

Warning devices can be divided into the following categories:

- personal conspicuity devices, and
- warning devices for crossing places:
 - reflective warning signs at the school crossings,
 - reflective road equipment (cones, flags, reflective jackets),
 - advance school signs,
 - flashing lights,
 - variable message signs.

Personal conspicuity devices

In countries where overcast or dark conditions occur during long periods in the winter months, such as in Denmark, personal conspicuity aids such as reflective clothing are commonly used.

Dark clothing or rainwear reduces the visibility of a child pedestrian or cyclist for a motorist. The OECD report (*Keeping children safe in traffic*: McMahon 2004) concludes that both child pedestrians and cyclists would benefit from conspicuity aids and the use of light-coloured and retroreflective clothing. The report suggests that designers and manufacturers are well-positioned to incorporate retroreflective material into product lines, and parents as well as public health and safety officials should encourage them to do so. Dangle tags, armbands, strips on school bags, and the use of cycle lamps are all recommended.

Australian research cited in Cairney (2000a) concluded that conspicuity of pedestrians, cyclists, and motor vehicles remains a major issue, and that reflective clothing was not reliably detected at a distance. Good street lighting is still the best option. Flashing tail lights on bicycles were particularly effective, especially when viewed against a complex background. However, as far as cyclists are concerned, the main problem is not the

quality of lights and reflective materials, but the cyclists' willingness to use and maintain them.

Cairney (2000a) also cites a study which found that, in pedestrian crashes, 66% of drivers and 64% of the pedestrians failed to see the other before the accident. Half of these accidents were as a result of other vehicles obstructing the view. Cyclists failed to see a motor vehicle in 38% of the crashes, while the driver of a vehicle did not see the cyclist in 85% of the accidents.

Warning devices for crossing places

Additional measures to increase the conspicuity of fixed signs are mentioned in the literature. These measures have usually been implemented to increase the awareness of reduced speed zones near schools and, in one such application described by Hawkins (1993), the school zone sign was supplemented with time-controlled flashing lights. The reduced speed limit was in force when the lights were flashing. The installation of the signs with the lights was designed to reduce the number of tickets that were given out for lack of compliance with the recently introduced reduced speed zones around schools. Hawkins also found a statistically significant reduction in the speed of the vehicles through the zones that had been treated. Even so, the reduction in speed of around 2.5 mph (4 km/h) was still significantly above the reduced school zone speed limit. The installation of the flashing light speed signs was nevertheless considered to be a success, and an effective solution to the problem of excessive speed in school zones.

Aggarwai & Mortensen (1993) found a reduction in speed with advanced school flashers which were designed to remind drivers of the reduced speed limit that operated before and after school. The signs were in a 40 mph (64 km/h) zone, while the limit outside the school was reduced to 25 mph (40 km/h) when children were present. They also found a significant reduction in speed when the flashing lights were operating, of up to 12 mph (19 km/h). However, as the speed survey did not compare speeds pre- and post-treatment, but instead compared different times of the day when the lights were on or off, the effect is not likely to be as large.

Davies (1999) reports that variable message signs have been tested around schools, and have been shown to produce some traffic slowing effects. Compared to physical calming measures though, they are less effective and, because they have a high cost of installation and maintenance, variable message signs are generally considered unsuitable. Flashing warning lights may also have a negative impact on the secondary speed reductions that are achieved outside the hours of operation.

A New Zealand study that evaluated similar variable message signs at trial school sites found that the electronic lights activated during the before- and after-school period, when the school speed zone operated, was felt to be an important feature of driver behaviour modification (Cottam 2001). A parallel study by LTSA at the same trial school sites concluded that the greatest impact on reducing mean vehicle speeds occurred when children were present on the roadside and the speed zone signs were illuminated. The initial results found however that the effect of the illuminated signs alone diminished over time (Osmer 2001).

From these New Zealand studies, LTSA developed guidelines for the use of variable message school zone signs (in conjunction with 40 km/h school zones), stating that the signs must be manually activated by a supervisor approved by the school principal. Signs should only operate for a maximum period of 35 minutes up to the start of school; 20 minutes at the end of school commencing no earlier than 5 minutes before the end of school; and 10 minutes at any other time of the day when the warrant conditions were met. The warrant conditions and requirements for installing illuminated variable message school zone signs are set out in the LTSA guideline (LTSA 2002c).

In South Australia, instead of a conventional children's crossing, a flashing-light school crossing is used. While the lights are flashing drivers are required by regulation to observe a 25 km/h speed limit when approaching and within 30 m of a crossing, and must give way to any pedestrians on the crosswalk. Portable yellow flashing lights were also trialled on a relatively high-speed rural road in South Australia. Other Australian states use time-based speed limits, and in some cases they include activated flashing lights and variable message signs (Austroads 1995).

Three Western Australian studies of school crossing-safety initiatives reviewed newly developed flags for the traffic wardens, and the use of flashing amber lights at school crossings. The studies assessed differences in the location of the lights and when they were activated, against motorist behaviour as seen on video. The results of this study indicated that the safest behaviour was evident when the lights were installed at the crossing site itself and activated by the warden for each individual crossing (Mabbot 2001).

Iowa City evaluated the effectiveness of modified speed-limit signs with flashing lights in school zones. This study (Hawkins 1993) was undertaken because of the number of cars speeding through school zones in defiance of the posted full-time restricted speed limit. The signs trialled were large signs on multi-laned roads with flashing beacons (operated for an hour at schools' start and finish times, and lunchtimes) activated by time clocks housed within a side-mounted cabinet on poles. The size of the signs was reduced for two-lane roadways.

Changes in the way signs were used was initiated to eliminate unreasonable speed limit sections along heavily travelled roadways, to legitimise police enforcement, and to reduce vehicle speeds in school zones. The new signage was found to be appropriate and beneficial for the following reasons:

- tailoring reduced school zone speeds to critical school hours made sense to motorists, improved sign credibility, and legitimised enforcement;
- produced statistically significant speed reductions during critical school crossing periods when compared to the previous 25 mph static speed limit signs;
- when several school signs with different critical times were located along the same arterial, the flashing beacons gave the motorist positive information as to when they must slow down; and

- produced positive feedback from parents, school representatives, police, and the public concerning the use of the flashing beacons. The police commented that they believe the signage had more effect on speeds than was measured in the study.

Overall, the city was pleased with the public awareness of the signage. The hours of operation for the beacon assemblies at each school was established by Iowa City Council resolution, and reviewed annually by staff and each school principal (Hawkins 1993).

Another American study (Aggarwai & Mortensen 1993) looked at the effectiveness of using advance school flashers (operating for one hour only during the schools' start and finish times) on reducing speed. The results identified considerable reduction in average speeds during the period when these advanced school flashing lights were operating. It was important to note that, although the average speeds seemed to have decreased considerably during the flashing operation, they were still far from complying with the posted speed of 25 mph when children were present.

A further study (Bowers 2001) surveyed the before- and after-effects of vehicle speeds and flows with safe route to school projects which incorporated the use of speed-actuated signs. The trigger to actuate the flashing lights around the speed limit signs was set at a speed just above the posted speed limit. Conclusions from this study included:

- Speed-sensitive signs are an effective means of reducing speed by several mph, and more in some cases. The signs appeared to be particularly effective when the alignment and appearance of the road otherwise encouraged speeds well in excess of the speed limit.
- Although accident reduction was not the focus of the scheme, the reductions in speed found in the initial results suggested that accident reduction was likely. It was hoped that monitoring the level of accidents over three years would confirm this proposition.

As well new pedestrian-operated systems are being installed on a trial basis in the US that turn on flashing LED lights installed in the roadway. School patrols use zebra crossings in conjunction with signs that are extended on to the roadway to signal vehicles to stop. These signs are operated by children trained as school patrol monitors and are overseen by an adult. The authors have not found any evaluation of these devices.

2.3.8 Bus stops

The literature reviewed on bus stops outside the school gate, and school bus stops in general, showed the main concerns to be the speed of vehicles passing buses, visibility of school buses, and problems of passengers alighting from buses. Guidelines are currently being developed to ensure that school bus stops offer maximum visibility as well as finding ways of raising motorists' awareness of the 20 km/h speed limit for vehicles passing a school bus that has stopped to pick up or set down children (LTSA 2002).

In most countries a speed restriction for passing school buses is mandatory. It is generally set at 25 km/h when signs indicate that children are present, or if flashing lights have been activated on the bus.

Close to school

Where a loading island is needed to accommodate a large number of bus passengers, Austroads recommended that the island be at least 2 m wide, and that fencing be provided to separate pedestrians from any adjacent traffic stream, and to channelise pedestrian movements to prevent indiscriminate crossing of the road between the island and kerbside. The guideline also noted that a pedestrian crossing may be required for the protection of pedestrians moving to and from the kerb and footpath (Austroads 1995).

In the rural situation, Austroads (1999b) recommended that schools, where the safety of children is of particular concern, should give consideration to the provision of one-way movement bus zones.

The literature reviewed did not provide any detail on dealing with large numbers of school buses, or the situation where a bus bay is combined with a pick-up and drop-off parking area.

Home-to-school journey

The literature reviewed showed that in both the Netherlands (Davis 1996) and in Denmark (Jensen & Hummer 2002), where children live a specified distance away from their school or the route to school are considered to be hazardous, free bus services must be provided.

In New Zealand a study undertaken by LTSA in 2002 showed that, between 1992 and 2001, 12 children were killed in bus-related crashes. Twenty children were seriously injured, and 80 received minor injuries with bus-related crashes during that same period. Three-quarters of the fatalities occurred on high-speed roads (roads with a 100 km/h speed limit), while just over half of the serious injuries and around half of the minor injuries were sustained on urban roads (roads with a 50 km/h speed limit). School bus-related fatalities were found to more likely to occur in the afternoon and to involve children who have just left the bus, a finding that was similar internationally (LTSA 2002b).

Austroads recommends that the recessed bus bays (widened road shoulders) are provided where sight distances are restricted, and where traffic speeds are generally high enough for a stopped vehicle to create a hazard. The recommendations state that bus stops and/or bus bays should be provided at regular intervals along recognised bus routes so that users generally do not have to walk more than 400 m from their home to the bus stop. Austroads (1999b) also recommended that consideration be given to providing one-way movement bus signs at schools.

2.3.9 Bus safety

The LTSA study (2002b) referenced community concerns that influence school bus safety in Australia, the speed of vehicles passing school buses, and the visibility of school buses. As an outcome of these concerns, the following measures to enhance school bus-related safety were suggested:

- place speed restrictions around stationary buses,
- require hazard lights on buses,

- increase visibility of buses,
- require flashing lights and signs as part of bus stopping procedures,
- improve school education and training campaigns, and
- introduce advertising campaigns that focus on school bus-related safety.

The LTSA study also recommended that a number of bus and road environment measures should be investigated to enhance school bus-related safety. Detailed measures to evaluate the feasibility, costs, and benefits of buses and the road environment include:

For buses:

- fixing auxiliary mirrors inside and outside buses to improve a driver's view of potential risk within and outside the vehicle,
- installing of three-point seatbelts in school buses,
- limiting buses to carrying one person to each single seat (no standees),
- fitting school buses with higher seat backs, and
- installing external loud speakers, which will allow drivers to communicate with pedestrians.

For the road environment

- developing a nationally consistent system for auditing bus routes,
- investigating the feasibility of having school bus routes that do not require children to cross hazardous roads, and
- investigating marking sections of the road exclusively for school students being picked up and dropped off. For example, provide areas marked like bus stops that are solely for picking up or dropping off children (Austroads 1999b, cited in LTSA 2002b).

The literature reviewed did not appear to provide a comparison on the safety impact of the conspicuity of buses between the type of buses used overseas and those currently used in New Zealand. In many other countries, school buses are readily identified by their consistent colour and warning devices, compared to the New Zealand situation where the only identifying devices are 'school bus' foldout signs on the front and back of each bus. Also, no literature was found on the current compliance with the speed limit of 20 km/h when passing a stationary school bus.

2.3.10 Security

Dravitzki et al. (2003) report that a study of pedestrian's concerns about personal security found that the most important factors contributing to people's feelings of fear were:

- people loitering,
- poor lighting, and
- places for strangers to hide.

These concerns can be divided into the following issues:

- personal security,

- lighting,
- stranger danger, and
- barrier fences.

Personal security

Concerns of safety from traffic, and concerns of personal security when walking, impede the number of walking trips being made. Opus also reported that, given the low-density New Zealand settlement patterns, many existing pedestrian networks make use of walkways and paths through parks and reserves. The report highlighted the need for research both with respect to network planning (e.g. development of alternative routes for use after dark), and for the provision of appropriate infrastructure/attributes along the route (e.g. pavement quality, lighting, etc.).

Although this research was aimed at pedestrians in general, the concern regarding personal security for children on their home-to-school journey is high, and the information is therefore relevant both for child pedestrians and cyclists. The type of vegetation and vegetation overgrowth can pose problems for the personal security of children walking through parks and reserves.

Lighting

Although the school journey normally takes place during daylight hours, in winter, overcast, or stormy conditions, lighting of footpaths, walkways, and cycleways is important for safety and security reasons. Austroads (1995) recommend that one of the other major objectives of lighting for pedestrians is the enhancement of personal security. This requires lighting levels, particularly in the vertical plane, and the control of glare, sufficient to enable people to recognise potential threats from other people in time to take appropriate action.

Stranger danger

The literature reviewed did not suggest any engineering devices that would address the concerns regarding 'stranger danger' for children on their home-to-school journey. It is considered that the information and recommendations for safer footpaths, walkways, and cycleways, and the issues addressed for personal security reasons, would assist in this matter.

Barrier fences

Barrier fences, when appropriately installed, can assist in the safety and security of children at some intersections, and can be used to prevent children from crossing at inappropriate locations. Austroads (1995) report that a significant number of pedestrian deaths and injuries occur as a result of pedestrians crossing the street close to but outside an intersection. Barriers and fences of various types can be used to reduce mid-block accidents. Use of such barriers or fences is common in conjunction with pedestrian crossing facilities, to channel pedestrians to safe crossing locations (e.g. to overpasses or underpasses or signalised crossings), particularly outside hospitals and schools.

Austroroads warns that pedestrian fences and barriers are usually not constructed robustly enough to eliminate penetration by an errant vehicle, and that 'vehicle barriers' can be used to perform this function. However, as discussed below, where vehicle barriers are provided they may also fulfil the function of restraining pedestrians from crossing or getting on the roadway. In these situations the vehicle barrier (generally less than a metre high) may need to be fitted with a height extension to provide the required pedestrian safety.

Austroroads (1995) also sets out common types and usage of pedestrian barriers:

- Vehicle (road) bridges that carry high volumes of traffic at speeds of 80 km/h or greater, and where pedestrian demand to cross that bridge is significant.
- Median fences, which usually are 'chain-link' or 'welded mesh' fences, to prevent pedestrians from crossing dual carriageway roads at mid-block locations. (This type of barrier may be added solely for pedestrian purposes, or may be incorporated with vehicle barriers, e.g. guardrail or concrete barriers.)
- Footpath fences, railings, or bollards, located between the footpath and the roadway to prevent pedestrians from crossing at hazardous locations, and to channel pedestrians to crossing locations. (Footpath fences are typically constructed of 'chain-link', 'welded mesh', posts or bollards, chain, concrete, planters, or hedges.)

2.4 Road environment

The road environment, or external physical features, plays an important part in the safety of children on their home-to-school journey. Children's safe mobility within the built environment is essential for their well-being, development, and social integration. When a road environment is designed so that it recognises children's capabilities as well as their limitations, it will also be of benefit to all road users, since what constitutes a safe road environment for children would usually be safe for the public at large (McMahon 2004).

The road environment includes (but is generally not restricted to) the following aspects:

- traffic volume,
- traffic speed,
- road geometry,
- road topography, and
- land use.

2.4.1 Traffic volume

High traffic volumes are one of the main concerns for children on their home-to-school journey, as noted by Jensen & Hummer (2002), Kennedy (2004), and Dissanyake et al. (1999). Safe Routes to School programmes also indicate traffic volume as being one of the perceived risks that needs to be addressed.

The results from a 1994 case-control study by Roberts (1994) for the Injury Prevention Research Centre, University of Auckland, showed that high traffic volumes are a major risk factor for child pedestrian injury. The risk of injury for children living in neighbourhoods with the highest traffic volumes was 13 times that of children living in the

neighbourhoods with the lowest traffic volumes. The risk of injury as traffic volume increased showed a steady increase. Roberts recommended that the volume of road traffic throughout the road system should be reduced by improving the amount and quality of public transport. As well as reducing the volume of traffic, this would provide an alternative means of travel for families without access to a car. Children from such families are a particularly high risk group for pedestrian accidents, probably because they walk more than other children.

2.4.2 Traffic speed

Traffic speed is one of the most commonly mentioned safety concerns for children on their home-to-school journey. Much of the literature reviewed mentioned the reduction of traffic speeds as being the primary method of improving safety for children in traffic. Vehicle speeds over 40 km/h is associated with a threefold increase in the risk of injury. Vehicle speeds in excess of the speed limit are common on residential streets in Auckland, and the average vehicle speed was in excess of the posted speed limit (50 km/h) at 42% of the pedestrian injury sites (Roberts 1994). As mentioned previously, Davies (1999) cites Webster & Mackie (1996) to show that accident reduction for pedestrians was around 3.85% for every km/h reduction in the speed limit.

McMahon (2004) stated that best practice examples included implementing traffic calming, which reduced vehicle speeds as the key measure to improve overall safety of road users, in particular children. The report compared the injury and fatality rate for school-age children in 21 countries, and found that the top performing countries for keeping children safe used area-wide traffic calming to a greater extent, and had a wider range of infrastructure safety measures. Making speed reduction a key objective in order to protect vulnerable road users was considered best practice.

Other examples of speed management recommended by McMahon as best practice are:

- using traffic-calming techniques and low speed zones, such as 'green district' and 'home zones', to make safe walking and cycling the dominant modes;
- making speed reduction a key objective in order to protect vulnerable road users;
- setting speed limits according to the function of the road hierarchy (roads with high pedestrian and cycling activity had designated limits no higher than 30 km/h);
- applying lower speeds on lower volume rural roads, and making footpaths and cyclepaths available;
- where low speed limits are less feasible (outside residential areas) and roads are wider with heavy traffic flows, designing safe places to cross the road is necessary (safety should be encouraged by use of zebra crossings and signalised intersections, pedestrian islands, and school crossing patrols where necessary); and
- for very busy roads, segregating pedestrians and motorised traffic, and providing foot bridges and tunnels may be necessary.

Austrroads report that small reductions in travel speed in pedestrian crashes makes a large difference to the outcome (with regards to the type and severity of injury). Small reductions in travel speed would result in a large increase in the proportion of pedestrians

surviving the accident, and a substantial proportion of pedestrian crashes would be avoided altogether. Lower speed limits would be likely to lower the frequency and severity of pedestrian and cycle crashes, although it is not possible to say by how much as it is not possible to predict what effect a lower speed limit would have on traffic speed compliance (Cairney 2000a).

New Zealand has an urban speed limit of 50 km/h, although where vulnerable road user activity is higher than usual, a lower speed limit may be used. LTSA have provided a guideline (LTSA 2004) for setting speed limits at less than 50 km/h. However, there are legal requirements when proposing a reduced speed limit. These include provisions as to where a lower speed limit would be likely to increase the safety of pedestrians, cyclists, or other road users. The guideline requires safe and appropriate traffic engineering measures to be installed so that the measured mean operating speed is within 5 km/h of the proposed speed limit. LTSA recommend that, along with installing low speed limit signs, a combination of traffic management treatments must be used (LTSA 2004).

2.4.3 Road geometry

Road geometry can impact on safety, with available sight distances to the crossing and the width of the road to be crossed being critical issues in the design and location of safe crossing places. The curvature (horizontal and vertical) of roads generally determines the available sight distances along the road. This together with the width of the road is an important feature in providing safe and attractive places for pedestrians and cyclists to cross (Dravitzki et al. 2003).

A number of guidelines, such as Austroads (1995), provide recommendations for the location of safe crossing places with respect to road geometry.

2.4.4 Road topography

The topography of the road encountered on the home-to-school journey can influence the type of engineering safety devices installed. Generally isolated traffic engineering devices, such as the speed hump or chicane, will not be implemented on roads with a steep gradient, or where sight distances are restricted because of vertical and horizontal curves. Engineering devices may require additional aids, such as advance signs or markers, to clearly indicate the presence of such devices. These issues highlight the importance of making sure the safety improvement measures are appropriate for the surrounding environment.

2.4.5 Land use

City planners and traffic engineers should take into consideration pedestrian preferences and perceptions when designing efficient pedestrian friendly facilities (Sisiopiku 2003).

The built environment should be planned in a way that stimulates children's growth and provides safe interaction with traffic. Urban design features can be used to support and complement children's safety in the road environment (McMahon 2004). Municipalities and local authorities can assist in the safety of children on their home-to-school journey by including safety features such as walkway and cycleway linkages and greenfield areas,

and ensuring that safety, from a child's perspective, is included when re-development takes place.

The road environment plays an extremely important part in choosing the type of engineering devices or treatment used to improve safety for children. Therefore it is essential that practitioners take the surrounding environment and road conditions into account when deciding the type of device to be used.

2.5 Safe routes to school programmes

Much has been written about Safe Routes to School (SRTS) programmes, and the literature has shown quite a variation in the interpretation of these programmes. Well-established SRTS programmes provide an integrated approach, looking at the whole home-to-school journey, the mode of travel, and the safety implications along travel routes. Education and enforcement, as well as the implementation of engineering devices, have been shown to be used effectively. However, although some initiatives are called SRTS programmes, they appear to focus only on one or two aspects of safety, such as primarily the situation at the school frontage, bus safety, or focusing on education.

As noted in the introduction, studies of SRTS programmes highlight the critical importance of providing an integrated approach with a balance across the three elements of engineering, education, and enforcement.

Evaluation of the outcome of these programmes can be difficult, depending on whether an evaluation focuses on the process of delivering the programme, or on the outcomes the programme produces in terms of reductions in road crashes (Rose 2000).

In terms of improving safety for schoolchildren on their home-to-school journey, the SRTS programmes that have been evaluated with regards to reduction in crashes are of the most interest. The Danish SRTS programmes have been evaluated over a long time period and in great detail, and the information gained is of importance to our research. Details of the Danish study can be found in the documents *Safe Routes to Danish Schools* (Jensen & Hummer 2002), and *Evaluation of Projects Regarding Routes to School in the Municipality of Odense* (Atkins 2002).

The Danish work outlines the history of the SRTS programmes which began with the municipal reform in 1970. It includes the Danish municipalities taking responsibility for primary and lower secondary schools. In 1976 the Danish Road Traffic Act required the police and road administrations to implement measures that protected children against moving vehicles on their way to and from school.

The Danish school route studies are part of the local road safety plans, as this found that the overlap of high risk locations, and spots where children feel unsafe, was large. School route studies are therefore very valuable in the development of local road safety plans because the number of accidents is often so low that it is impossible to identify blackspots from accident data alone. With the significant increase in car traffic volumes near schools, the management of traffic has been a major issue in many Danish municipalities in the period 1995 to 2000. The measures implemented to address these issues include:

- kiss-and-learn spaces (spaces meant for parents to drop their children off at schools),
- information to parents about stopping and parking,
- creation of one-way streets,
- traffic calming at schools,
- time-limited parking,
- speed limits,
- different start and finish times for children in different classes,
- improvement of access to school, e.g. drop-off/pick-up areas,
- better planning of school districts (land transport/land use planning),
- improvements of bus arrangements where routes are planned to reach all homes up to and including Class 3 – statutory obligation (free for younger children, with older children paying),
- adjusting students' meeting times (start and finish times),
- route advice to school children and parents,
- campaigns for personal safety equipment, e.g. reflective equipment on clothing, lamps, etc.,
- other safety campaigns,
- transport (habits) campaign (choice of travel mode),
- improvement to school's traffic safety education,
- cyclepaths, and
- speed control measures.

Other special measures that were targeted to school children's travel and road safety in Denmark during the period 1995 to 2000 (which was the SRTS evaluation period) consisted predominantly of:

- school route studies,
- physical measures to improve school child road safety, management of car traffic at schools, and increased level of service for walking and cycling,
- reduced school bus fares, and
- road safety campaigns and campaigns to discourage car travel by children to and from school.

The method of evaluating the traffic safety effect of the projects has been calculated on the basis of an assessment of accidents before and after the projects, balanced against a control group to correct for the general accident trends. The control group consisted of accidents which occurred in municipalities comparable to the city of Odense in terms of population, development, and level of urbanisation. The evaluation was conducted for the period 1989 to 1999.

The road safety evaluation indicated that school route studies do not have a significant direct effect on child safety, but they do nearly always result in other measures being

introduced, e.g. physical measures, campaigns, and changed school bus arrangements (Jensen & Hummer 2002).

The Danish evaluation concluded that:

- The school route projects have significantly reduced the number of accidents registered with the police, in fact by 18%, corresponding to 17.7 accidents a year. A falling trend in personal injuries was also identified, a fall of 20%, or 8.8 personal injuries per year. They saved the Danish nation some DKK (kroner) 15.7 million per year in the costs of accidents.
- The school projects have especially reduced serious accidents. Traffic safety has been improved for pedestrians, motorists, and motorcyclists, whereas the safety of cyclists and moped users has not been improved by the projects. Children and adults have benefited equally by the projects.
- The categorisation of the projects relating to routes to school clearly shows that measures such as:
 - traffic calming,
 - low-speed roads,
 - speed humps,
 - raised surfaces, and
 - signals,have been most effective in improving traffic safety. The relatively few projects using these account for two-thirds of the effect.

Importantly, the evaluation showed that the traffic safety effect of projects involving cyclepaths, tracks, and stripes showed significant statistical differences, where some projects made traffic safety considerably worse, while some others produced a considerable improvement. The recommendations (Atkins 2002) that came from this evaluation include:

- The introduction of low-speed roads, traffic calming systems, raised intersections, and various types of signalling systems are the initiatives which have resulted in the most benefit in terms of traffic safety. Thus the recommendation is to focus on this type of speed reducing measure, as well as the system of regulation at intersections.
- The investigation of accidents should be accorded a higher priority, rather than just using the students' expressions of perceived danger.
- To produce the best results, an in-depth analysis of projects involving cyclepaths should be made to identify the reasons why some of the cyclepath projects have been very successful, while others have actually reduced the level of traffic safety.

The evaluation of the Danish SRTS projects (Jensen & Hummer 2002) clearly show that:

- Local safer routes to school projects, and increased use of safety belts among children, are the most important reasons for the major reductions of children's risks on the roads in Denmark.

- The legislation has been successful in motivating local authorities to increase the number of safer routes to school projects.
- Road safety education and campaigns need to be focused more towards teenagers' motivation and other personality considerations.
- Traffic calming and the provision of better facilities for pedestrians and cyclists are dominant elements in Danish safer routes-to-school projects.
- The levels of walking and cycling among Danish children have decreased despite impressive safety gains and improved physical conditions for cyclists and pedestrians.
- Influencing parents' and children's attitudes through campaigns aimed at increasing the levels of walking and cycling is highly important if children's travel is to develop in a more sustainable direction as regards economic and social relations, the environment, and health.
- Attention to school structure is also highly important, because long school journeys are probably one of the largest threats to the creation of more sustainable transport.
- The number of children aged 6 to 16 years killed and injured in road traffic dropped by 46% during the period 1985–2000. About one quarter of the reduction in injuries was related to a drop in the number of children, and a lower average age.
- Increasing numbers of children and an increasing average age, with other things being equal, was predicted to result in a rise in the number of injuries in the period 1998-2000.

A number of other studies have summarised SRTS programmes in different countries, the more recent of these being *Safe Route to School Implementation in Australia* by Rose (2000), and *A Review of Safe Routes to School* by Davis (1996).

The work undertaken by Rose (2000) reports that the UK safe routes to school system is based on the Danish model, and has engineering treatments as an integral component of the programme. The measures include reduced speed limits near schools (linked to school start and finish times), traffic calming, intersection improvements, cyclepaths, crossing facilities, and enhanced signing. The Australian programmes include engineering treatments such as signage, and new crossings, pedestrian refuge islands, speed humps, reviews of parking signage, construction of pick-up/drop-off points, fencing, and curb extensions.

The American published literature was reported to have a major emphasis on the safety issues associated with bus transport to and from school. Traffic engineering treatments included in some programmes are evaluated on the basis of the cost, effectiveness, physical feasibility, and impacts on traffic flow. Higher ranked treatments included increased maintenance, speed reductions through enforcement, improving sight distances, installing bicycle detectors at intersections, and providing adult crossing guards (Rose 2000).

In New Zealand the evaluation of the SRTS programme showed that, generally, school principals felt it is an excellent programme, and they were especially impressed with the

engineering works which resulted. The principals believed that the SRTS programmes had the effect of widening horizons out into the community, and focusing staff on children's needs beyond the school gate. The programme was felt to be limited in the impact it had on the children themselves, as most children were only involved in the travel survey and in a classroom project in road safety for the week or two during the time the surveys were taking place. The paper by Williams (2000) resolved that *Safer Routes to School* will not create a road safety culture on its own.

Davis (1996) aimed to stimulate discussion rather than provide a particular approach to school travel issues. The paper suggests that highway authorities' resources were already limited, and how much progress could be made on school travel plans without greater political commitment was questionable. Davis reports that, only as traffic calming has moved into a 'mature' state, has interest in safer routes to school revived. County councils do recognise the importance of encouraging children to walk or cycle to school, mainly however to reduce the number of motorised school trips. Popular measures on school routes are road narrowing, cyclepaths, warning signs, and traffic islands.

Davis (1996) also examined the state of SRTS programmes in other countries, and sets out the state of them in Germany and the Netherlands. In Germany over the past decade a sizable number of traffic-calming programmes have been linked to the control of traffic in the vicinity of schools. Some places have invested heavily in favour of cycling and other measures to reduce car use. The general approach has been to pursue safety improvements within the framework of the widespread introduction of Tempo 30 zones, which are now commonplace throughout Germany and a number of other northern European countries (e.g. Switzerland and Austria).

The basis of the approach in the Netherlands is to develop a clear road hierarchy, with 30 km/h zones having a level of uniformity in design so that road users will readily understand what the expected speed limits are in conjunction with the nature of the area they happen to be travelling through. From this approach, safety on the school journey is part of the wider general safety concern (Davis 1996).

2.6 Perceived safety risks

Perceived safety risks are an important factor for parents in making the decision to allow children to journey to school unaccompanied. Research that has surveyed the reasons why children feel unsafe on the journey to and from school is available, and similar surveys have investigated the reasons parents have for driving children to school by car.

Common reasons children gave for feeling unsafe were found in the work undertaken in Denmark (Jensen & Hummer 2002), New Zealand (North Shore City Council 2004), and America (Dissanayake et al. 1999). The children's most often mentioned causes to their unsafe feelings include:

- high vehicle speeds,
- high vehicle volumes,
- missing cyclepaths and footways,

- lack of safe crossing places (including lack of crossing guards),
- poor sight conditions at crossings,
- poor maintenance of roads and paths (including vegetation that restricts footpaths and sightlines),
- poor intersection design (including confusing junctions, poor visibility at crossings, and lack of proper signage and traffic signals),
- lack of drop-off and pick-up zones (including confusing parking conditions close to the school), and
- drivers not giving way.

Other perceived risks identified include:

- lack of parental supervision,
- lack of secure cycle facilities at school (including lack of cycle safety programmes),
- inadequate or non-existent road lighting, and
- high volumes of heavy vehicles like trucks and buses.

The same research lists the parents' most frequently mentioned reasons for driving their children to school by car as being:

- parents are also travelling on the same route,
- the school route is perceived to be dangerous,
- the school journey is too long to walk or cycle,
- children too young for independent transport,
- younger siblings are driven,
- the weather, and
- lack of cyclepaths.

The New Zealand *Travelwise to School* programmes also identified the following additional reasons why parents drove their children to school:

- school bags are too heavy,
- before and after school activities, and
- prefer to accompany the child for more quality time.

Actual risk per trip, hour, or kilometre that children experience reveals that the risk among older children is highest for any individualised mode of transport despite the fact that older children have better skills. Older children sustain more injuries because they have a longer travel time to get to school, on major roads with higher speeds (Jensen & Hummer 2002).

Older children also exhibit lower adherence to responsible social values than young children (Jensen & Hummer 2002).

Suggested engineering countermeasures to address perceived safety included:

- school zones speed control,
- intersection improvements,

- traffic calming schemes,
- provision of safe crossing places on roads with higher traffic volumes,
- low speed roads,
- speed humps,
- raised surfaces,
- signals, and
- reduced pedestrian crossing distances.

2.7 Legislation

The legislation and policies that are in place to reduce injuries to children gives some indication of the political will to address these issues. Transport and traffic legislation regulate motorised traffic, but it often fails to focus on children's safe mobility as cyclists and pedestrians. In a debate on children's rights to a safe and accessible environment for their independent travel, Hillman (1993) in the UK reported,

How important these rights are can perhaps be inferred from our former Prime Minister's statement at the World Summit on Children in 1991, when she said, 'The well-being of children requires political action at the highest level. We [meaning no doubt the British Government] make a solemn commitment to give priority to the rights of children'.

It seems that we need to state emphatically that children must have a safe and accessible environment outside their homes if Article 6 of the UN Convention of Children's Rights, aimed at ensuring as far as possible no impediments to their emotional and physical environment, is adhered to. To this end, we need new indicators both of a 'safe' and of an 'accessible' environment (Hillman 1993).

The OECD report *Keeping Children Safe and Traffic* (McMahon 2004) examined legislation that benefited children. The report provides information on the OECD countries that had active progressive legislation that benefited children's safety in the built environment. These countries included Denmark, Norway, Belgium and Netherlands, France, Germany, Poland, and Switzerland. The legislation provided is summarised (McMahon 2004) as follows.

Driver responsibility

- France has adopted the 'Badinter Law' which places the burden of responsibility on drivers involved in a collision with a child. An OECD survey found that the top-performing countries on children's road safety have similar regulations, including Germany, Iceland, the Netherlands, and Sweden.

Child pedestrians

- Several countries have adopted a minimum pavement width requirement of 1.5 m (including accommodating the placement of lamp posts, traffic signs, and post boxes); 2 m for one-way cyclepaths, and 3 m for two-way paths.

- In Germany drivers are required to respect children's safety by reducing speed and yielding to children.
- Also in Germany, drivers are required to honk their horn to provide a warning signal when they perceive children and traffic who are not paying attention.

Child cyclists

- In Denmark children under the age of 6 who cycle in traffic must be accompanied by a person of at least 15 years of age.
- In Germany and Poland children up to 10 years of age are allowed to use the footpath for cycling, and children under 8 years must cycle on the footpath if there are no separate cycle lanes.
- New Zealand requires that cyclists, including schoolchildren, wear approved cycle helmets while cycling.

Public transport

- In both Norway and Denmark children up to the age of 6, living 1 km or more from school, or older children living more than 3 km from school, are entitled to free school transport. When the route is deemed unsafe the municipality is required to provide children free transport for shorter distances.

Parking

- Some Dutch schools prohibit parking in front of schools. Parking prohibitions are in place near school crossings or zebra crossings to provide the children with unobstructed views of intersections.

Land use planning

- In Norway each municipality appoints one department head or other civil servant to be specifically responsible for children's interests when proposing development plans and building proposals.

The New Zealand legislation (LTSA 2003) includes speed restrictions requiring drivers to slow down to 20 km/h or less until the driver is well past a school bus, no matter which direction the driver is travelling. The regulations also require that, when any school patrol sign is out, vehicles coming from both directions must stop and stay stopped until all signs have been pulled in, and that drivers need to look out for school patrol warning signs. These signs include cones which may be placed in the centre of the road close to the crossing, or red flags attached to poles at the side of the road.

Drivers are required to be alert for cyclists on the road and drive carefully when near them (LTSA 2003). Traffic Note No. 37, *40 km/h school zones – guidelines*, allows slower speed zones to be established provided that they comply with the guidelines (LTSA 2002c).

In America, Californian regulations (CDMV 2004) state that pedestrians have the right of way at corners, whether or not the crosswalks are marked by painted white lines. Drivers are required to stop for any pedestrian crossing at corners or other crosswalks, and are not allowed to pass any car from behind when it is stopped at the crosswalk. There are special speed limits around children, and motorists are required to drive more carefully

near schools. The speed limit is 25 mph (40 km/h) within 500 feet (c.150 m) of a school while children are outside or crossing the street. If a lower speed limit is placed near schools, it should be complied with.

The Californian laws concerning school buses require that the motorist must stop when coming upon a school bus that is stopped on either side of the road with flashing red lights. The motorist must remain stopped as long as the red lights are flashing, as children will be crossing the road to and from the school bus. Flashing yellow lights on buses are a warning to the motorist to prepare to stop because children are preparing to leave the bus. Failure to comply with these rules results in a heavy fine and/or a driving suspension (CDMV 2004).

In South Australia, motorists are restricted to a 25 km/h speed limit where this is signed outside a school zone. The speed limit only applies when children are present, or if time periods are shown.

Legislation that gives greater rights to pedestrians, and in particular to vulnerable pedestrians (such as children and the elderly), is needed in New Zealand if the country is to reach the safety performance levels of many other countries.

2.8 Key themes

As the literature review showed, the issues that surround school journeys are very complex and intertwined. It is vital that the literature is considered when designing guidelines for best practice. The low number of incidents that involve children at specific locations means that it is very difficult to draw substantive conclusions except through a long-term study. All of the literature is general, and care needs to be taken when interpreting the information or applying it to real-life situations.

Traffic management, traffic calming and safe places to cross are the focus of much of the literature. Crossing a road is the most dangerous part of the school journey and affects the users of all of the different modes of travel. This may include crossing the road at the school gate to reach a waiting private vehicle, crossing the road when being dropped off by a school bus, or crossing a road as a pedestrian or as a cyclist. Safe crossing places need to fit the road environment that they are in. The literature shows that no one 'magic bullet' exists that will be the best solution for every crossing situation. The best solution will be found only through understanding the suitability of each kind of device given the road conditions such as traffic speed and traffic volume on reduced speed zones.

Reduced speed zones are shown by the research to be strongly effective. In many countries speed zones of 30 km/h have successfully been implemented both around schools and in residential areas. New Zealand has introduced 40 km/h speed zones around some schools. The reduced speed zones in New Zealand have the advantage of using technology to ensure that the zones seem reasonable and necessary. Even so, cost makes wide scale implementation unlikely. Lowering the speed limit by only 10 km/h does not maximise the safety outcomes of such a system. Unless reduced speed limits are strictly enforced the new zones will be pointless.

The use of signalised mid-block crossings is one of the most contentious issues in the literature, and evidence regarding the suitability of these signalised crossings is conflicting. Some studies have indicated in that, in terms of safety, signalised crossings are less safe than intersection signalised crossings. Signalised mid-block crossings tend to be plagued with high rates of non-compliance by both pedestrians and drivers. Compared to signalised intersection crossings, the injuries tend to be more severe because of the speed of the traffic. However, situations also occur where the signalised mid-block crossing is the most suitable crossing, for example, when the distance between intersections is long and multiple lanes have to be crossed in each direction. Where possible the crossing should be moved to an intersection, with visual cues added for the driver and, for single-lane roads, zebra crossings should be considered as an alternative.

School bus safety and safety at railway level crossings are highlighted in the research as being worldwide issues of concern.

Legislation that supports these key issues and focuses on vulnerable road users is needed.

Integration of issues and the changing way that students travel to school need to be considered in developing all home-to-school travel programmes. Taking engineering devices in isolation, or ignoring the substantial research in to traffic education, will not achieve the best safety results. Bishai et al. (2003) report that parents are concerned with the safety of their children, and are prepared to spend time and money on safety improvements, and these safety improvements can be physical measures or education measures. It is important that any safety message to be considered is relevant.

Hoffage et al. (2003) have a novel approach to safety education. Instead of targeting all children with general rules, they recommend targeting those children who are more likely to make risky decisions when crossing.

3. Survey of engineering devices

3.1 Methodology

Two questionnaires were prepared and circulated both in New Zealand and other countries.

The type 'A' Questionnaire was intended for RCAs and was completed by traffic engineers and road safety officers.

The type 'B' Questionnaire was intended for major stakeholders such as policy and standards organisations, police and other injury-prevention groups interested in improving safety for children on their home-to-school journey.

The questionnaires to the RCAs were more extensive, reflecting their role and knowledge of the road networks. Copies of the questionnaires are appended to this report as Appendices 1 and 2.

The questionnaires were aimed at obtaining a list of current interventions used in New Zealand and overseas. From reviewing the information submitted a list of the most effective countermeasures was developed. The questions sought a ranking of the effectiveness of the devices along with views of where they were appropriate to be used.

The analysis of the New Zealand responses was compared against the overseas responses in terms of their safety and cost effectiveness.

3.2 Response rate

3.2.1 Summary of Questionnaire A – New Zealand respondents

Questionnaire A received 25 responses, of which 21 RCAs completed the summary sheet, one provided a descriptive email response, and three declined to complete the survey because of resource reasons. A total of 141 engineering devices were described and the table below lists the districts that did respond.

Council	Devices
Rodney District Council	6
Queenstown Lakes District Council	9
Far North District Council	1
Whakatane District Council	3
New Plymouth District Council	8
Hutt City Council	8
Marlborough District Council	3
Timaru District Council	11
Palmerston North City Council	5
Waimate District Council	2

Council	Devices
Otorohanga District Council	3
Hastings District Council	8
Clutha District Council	3
Auckland City Council	10
North Shore City Council	23
Manukau City Council	6
Franklin District Council	1
Wairarapa Subregion: South Wairarapa, Masterton, Carterton District Councils	12
Manawatu District Council	2
Rotorua District Council	11
West Coast Regional Council	3
Mackenzie District Council	3*

* Descriptive email response

3.2.2 Summary of Questionnaire A – Overseas respondents

The four overseas jurisdictions who responded to Questionnaire A are shown in the table below. Forty two devices were described by them.

Location	Devices
City of Calgary, Calgary, Alberta, Canada	9
City of Saskatoon, Saskatoon, Saskatchewan, Canada	7
Brisbane City Council, Brisbane, Queensland, Australia	16
City of Ottawa, Canada	10

3.2.3 Summary of Questionnaire B – New Zealand respondents

Six organisations responded to Questionnaire B. Thirty two devices were detailed in the responses, as shown in the table below.

Organisation	Devices
NZ Police & Youth Education	3
NZ Police Northland District HQ	5
NZ Police Pukekohe	9
NZ Police Kerikeri	6
LTSA – Safer Routes	7
NZ Police Horowhenua	2

3.2.4 Summary of Questionnaire B – Overseas respondents

Only one response to the Overseas Summary Questionnaire B was received. Eleven devices were detailed in the response.

Organisation	Devices
Road Wise Western Australia	11

The responses have provided valuable information and feedback on the devices used.

The survey included questions about locations where the devices are typically used. This included type of road, typical speed limit, how close they were to the school, and the predominant surrounding land use. The responses also provided information on the effectiveness and order of cost of the devices.

The respondents included RCAs from large cities, medium cities, and district councils who are largely responsible for the rural areas. The overseas responses to the questionnaires were from cities only.

The responses do show, in most cases, an alignment in the views being expressed.

3.3 Inventory of responses and devices

3.3.1 Responses

The following table of devices has been derived from the responses to the summary section of Questionnaire A.

In some cases very few of the devices were in place, only a small number respondents mentioned them, or they were new (for example the 40 km/h zones). Some caution is therefore required in interpreting the results.

The costs require further evaluation as they show a considerable range which may reflect whether other complementary engineering work was also required.

The blank section is where no information was received from the respondents. The estimated number of devices are generally the sum of all the responses. However, not all respondents were able to provide information on the number of devices in their jurisdiction.

The number of respondents providing a response on a device is shown in brackets. Effectiveness is out of 10 with 10 being the most effective.

Table 3.1 Responses from New Zealand sources to Questionnaire A with an inventory and effectiveness of the devices they use.

Device	Cost \$	Urban		Rural	
		Estimate of numbers	Effective-ness	Estimate of numbers	Effective-ness
Safe crossing places					
<i>Uncontrolled</i>					
Kerb extensions					
Pedestrian refuges (9)	800-10,000	303	5-9, 10	18	5-7
Adult wardens					
Crossing wardens	100	6	6		
<i>Controlled (part time)</i>					
Kea crossing (15)	3000-16,000	109	6-10, most = or >8		9
School patrols (4)	4-10,000	42	8-10		
<i>Controlled (full-time)</i>					
Pedestrian (zebra) crossings (18)	800-20,000	411	4,6-10 most = or > 8	4	
Pedestrian traffic signal crossing (4)	8000, 40-80,000	21	8-10		
Traffic signals at intersections					
Traffic signals with pedestrian time adjustments at school times					
Cycle signals (1)	2000	1	8		
Warning devices for crossing places					
School crossing signs					
School crossing ahead signs					
Flashing lights on approaches & at crossings (2)	1500-4000	2	4-8	3	7
Fluoro discs at pedestrian crossings (8)	60-100	839	6-8		
Belisha beacons		6	8		
Portable speed indication variable message signs (1)	12-20,000	1	10	1	10
Speed-sensitive signs					
<i>Special markings</i>					
Limit lines before crossings (1)	50	200	6		
<i>Special signs</i>					
School crossing sign (1)					
School area signs					
Children crossing sign (2)					9
Foldout day-glo school signs (1)	100	6	6	2	6
Billboards (2)	200-600	12	7	10	10
Green man crossing signs (2)			6-10		10
Vulnerable road user sign (1)	300		7		
Special signs (3)	100-250	210	7-8		
Special markings (2)	25/km, 200	1km, 10	7-9		
Traffic cones (4)	50ea, 100	60	6-10		

Device	Cost \$	Urban		Rural	
		Estimate of numbers	Effective-ness	Estimate of numbers	Effective-ness
Slow traffic speeds/ reduce traffic volumes					
Speed humps (8)	3-10,000	95	5-8		
Chicanes (1)	10,000	20	5		
Raised platforms/tables (3)	6,000	30	7		
Road narrowings (7)	2-12,000	75	5-8	1	7
Roundabouts					
Restricted speed limits		1	6	2	6
Speed limits					
40 km/h zones (1)	45,000			1	8
Safe route to school programmes					
Footpaths					
Footpaths					
Protection of footpath from roadside vehicles					
Pedestrian barriers/fences (4)	100/m 500-1000	29	6-7	200m	7
Bollards					
Special markings for pedestrians (feet at road edge)					
Barrier to control entrance to parking areas (1)	100	20	8		
Underpass/ overbridge (1)	500,000	1	10		
Road closures					
Conspicuity devices					
Safety Jackets			8		
Personnel reflective conspicuity aids					
Cyclepaths					
Cycle lanes on roads (4)	2,500/km, 150/km/side	12, 10km, 12km	5-10	2	10
Cycle lanes on footpaths		6	6		
Bus safety					
Recessed bus stops					
Bus waiting areas (1)	60/sqm	10	6		
Conspicuity of buses					
Warning signs on buses					
Parking					
Pick-up-drop-off zones (1)	10-20	20	8		
Car parks		4	10	2	8
Recessed parking bays					
Parking restrictions (1)	100ea	60	6		

The following is the inventory of the responses from other countries.

Table 3.2 Responses from other countries to Questionnaire A, with an inventory and effectiveness of the devices they use.

Device	Urban		Rural	
	Estimate of numbers	Effective-ness	Estimate of numbers	Effective-ness
Safe crossing places				
<i>Uncontrolled</i>				
Pedestrian refuges (3)	50	8-9		8
<i>Controlled (part time)</i>				
Adult crossing guards (1)	22	9		
Flashing LED stop paddles (1)	2	8		
<i>Controlled (full-time)</i>				
Pedestrian (zebra) crossings (4)	1500	3, 7-9		3
Pedestrian traffic signal crossings (1)	6-8	8		
Pedestrian crossing with overhead lighting				
Warning devices for crossing places				
<i>Special markings</i>				
Special markings (1)		7		7
Special signs (1)		5		5
Flashing lights on approaches and at crossings (1)	2	7		
Special signs (1)	589	6	72	6
School Area Signs (1)	253	6	17	6
School crossing signs (1)	137	6	7	6
<i>School crossing ahead signs</i>				
Billboards				
Painted kerbs (1)	150	7		
School zones (1)	100	9		
Slow traffic speeds/ reduce traffic volumes				
Road narrowings (5)	5-10	5-8		7
Kerb extensions				
Speed humps (3)	5	3-7		3
Raised platforms (1)		9		
Chicanes				
Speed limits				
Portable speed variable message sign				
30km/h school zones				
40km/h zones & thresholds (Aust) (2)	900	8-9		8
Footpaths				
Footpaths (1)		9		10

Device	Urban		Rural	
	Estimate of numbers	Effective-ness	Estimate of numbers	Effective-ness
Protection of footpath from roadside vehicles				
Pedestrian barriers/fences (4)	2	6-10		
Bollards				
Special markings for pedestrians (feet at road edge) (1)	150	8		
Cyclepaths				
Cycle lanes (2)		4-9		4
Parking				
2 minute parking restrictions				
Safety Programmes				
Safe Routes to school (1)	6	7		
Kiss & Ride programme (1)	3	7		
Traffic Safety outreach programme (1)	243	7		
Walking school bus (1)	2	6		
Ottawa Safety Village (1)	8000 children/yr	7		

3.3.2 Effectiveness

The survey requested responses on the effectiveness of the various devices based on the experience of the respondents. The following table outlines the rating of the respondents. The table uses four ticks for the greatest support with a single tick for the least. The survey did not get responses for all the devices hence the blank sections.

The Questionnaire was aimed at two groups:

- A the RCAs, and
- B the major stakeholders.

The responses for effectiveness of devices for Questionnaire B showed a similar pattern of support to those for Questionnaire A.

Table 3.3 Effectiveness of engineering devices employed by RCAs in New Zealand, from responses to Questionnaire A.

The devices are ranked in groups, with most ticks for the group having the highest support

Device	Safety				Encouragement			Support				
	Improving safety for children	Slowing vehicle speeds	Children more conspicuous to motorists	Motorists aware of children	Encouraging more children to walk	Encouraging more children to cycle	Encouraging children to use other non-motorised modes	Degree which funding influenced installation	Support from Policy & Standards organisations	Police support	RCA support for use	School support
Crossing roads												
Pedestrian (zebra) crossings	√√√	√√√	√√√	√√√	√√	√√	√√	√√√	√√√	√√√√	√√√	√√√√
Pedestrian traffic signal crossings	√√√√	√√√√	√√√√	√√√√	√√√√	√√	√√√√	√√	√√√√	√√√	√√√	√√√√
Traffic signals												
Traffic signals with adjustments for pedestrians at school times												
Cycle signals												
Kea crossings	√√√	√√√	√√√	√√√	√√√	√√	√	√√√	√√√√	√√√	√√√	√√
School patrols	√√√√	√√√√	√√√√	√√√√	√√√√	√√√√	√√√√	√√√	√√√√	√√√	√√	√√√√
Pedestrian refuges	√	√	√√	√√	√√	√√	√√	√	√√	√	√√	√
Adult wardens												
Crossing wardens												
Speed control measures												
Speed limits												
Restricted speed limits												
40 km/h zones	√√√√	√√√√	√√√√	√√√√	√√√√	√√√√	√√√√	√√√√	√√	√√√√	√√√√	√√√
Modifying roads												
Road narrowings	√√	√√	√√	√√	√√√	√√√	√√√	√	√√√	√√	√	√√
Kerb extensions												
Speed humps	√	√√√	√	√	√√	√√√	√√√	√√	√	√	√√	√
Raised tables												
Chicanes	√√	√√	√√	√√	√√√	√√√	√√√	√	√√√	√√	√	√√
Roundabouts												

3. Survey of engineering devices

Device	Safety				Encouragement			Support				
	Improving safety for children	Slowing vehicle speeds	Children more conspicuous to motorists	Motorists aware of children	Encouraging more children to walk	Encouraging more children to cycle	Encouraging children to use other non-motorised modes	Degree which funding influenced installation	Support from Policy & Standards organisations	Police support	RCA support for use	School support
Parking management												
Bus stop waiting area												
Pick-up drop-off zones												
Parking restrictions												
Car parks												
Warning information for motorists												
Special signs	√√√	√√	√√	√√	√√√	√√√√	√√√	√√√√	√√	√√√√	√√√√	√√√
Special markings	√√√	√√	√√	√√	√√√	√√√√	√√√	√√√√	√√	√√√√	√√√√	√√√
Billboards												
Flashing lights on approaches, & at crossings	√	√√	√	√√√	√	√	√√	√	√	√√	√	√√√
School area signs												
School crossing signs												
Vulnerable road user signs												
School crossing ahead signs												
Foldout day-glo school signs												
Portable speed indication variable message signs												
Fluoro discs at pedestrian crossings	√√	√	√√√	√	√	√	√	√√	√√√	√√	√√√	√
Belisha beacons												
Limit lines before crossings												
Safety jackets												
Green man crossing signs												
Traffic cones												

Device	Safety				Encouragement			Support				
	Improving safety for children	Slowing vehicle speeds	Children more conspicuous to motorists	Motorists aware of children	Encouraging more children to walk	Encouraging more children to cycle	Encouraging children to use other non-motorised modes	Degree which funding influenced installation	Support from Policy & Standards organisations	Police support	RCA support for use	School support
Protection from roads/vehicles												
Pedestrian barriers/ fences	√√	√	√	√	√	√	√	√√√√	√	√	√√√√	√√
Special markings for pedestrians (feet at road edge)												
Bollards												
Footpaths												
Cycle lanes on roads												
Cycle lanes on footpaths												
Barrier to control entrances to parking areas												
Underpass/ overbridge												
Road closures												

Table 3.4 Effectiveness of engineering devices employed by major stakeholders in other countries, from responses to Questionnaire A.

The devices are ranked in groups, with most ticks for the group having the highest support

Device	Safety				Encouragement			Support				
	Improving safety for children	Slowing vehicle speeds	Children more conspicuous to motorists	Motorists aware of children	Encouraging more children to walk	Encouraging more children to cycle	Encouraging children to use other non-motorised modes	Degree which funding influenced installation	Support from Policy & Standards organisations	Police support	RCA support for use	School support
Crossing roads												
Pedestrian (zebra) crossings	√	√	√	√	√√	√	√					
Pedestrian traffic signal crossings												
Pedestrian crossing with o/head lighting												
Pedestrian refuges	√√√√	√√√	√√√√	√√√	√√√√	√√	√√					
Adult crossing guards												
Flashing LED stop paddles												
Speed control measures												
Speed limits												
Portable speed variable message sign												
30 km/h zones	√√√√	√√√	√√√√	√√√√	√√√	√	√					
Modifying roads												
Road narrowings	√√√	√√√√	√√√√	√√√√	√√√√	√√√√	√√√√					
Kerb extensions												
Speed humps	√	√√√	√√	√	√	√	√					
Raised platforms												
Chicanes												
Cycle lanes	√	√√	√√√	√√	√	√√√√	√					
Parking management												
Two-minute parking restrictions												

Device	Safety				Encouragement			Support				
	Improving safety for children	Slowing vehicle speeds	Children more conspicuous to motorists	Motorists aware of children	Encouraging more children to walk	Encouraging more children to cycle	Encouraging children to use other non-motorised modes	Degree which funding influenced installation	Support from Policy & Standards organisations	Police support	RCA support for use	School support
Warning information for motorists												
Special signs	√√	√√	√	√√	√√	√√	√√√					
Special markings	√√√	√√√√	√√	√√√√	√√√	√√√	√√					
Billboards												
Flashing lights on approaches, & at crossings	√√	√√√	√	√√√	√√	√	√					
Portable speed indication variable message signs												
Protection from roads/vehicles												
Pedestrian barriers/ fences	√√	√	√√	√√	√√√	√	√					
Special markings for pedestrians (feet at road edges)												
Bollards												
Footpaths	√√√√	√	√√√	√√	√√√√	√√√	√					

3.4 Key themes

A key theme that has come from the survey, from both New Zealand and overseas sources, is the increased use of visibility enhancing devices such as traffic cones, fluoro signs at pedestrian crossings, day-glow message signs, and bright fluoro jackets. The commonly held view is that these devices make a difference in making crossings more prominent. A range of colours are being used and a range of messages are displayed on the signs. However, the brightness or conspicuity of the device would seem to be the most significant factor.

An increasing use of devices to manage speed is taking place, with speed humps and tables being installed for pedestrian safety reasons in the residential areas where they can be provided.

The respondents, especially those answering Questionnaire B, favour devices that involve more control of motorists, such as speed limits and traffic signal-controlled crossings.

Although not technically an engineering safety device, safety programmes are a growing area of safety opportunity, with walking school buses being increasingly adopted as a safety measure in New Zealand. The City of Ottawa survey response has shown that five schools there have walking school bus programmes. In New Zealand road safety officers, who help to implement such programmes, are funded by LTSA and the RCAs. The cost of associated physical works is often shared by local, regional and national providers.

4. Discussion

This chapter brings together the key findings of the literature review (Chapter 2), and the survey of engineering devices used (Chapter 3), with the aim of establishing 'best practice' treatments for improving safety for children on their home-to-school journey. Gaps in knowledge of the effectiveness of safety devices used are also identified.

From the work in the previous sections, the engineering devices used can be re-grouped under the following sections:

- safe crossing places and warning devices for crossing places,
- slower traffic speeds/reduced traffic volumes,
- safe route to school (or similar) programmes,
- footpaths and protection of footpath from roadside vehicles,
- conspicuity aids for children walking and crossing roads,
- cyclepaths,
- bus safety,
- parking, and
- personal security.

4.1 Literature review and survey of engineering devices

From the literature review the main points for comparison are:

- Traffic calming, low speed roads, speed humps, raised surfaces, and centralised crossing places are the most effective treatments for improving traffic safety.
- In projects involving cyclepaths, tracks, and markings, it is unclear which of these has produced notable improvements. Significant statistical differences have been recorded, ranging from safety being much worse to being considerably improved.
- The slowing of traffic speed in the vicinity of children and where children congregate has a greatly improved safety effect, with a reduction in both incidents and the severity of injuries.
- Warning devices, such as flashing amber lights located at crossing places in front of schools, have an effect on safety by making motorists aware of the crossing.
- Focusing on perceived problems raised by school-age children and parents helped to identify problem areas or areas of concern. However, it is equally important to investigate crash data.

From the survey of engineering devices the main devices that were seen as being most effective in improving safety are:

- school patrols,
- signalised crossings,
- speed zones,
- pedestrian (zebra) crossings,

- kea crossings,
- footpaths, and
- pedestrian refuge islands.

These devices improve safety by slowing vehicle speeds, making children more conspicuous to motorists, and making sure motorists are aware of children.

Relatively few responses were received from overseas organisations. The responses that were obtained indicated that footpaths, speed zones, pedestrian refuge islands, special markings, and road narrowings were used to improve the safety of children. These devices were also used to slow vehicle speeds.

Differences between urban and rural situations drastically affect the appropriateness of devices, and highlights the need for practitioners to clearly establish the type of environment the device is to be used in. There is a need to separate urban and rural areas when applying any guidelines and toolbox recommendations. The list below sets out some of the important differences between urban and rural areas.

Schools in rural areas generally have:

- lower vehicle numbers,
- smaller pedestrian numbers,
- possibly high heavy vehicle numbers (certainly as a percentage of the total traffic volume),
- an open road speed environment, usually 100 km/h,
- generally high speeds on the approaches to a school, even if a lower speed zone is in place at the school,
- surrounding land may be of open rural character with little to encourage lower vehicle speeds,
- classification of the road may be a highway, and
- a higher proportion of motorists will not be local (probably on a through trip) and therefore will be unfamiliar with the environment and school activities.

Schools in urban areas essentially have the opposite characteristics, such as:

- lower speed limit, generally 50 km/h within the city boundaries, with some exceptions with speed limits of 60 km/h,
- high traffic volumes,
- consistent travel commuting patterns where motorists are familiar with the surrounding environment and activities, and
- an urban infrastructure and surrounding land uses.

4.2 Summary of information

Table 4.1 provides a summary of the information obtained from the literature review and survey of engineering devices. This table enables some comparisons to be made, indicates gaps in knowledge, and gives an indication where it is or is not appropriate for a device to be used. Because the number of responses to the survey was low, caution needs to be taken in interpreting the results. Even so, the authors believe that important information can be gleaned from it.

Table 4.1 Summary of literature review and survey of engineering devices.

Type of device	Survey results	Literature review results
Safe crossing places		
<i>Uncontrolled:</i>		
Kerb extensions / road narrowings	Well used in NZ, average to moderate rating for safety effectiveness (5-8 out of 10). Cost – \$2,000-\$12,000 each. Response from Canada: they are used with bollards at major crossing points both at intersections and mid-block.	Useful for channelling pedestrians to a crossing point. More effective when combined with parking restrictions (to preserve sight lines between pedestrians and motorists).
Pedestrian refuge islands	Extensively used in NZ moderate to higher rating for effectiveness (5-9 out of 10). Cost – \$800-\$10,000 each.	Increase driver awareness. Safety gains minor, however where refuge islands are installed without kerb extensions (i.e. when road width is not narrowed), safety problems may increase.
Adult supervision or warden crossings	Adult supervision required at NZ school pedestrian crossings, and warden crossings; however not listed in survey responses. Crossing warden's moderately rated for effectiveness (6 out of 10). Adult Crossing Guards rated high for safety effectiveness from overseas survey responses (9 out of 10). Guards hired by the municipality to assist children and crossing the road at peak times. Cost – c.\$12,000/guard/year.	
<i>Controlled (part time)</i>		
Kea crossing (School crossing)	Increasing use of kea crossings, generally rated as being quite effective (6-10 out of 10). Cost – \$3,000-\$16,000 each. Local or Collector roads only, not on rural roads or urban arterial (or main) roads.	NZ has a high non-compliance rate with the installation of these crossings to standards and recommendations. Anecdotally the crossings are effective. Some anecdotal evidence about non-compliance rates of drivers around these devices.
School patrols	Rated high for safety effectiveness (8-10 out of 10), moderate use in NZ. Cost – \$4,000-\$10,000 each.	

Type of device	Survey results	Literature review results
Controlled (full-time)		
Pedestrian crossing (zebra)	<p>Rated moderate to high for safety effectiveness (6-10 out of 10), average 8. Widely used in NZ, primarily in urban areas.</p> <p>Cost – \$800-\$20,000.</p> <p>Not over multi-lane roads with two or more lanes in one direction. Not on high speed roads and generally not in rural areas (where speeds are high).</p> <p>Moderate rating for safety effectiveness from overseas survey responses (7 out of 10), used in urban areas only.</p>	<p>May be safer for children than crossing elsewhere, however crashes still occur on marked pedestrian (zebra) crossings. NZ crossings have a high non-compliance rate with installation of crossings to standards and recommendations.</p> <p>Australia reports no reduction in crash numbers when pedestrian crossings installed. However such installation results in 30% reduction in total number of accidents in the pedestrian network. Pedestrian crossings marked on raised platforms (wombat crossing) has 8% reduction in traffic crashes.</p> <p>Response from Canada mentions that effectiveness is reduced in winter by snow cover.</p>
Mid-block signalised crossings	<p>Rated high for safety effectiveness (8-10 out of 10), not a large number of installed in NZ.</p> <p>Cost – \$8,000 to \$80,000.</p> <p>Higher rating for safety effectiveness and overseas response (8 out of 10). Used in urban area only.</p> <p>Cost – c.\$45,000-\$65,000 each.</p> <p>Comments from Canada about high standards of signs and markings required.</p>	<p>Some safety improvements include non-skid surfaces and guard rails at mid-block pedestrian crossings. Signalised mid-block crossings have higher crash rate than signalised intersections, and pedestrian injuries more serious at mid-block crossings compared to those at signalised intersections. Both pedestrian and motorist non-compliance with signals is a problem. Adjustments to signal phase times may provide some safety benefits. However mid-block signalised crossings are effective on high volume roads.</p>
Signalised intersection		<p>Generally effective, crashes mainly involved turning traffic, injuries less severe (than mid-block crashes). Compliance with traffic signals a problem in low traffic volume of situations.</p>
Grade separation	<p>Very effective, relatively small number used in NZ and overseas.</p> <p>Appropriate for very high traffic flows and/or very high traffic speed, e.g. motorway or freeway.</p>	<p>Most effective, however very expensive. Some problems with personal safety for subways, and lack of use for overbridges.</p>
Crossing railway lines		<p>Safety gates, mazes, fences, warning lights at signals recommended for at-grade crossings. Grade separation. Specific safety audits needed.</p>
Warning devices for crossing places		
School crossing signs	<p>Moderate rating for safety effectiveness in both urban and rural areas overseas (6 out of 10). Large number used as reported in overseas survey responses.</p> <p>Cost – c.\$65 each.</p> <p>Comment from Canada on change from blue and white format to fluorescent yellow-green is effective.</p>	

Type of device	Survey results	Literature review results
School crossing ahead signs	Moderate rating for safety effectiveness in urban and rural areas (6 out of 10), moderate number reported from overseas survey responses. Cost – c.\$65 each.	
Advance flashing lights	Rating ranges from low to moderate for safety effectiveness (4-8 out of 10 in urban areas; and 7 out of 10 in rural areas). Relatively small number installed in NZ. Cost – \$1,500-\$4,000 each. Moderate rating for safety effectiveness by overseas response (7 out of 10), low number used overseas. Often used in conjunction with speed restriction sign. In Canada typically a flashing amber light is used to enhance school area and speed limit signage.	Effective for slowing vehicle speeds; however speeds are still above the signed speed limit. Reductions in speeds when lights operating (significant in some cases). Less effective when compared to physical traffic calming measures. Flashing lights may also have a negative impact on secondary speed reductions outside hours of operation. Can be more effective when installed at the crossing site itself and activated by the warden. Flashing lights highlight crossing places and reinforce school zones.
Fluoro discs	Moderate to high safety rating (6-8 out of 10), extensively used in NZ. Note: applicable only to pedestrian crossings and are attached to the black and white poles to enhance visibility. Cost – \$60-\$100 each. Only used with marked pedestrian (zebra) crossings. Not appropriate elsewhere.	
Belisha beacons	High rating for safety effectiveness (8 out of 10). Very few reported to be used by the survey responses. Cost – variable.	
Variable message signs	Rated high for safety effectiveness (10 out of 10 for both urban and rural areas). Very few installed in NZ. Cost – \$12,000-\$20,000.	
Speed-sensitive signs		Effective when alignment and appearance of road otherwise encourages high speeds. Effective at specific locations. Effectiveness diminishes with time.
Flashing lights at signals	Varied rating in urban areas (4-8 out of 10), and moderate rating in rural areas (7 out of 10). Very few installed in NZ. Cost – \$1,500-\$4,000 each.	
Flashing LED lights on pedestrian crossing	High rating for safety effectiveness from overseas survey responses (8 out of 10). Flashing LEDs controlled by adult guards only. Cost – c.\$300 each.	Installed on a trial basis. However no evaluation available.
Special markings		
Limit lines	Moderate rating for safety effectiveness (6 of 10). Extensively used in NZ. Cost – \$50 each.	

Type of device	Survey results	Literature review results
Special signs		
School crossing sign	Not listed in survey responses.	
School area signs	Moderate rating for safety effectiveness in both urban and rural areas overseas (6 out of 10), extensively used overseas. Cost - c.\$65 each.	
Children crossing sign	Moderate rating for safety effectiveness (7 out of 10). Extensively used in NZ. Cost - \$300 each.	
Foldout day-glo school signs	Moderate rating for safety effectiveness (6 out of 10). Cost - \$100 each.	
Billboards	Moderate rating for safety effectiveness in urban areas and high safety rating in rural areas (7 out of 10 in urban areas, 10 out of 10 in rural areas). Small numbers used according to survey responses. Cost - \$200-\$600 each.	
Other		
Traffic cones	Moderate to high rating for safety effectiveness (6-10 out of 10). Moderate use reported. Cost - \$50-\$100 each.	
Slow traffic speeds / reduce traffic volumes		
Traffic calming	Appropriate for local and collector roads. Not appropriate for high volume main roads.	Found to be the most effective way of improving safety close to schools and in residential areas (by slowing vehicle speeds and reducing traffic volumes).
Speed humps	Moderate to high rating for safety effectiveness (5-8 out of 10). Large number reported to be used in survey responses. Cost - \$3,000-\$10,000 each.	Most effective in slowing vehicle speeds and decreasing traffic volumes (if an alternative route is available). Speed humps reduced the number of child injuries in residential streets (by reducing speed).
Chicanes	Low to average rating for safety effectiveness (5 out of 10). Relatively few reported in survey responses. Cost - \$10,000 each.	
Raised platforms (used to slow traffic speed)	Moderate use in NZ and moderate safety rating (7 out of 10). Cost - \$6,000 each. Response from Canada: also used as part of pedestrian crossings, 2-3 m width.	Restricted mainly to CBD.
Road narrowings	Average to high rating for safety effectiveness in both urban and rural areas (5-8 out of 10 in urban areas, and 7 out of 10 in rural areas). Moderate number reported in survey responses. Cost - \$2,000-\$12,000 each.	

Type of device	Survey results	Literature review results
School zones with reduced speed limits	<p>40 km/h speed zone rated high for safety effectiveness in rural areas (8 out of 10), very few reported in survey responses.</p> <p>Restricted speed limits in urban areas rated moderate for safety effectiveness (6 out of 10).</p> <p>Cost – \$45,000.</p> <p>Comment from Canada: compliance with speed limits is highly dependent on police enforcement.</p>	<p>Used in many countries, most effective when targeted to school start and finish times (when children are present), and when combined with warning devices such as flashing lights or variable message signs.</p> <p>Can be problems with compliance to the reduced speed limit.</p> <p>Australia has School Speed Zones, and these vary in terms of speeds and times they occur from state to state.</p>
Reduced speed limits (general)		<p>Reported 60% reduction in fatalities if a pedestrian is involved in an accident when average vehicle speeds are reduced from 48 km/h to 40 km/h, i.e. an accident reduction of 3.85% for every km/h in reduced speed limit.</p>
Safe route to school programmes (SRTS)		
Safe route to school programmes	<p>SRTS programme rated moderate for safety effectiveness from overseas survey responses (7 out of 10). Used in urban areas only.</p> <p>Walking school buses rated moderate for safety effectiveness from overseas response (7 out of 10). Used in urban areas only.</p>	<p>High overlap with local road safety plans, and therefore very valuable to include school route studies in the development of local road safety plans.</p> <p>Traffic calming, low speed roads, speed humps, raised surfaces and signals most effective in improving traffic safety. These measures aim to reduce the speed.</p> <p>Speed reduction and provision of safe crossing places (together with education and enforcement programmes) is common to most SRTS programmes.</p> <p>Important that both perceived problems and crash records are examined in these programmes.</p>
Footpaths		
Safety audit (from child's perspective)		<p>Pedestrian safety audits made from child's perspective, and the subsequent implementation of the audit results is effective.</p>
Maintenance		<p>Clearing vegetation and keeping the footpath cleared of obstructions (e.g. parked cars, advertising boards, street furniture etc.) addresses children feeling unsafe when walking to school.</p>
Widening		<p>Helps to address children's feeling of being unsafe (by providing greater protection from roadside vehicles), and promotes increased pedestrian use.</p>
Walkway		<p>Continuity of walkway/footpath with appropriate safe crossing places effective.</p>
Protection of footpath from roadside vehicles		
Pedestrian barriers / fences	<p>Moderate rating for safety effectiveness (6-7 out of 10), moderate use.</p> <p>Cost – \$100 per metre (\$500-\$1,000).</p> <p>Rated high for safety effectiveness from overseas response (10 out of 10), used to prevent students from crossing mid-block.</p> <p>Cost – c.\$75 per metre.</p>	<p>Effective to re-route pedestrians and cyclists away from dangerous crossing areas or places.</p>

Type of device	Survey results	Literature review results
Bollards	None reported in survey responses.	
Special markings for pedestrians (feet at road edge)	Effective in channelling pedestrians to crossing places.	
Barrier at entrance to on-site school parking areas	Rated high for safety effectiveness (8 out of 10), moderate use reported in survey responses. Cost - \$100 each.	
Underpass / overbridge	Rated very high for safety effectiveness (10 out of 10), very few reported in survey responses. Cost - \$500,000 each.	
Road closure	None reported in survey responses.	
Conspicuity devices for children		
Safety jackets	High rating for safety effectiveness (8 out of 10), used primarily for adult supervisors at crossing places. Cost - \$300 each.	
Personal reflective conspicuity aids (dangle tags, sashes, etc.)		Conspicuity of pedestrians, cyclists and motor vehicles remains a major safety issue. Benefits child pedestrians and cyclists. Reflective dangle tags, armbands, strips on school bags etc. are recommended.
Cyclepaths		
Cycle lanes on roads	Average to high rating for safety effectiveness in urban areas, high rating and rural areas (5-10 out of 10 in urban areas; 10 out of 10 in rural areas). Small number reported in survey responses. Cost - between \$150 to \$2,500/km to install.	
Cycle lanes on footpaths	Moderate rating for safety effectiveness (6 out of 10). Small number reported in survey responses. Cost - ?? per linear metre.	Cycle safety projects have shown varied results, with some projects making traffic safety considerably worse while others produce considerable safety improvements. These schemes include cyclepaths, tracks and road markings. In Australia children under 12 are allowed to ride on footpaths.
Bus safety		
Recessed bus stops	Moderate rating for safety effectiveness (6 out of 10). Small number reported in survey responses.	Recommended where sight distances are restricted, and where traffic speeds and volume are high.
Bus waiting areas		Wide waiting area (minimum 2 m) and fencing recommended where large numbers of bus passengers wait. One-way bus system recommended in rural areas at schools.
Conspicuity of buses		Recommended that visibility of buses is increased.
Warning signs on buses		Flashing lights recommended when buses are stopped.

Type of device	Survey results	Literature review results
Legislation for vehicles passing buses		Non-compliance with reduced speed limit around stationary buses a problem
Parking		
Drop-off/pick-up zone	Higher rating for safety effectiveness (8 out of 10), small number reported in survey responses. Kiss-and-ride programme rated moderate for safety effectiveness from overseas response (7 out of 10), but with controlled location for dropping off or picking up children, and parents not allowed to leave vehicle. Cost – \$2,000 per school	Found to be effective if comprehensive treatment at school frontage has been made, including access to internal car parks, indented bus bays and passenger drop-off zones.
Car parks	Rated high for safety effectiveness in both urban and rural areas (10 out of 10 in urban areas, 8 out of 10 in rural areas). Small number reported in survey responses.	
Recessed parking bays		Effective in increasing visibility between child pedestrian and motorists.
On-road parking		High-density on road parking may increase the risk for child pedestrian injury. Visibility of child pedestrian affected by on-road parking.
Part-time restrictions	Moderate rating for safety effectiveness, moderate numbers reported in survey responses. Cost – \$100 each	
Personal security		
Lighting		Recommended
Visibility	Maintaining control of vegetation is important.	Maintaining standards for planting and control and use of appropriate vegetation on footpaths and walkways through parks and reserves are recommended.
Planned routes		Open environment encouraged, to address fear of people loitering.
Legislation		
Burden of responsibility for child pedestrian cycle crashes		Best-performing countries on children’s safety in traffic have the Badinter law, which places burden of responsibility on drivers involved in a collision with a child. Legal requirements for child cyclists under the age of 6 to be accompanied by an adult (15 or more years of age) in some countries. Cycle helmet-wearing regulations in some countries. In Australia, pedestrians have right of way at corners, whether or not crosswalks are marked by painted white lines. Drivers required to stop for any pedestrian crossing at corners or other crosswalks, and are not allowed to pass a car stopped for that purpose.

Type of device	Survey results	Literature review results
Willingness to fund engineering safety improvements		Evidence shows that the community is more likely to be prepared to pay for traffic safety in communities of economic equality. Communities in general seem to be willing to pay reasonable amounts for safety improvements and time for education programmes.
Speed limits		Motorists are required to stop when coming up to a school bus that has stopped on either side of the road with its lights flashing in some countries. Reduced speed limits when passing a school bus in some countries.
Land-use planning		<p>City planners and traffic engineers need to take into consideration in pedestrian perceptions of risk when designing efficient and pedestrian-friendly facilities.</p> <p>The built environment should be constructed in a way that stimulates children's growth while guarding against unsafe interaction with traffic. Urban design features can be used to improve the safety of children in the road environment.</p> <p>Municipalities and local authorities need to improve the safety of children on their home-to-school journey by including safety features such as walkway and cycleway linkages and greenfield areas, and ensuring that safety, from child's perspective, is included when re-development takes place.</p>

4.2 Gaps in knowledge

This study has identified gaps between overseas knowledge and New Zealand practice in several areas, with regards to improving safety for children on the school journey.

These gaps include:

- mid-block crossings,
- pedestrian safety audits,
- long-term evaluation studies of safety in school catchment areas,
- school bus safety,
- conspicuity of school buses, and
- legislation.

4.2.1 Mid-block crossings

The authors note a need for further research into the effectiveness of signalised mid-block crossings compared to the other options available, and further information is required on where they should or should not be installed. Although the overseas research highlights safety concerns regarding the non-compliance and the severity of injury in pedestrian/vehicle collisions, yet in New Zealand the survey results indicated that practitioners

considered mid-block crossings to be effective, and they have a growing popularity as a treatment.

4.2.2 Pedestrian safety audits

In New Zealand no safety audit guidelines that specifically focus on safety for pedestrians appear to be available. Guidelines are available for walkability audits and road safety, but the authors could not readily find guidelines that dealt with safety audits from a child's perspective, or for pedestrian safety along railway tracks. Such audit guidelines would assist the safety assessment of routes in 'walking school bus' or 'safer routes to school' type programmes. The audit process itself needs to include a review process to ensure that any recommended improvements are implemented.

4.2.3 Long-term evaluation study of safety in school catchment areas

The authors found the most comprehensive study for evaluating the safety effects of engineering devices as part of safe routes to school projects was the Danish study in the municipality of Odense. It is recommended that a similar study be conducted in New Zealand to establish the safety (and transportation) benefits of implementing area-wide engineering safety devices aimed at improving safety for school children.

4.2.4 School bus safety

The literature review did not reveal any New Zealand studies on the current compliance rate for the speed of vehicles passing school buses.

4.2.5 Conspicuity of school buses

In many countries, school buses are readily identified by their consistent colour and warning devices. In New Zealand the only way to identify school buses is the foldout 'school bus' sign on the front and back of each bus. It is not known what effect the lack of conspicuity of New Zealand buses has on safety compared to overseas practice.

4.2.6 Legislation

This study has highlighted the importance of having a supportive legal framework and political will for addressing safety issues for children on the school journey. The authors note that greater legal rights for pedestrians – particularly vulnerable pedestrians (such as children and the elderly) – is needed if New Zealand is to attain the safety performance levels of many other countries.

5. Development of toolbox

This research is intended to be the foundation of a toolbox that will fit within a wider framework for improving safety for children on their home-to-school journey. The toolbox will provide a comprehensive methodology for selecting the appropriate engineering treatment to improve specific safety concerns. The literature review has shown that the best performing OECD countries provide comprehensive strategies and schemes to improve children's safety with legislation in place to support keeping children safe in traffic.

Ideally, local authorities and municipalities will have a structured process for auditing or implementing such programmes as *Safer Routes to School* or *Travelwise to School*. These integrated programmes will, as part of the consultation process, identify routes or areas where safety improvements are needed. In undertaking audits or SRTS-type programmes, possible adjustments to the process may be needed where differences between high-decile and low-decile schools are significant, or where differences exist in the level of infrastructure provided within a city or district.

5.1 The three 'E's of road safety

The holistic approach to safety encompassing the three 'E's of road safety is well documented to be the most effective way of improving safety. These are:

- Engineering treatments
- Education
- Enforcement.

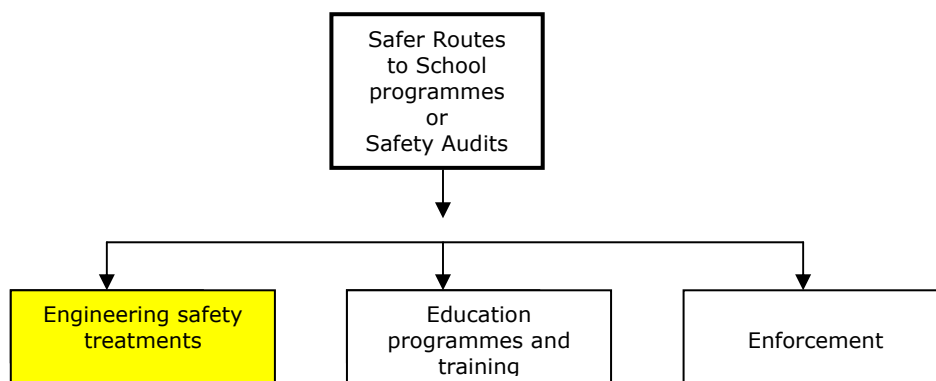


Figure 5.1 The three 'E's of road safety: engineering, education, enforcement.

The proposed toolbox deals with the engineering element of this three-part approach to safety.

The literature review of best practice, and the survey of engineering devices used both in New Zealand and overseas (as shown in Chapters 2 and 3), forms the basis of a toolbox. Note that this toolbox, and indeed this research, is focused specifically on children's safety, and devices and processes suggested here may possibly not be appropriate or necessary for the wider population.

The process recognises the essential element of visiting the site and ensuring the proposed safety intervention device chosen fits the existing and future road environment and use.

5.2 Aim of the toolbox

To assist in the development of the toolbox it is helpful to set out what the toolbox should be used for.

The toolbox should:

- aim to treat identified specific safety concerns,
- provide information on 'best practice' engineering safety treatments,
- provide an easy to use framework for deciding the type of device to be used,
- provide a reference (or platform) that can be the basis for discussion between non-technical persons and practitioners about the most appropriate way to improve children's safety,
- clearly emphasise that implementation of engineering safety devices is only one part of the holistic approach necessary to improve safety, which includes education and enforcement,
- clearly emphasise the need to investigate and establish the wider impact of the implementation of any device,
- emphasise the need to look at the wider road environment and the potential use of a selected treatment,
- warn that caution is needed if looking at devices in isolation (of the wider road environment),
- emphasise the need to refer to current standards, guidelines, or policies, and
- be recognised as providing the engineering basis of an integrated system, rather than a complete 'quick-fix' solution.

The process needs to include (but not necessarily be restricted to) the following steps:

- identify the safety concerns or problems,
- identify a range of possible solutions,
- check the fit with relevant standards, guidelines, and policies,
- assess the benefits and disbenefits of selected options,
- check the fit in surrounding road scene, and
- consult with all stakeholders.

Identify the safety concerns or problems

The identification of perceived safety issues may come from one or many of the following sources: children, community, school, local authority, or the police. Once the problem or concerns have been identified, information on the source of the problem and existing road environment (traffic volume and speed, type of road, etc.) needs to be gathered.

The level of data collection will depend on the type of safety concern and the level of intervention proposed. At the very least, site visits and observations may be required. However, as the level of traffic volume and traffic speed increases these will become the dominant factors in determining which traffic measurements may be necessary.

Identify a range of possible solutions

Investigate from the toolbox matrix the type of engineering devices or treatments that will best address the perceived and/or actual safety problems that have been identified. Establish whether a treatment can be installed in isolation or whether a wider treatment is more appropriate.

Check the fit with relevant standards, policies, and guidelines

A check against the current relevant national and local authority guidelines and standards is required to ensure that the options selected (in the previous step) comply or fit within these guidelines. The RCA may have specific policies that also need to be referred to.

Assess the benefits and disbenefits of selected options

The benefits and disbenefits or disadvantages of each option should be assessed, and the options should be prioritised for the device that offers the most benefit in addressing the safety concerns or problems with the minimum disadvantage to the community. The impact on the surrounding environment of installing the selected engineering devices or treatments should be investigated.

Check the 'fit' of the chosen device in the surrounding road scene

The site needs to be revisited to check the appropriateness of the chosen device in the surrounding road environment, and adjustments made or additional treatments installed as needed.

Consult with all stakeholders

The proposed solution to the safety problem or concern should be taken back to the identifier of the problem to check that the concerns have been adequately addressed. Consultation with other stakeholders should also be undertaken before funding is obtained and implementation occurs.

5.3 Decision tree flowchart

A 'decision tree' flowchart, as illustrated in Figure 5.2, could be used as a model for assisting practitioners and the community in the process of selecting appropriate devices. It is an example only, and the process steps outlined earlier need to be considered when determining the most appropriate engineering safety devices/treatments required to address a safety concern or problem.

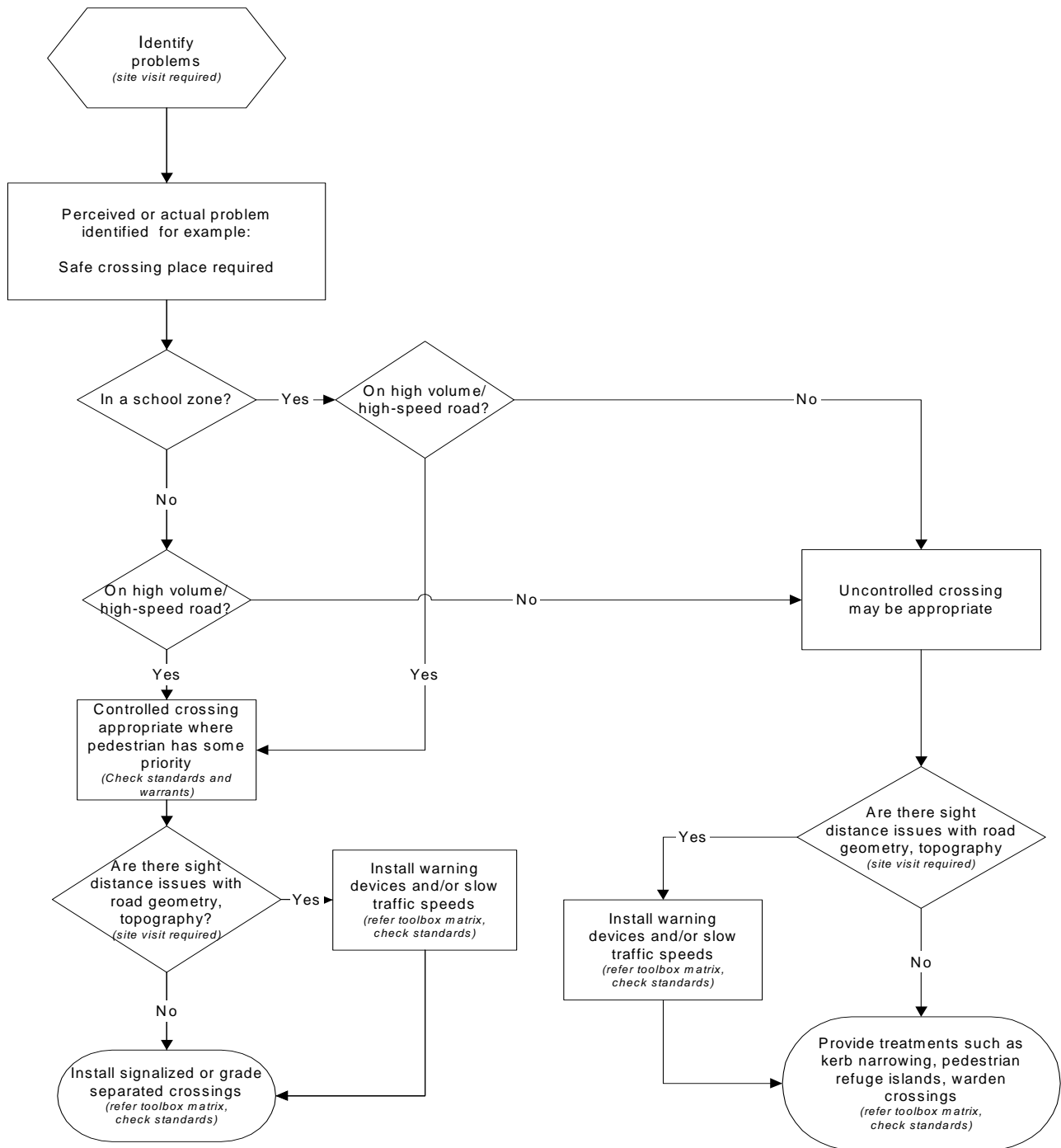


Figure 5.2 Decision tree flowchart for selecting appropriate engineering devices.

5.4 Toolbox matrix of engineering devices

The literature has revealed different methods for developing a toolbox that could be used for determining appropriate engineering solutions that improve safety for children. These include:

Method 1 A matrix matching types of effective treatments to children's perceived safety concerns (Jensen & Hummer 2002). This method identifies the problem first, then looks at a range of possible appropriate solutions. The matrix could be developed to group engineering devices that can be used to address the perceived and actual safety problems for children on their home-to-school journey. Note, however, a matrix is only part of the process necessary to identify appropriate safety solutions to address identified problems, and it is important that solutions suggested in the matrix are not used in isolation without consideration of the steps identified in the process.

Method 2 A table of engineering devices to determine where the devices are most appropriately placed, and the benefits and disbenefits of each. This method identifies the type of device first, then looks at what type of situation it is best suited to. Two examples are shown on the following pages.

Method 3 An interactive computer program using different parameters and criteria to determine the most appropriate engineering devices available to address a safety problem. A Queensland system that is currently being considered as part of an updated warrant procedure for Land Transport NZ (LTNZ in press 2006) is a high-level analysis tool that is aimed primarily at technical engineering practitioners. As such, it is not considered appropriate as a tool that can be used as the basis for discussion by the community (including the school and parents) with the local authorities and engineering practitioners.

Investigation into the most effective methodology for end-users is needed before a recommendation and further development can be given. Case studies for a range of issues that impact on children's safety within different road environments will need to be undertaken in the investigation and development process.

As this report is the first stage in developing a toolbox, an in-depth investigation is expected to take place at a later separate stage.

Table 5.1 Example of a Toolbox Matrix.

This matrix showing the relationship between causes of unsafe feelings experienced by children and physical measures frequently used to overcome them, is based on work by Jensen & Hummer (2002).

Cause of unsafe feelings								Frequently used physical measures
High motor vehicle speed	Poor sight conditions	High motor vehicle volumes	High volumes of heavy vehicles	Confusing give way conditions	Cars driving too close to cyclists	Lack of safe pedestrian crossings	Drivers not respecting give way signs	
✓								Humps
✓								Pinch Points
✓						✓		Raised junctions
✓								Town gates (traffic calming at town entrances)
✓								Rumble strips
	✓							Remove/cut planting
	✓							Remove/relocate road signs
	✓							Remove/relocate fixed objects
	✓							Marking and traffic islands at junctions
✓	✓	✓	✓		✓			Cycle tracks
		✓	✓					Signalised pedestrian crossings
				✓				Re-marking
				✓				Give way marking
				✓				Through-going footways or cycle tracks
						✓		Stop signs
							✓	Improved road marking
✓	✓							Median islands
✓	✓							Wide paved shoulders
✓	✓							Mini roundabouts
✓	✓		✓					Reconstruction of Y-junctions to T-junctions
✓	✓	✓	✓					Paved shoulders
	✓	✓						Coloured asphalt outside school entrances
✓		✓					✓	Staggered stop lines at signalised junctions
✓		✓				✓		Reduced speed limit
✓		✓				✓		Median islands at pedestrian crossings

Table 5.2 Examples of an engineering devices table, and appropriateness of use.**Example 1** Generalised assessment of traffic calming.

Traffic management device	Traffic reduction	Speed reduction	Noise & pollution	Safety	Traffic access restrictions	Emergency vehicle access	Maintenance problems	Level of violation	Cost
Speed humps	Possible	Limited	Increase noise	No documented problems	None	Minor problems	None	Not applicable	Low
Stop signs	Unlikely	None	Increase	Unclear	None	No problems	None	Potentially high	Low
No left/right turn signs	Yes	None	Decrease	Improved	No turn(s)	No problems	Vandalism	Potentially high	Low
One-way street	Yes	None	Decrease	Improved	One direction	One direction	None	Low	Low
Road narrowings (Chokers)	Unlikely	Minor	No change	Improved for peds	None	No problems	Trucks hit curbs	Not applicable	Moderate
Roundabout	Possible	Likely	No change	Unclear	None	Some constraint	Vandalism	Low	Moderate
Median barrier	Yes	None	Decrease	Improved	Right turn only	Minor constraint	None	Low	Moderate
Forced turn channelisation	Yes	Possible	Decrease	Improved	Some	Minor constraint	Vandalism	Potentially high	Moderate
Semi-diverter	Yes	Likely	Decrease	Improved	One direction	Minor constraint	Vandalism	Potentially high	Moderate
Diagonal diverter	Yes	Likely	Decrease	Improved	Thru traffic	Some constraint	Vandalism	Low	Moderate
Cul-de-sac	Yes	Likely	Decrease	Improved	Total	Some constraint	Vandalism	Low	High

Source: Street Transportation Division City of Phoenix, Arizona, USA (Ewing 1999).

<http://www.ite.org/traffic/tcsop/Chapter3a.pdf>

Example 2 Summary of engineering devices used as traffic safety tools.

Beginning with the goals you are seeking at the left side, move right to review the effectiveness of each tool for your street classification

Primary goal	Street type permitted on	Tools	Speed reduction	Less traffic	Emergency delay	Testable	Cost
Auto speed reduction	All streets	Enforcement	varies	No	No	Yes	\$60-\$90/h
		Smart card					
		Medians					
	Local service	14ft speed bumps	Yes 85% to 25 mph	Maybe	Yes 1.0 – 9,4 sec each	yes	Varies

Source: Internet site of the City of Portland.

5.5 Funding

Funding is an important factor that will influence the type of engineering safety devices used. While a broad estimation of the cost of devices has been obtained with the survey of engineering devices currently used, this research has not focused on funding issues in any great detail. If obtaining adequate funding for the more expensive (but effective) engineering safety schemes or treatments is a barrier to their implementation, then the need for further investigation into funding issues and possible sources of funding is suggested.

5.6 Where to from here?

This study has provided a basis for developing a practical and user-friendly means of selecting best practice engineering devices that can be used when investigating and addressing safety issues for children on their home-to-school journey. Because of the complexity of selection of appropriate devices (or treatments), and the importance of using a holistic approach when matching engineering safety improvements to the environment, a well thought-out process accompanying the toolbox is essential.

As a follow-on second stage to this research, the recommendation is that the different formats for the process and toolbox, highlighted in this report, are developed further and tested with a number of schools as case studies to determine the most appropriate model. It is essential that key stakeholders such as Land Transport NZ, school road safety reference groups, RCAs, and injury prevention groups such as *Safekids* are involved and/or consulted during development.

Also an investigation of funding issues is recommended to be included at this follow-on stage. For this it is suggested an audit of the existing situation at schools selected for case studies is undertaken to establish the situation with regards to safety, funds allocated and funds required to address safety concerns. If a lack of knowledge on alternative available sources of funding is identified, then advice and assistance on this matter can be included within the process flowchart (or decision tree).

6. Conclusions and recommendations

The issues that surround school journeys were found to be very complex and intertwined, and that no one 'magic bullet' or quick fix can be applied. The low number of incidents that involve children at specific locations meant that it was very difficult to draw substantive conclusions except where a long-term study had been conducted.

When selecting and implementing engineering devices to be used around schools this study has found that attention needs to be paid to:

- the matching of the device to the capabilities of the users,
- the wider road environment, and whether the site is rural or urban,
- the ongoing effects from the installation of the device, and
- the details of design.

A range of devices that can be used for different situations, often with the addition of complementary devices, has been identified. This investigation has highlighted the importance of understanding the suitability of the device for targeted user groups rather than focussing on the effectiveness of the device in the wider population. Each situation is unique, and the device (or devices) chosen need to be tailored to the physical environment, and the wider effect the installation may have. The differences between urban and rural situations are significant, and these can drastically alter the effectiveness and appropriateness of any device or devices that are considered for selection.

Although not technically an engineering safety device, safety programmes were seen as a growing area of safety opportunity with Walking School Buses being increasingly adopted as a safety measure in New Zealand. In New Zealand, Land Transport NZ and the RCAs fund Road Safety Officers, who help to implement such programmes. The costs of the associated physical works are often shared by local, regional and national providers.

This research has highlighted that it would be wrong to provide a list of 'best practice' devices only, without including a warning regarding the detail and investigation that needs to be undertaken before implementation. Companion documents that are likely to be most beneficial for practitioners include a process flowchart (or decision-making tree) and a matrix (or list) of appropriate devices that have been found to be effective in improving safety.

6.1 Literature review

With the above concerns taken into account the literature review does produce some important results:

- Traffic calming, low-speed roads, speed humps, raised surfaces, and centralised crossing places are the most effective treatments for improving traffic safety.
- Providing wide footpaths with greater protection from roadside vehicles together with regular maintenance and removal of footpath obstructions and overgrown

foliage helps to address children's feelings of being unsafe, and promotes pedestrian use.

- Projects involving cyclepaths, tracks, and markings do not show clearly which measures have produced significant improvements: differences that are statistically significant range from safety being made much worse to being considerably improved.
- Slowing the traffic speed near children and where children congregate has been shown to have marked benefits, often with both a reduction of incidents and a reduction in the severity of injuries. Speed limit signs need to be accompanied by other traffic management treatments.
- Warning devices, such as flashing amber lights located at crossing places in front of schools, have a notable safety improvement impact. However, variable message signs, although having some effect on slowing speeds, were not as effective as physical traffic calming measures, or had as much impact as children being present on the roadside, with the impact of the sign diminishing over time.
- Focusing on perceived problems raised by school-age children and their parents helped to identify problem areas or areas of concern. However, it is equally important to investigate crash data.
- At railway level crossings, very little has been done to warn pedestrians, especially children, of approaching trains. Trespassing on railway corridors is a serious safety concern.
- Increasing school bus conspicuity, improving vehicle design and the roading environment, and introducing consistent national audits are needed. School bus-related fatalities are more likely to occur in the afternoon and involve children who have just left the bus.
- Designing a road environment that recognises children's capabilities as well as their limitations will inherently provide a safer place for children. Best performing countries in terms of keeping children safe in traffic have supportive, active and progressive legislation.

6.2 Survey of engineering devices

The most common findings from the survey of engineering devices are that:

- Use of visibility-enhancing devices is increasing;
- Other devices considered effective in improving safety include:
 - school patrols,
 - signalised crossings,
 - speed zones,
 - pedestrian (zebra) crossings,
 - kea crossings,
 - footpaths,
 - pedestrian refuge islands, and
 - special markings and road narrowings;

- Use of slow speed treatments in residential areas is increasing overseas;
- Stakeholders favoured devices that controlled motorists.

6.3 Summary of comparisons of engineering devices

Comparison of devices – Close to schools	Considered effectiveness		Comments
	NZ	Overseas	
Pedestrian crossings (zebra)	Moderate to High	Moderate	High non-compliance in NZ. Not over multi-laned roads, effectiveness reduced by snow.
Warning devices – crossing places	Signs Moderate (NZ, o/seas) – colour change trend. Fluoro disks: Moderate to High (NZ). Flashing lights: Low to Moderate (NZ), Moderate (o/seas).		
School patrols, Crossing guards	High	High	May be paid by municipalities (o/seas).
Kea crossings	Moderate to High		High non-compliance for installation, and drivers.
School zones, Reduced speed zones	Few in NZ, however rated High. Reported accident reduction of 3.85% for every km/h reduction in speed limit. School zones used in most o/seas countries, can be a problem with compliance to reduced speed.		

Comparison of devices – Home-to-School Journey	Considered effectiveness		Comments
	NZ	Overseas	
Traffic calming	Most effective way of improving safety close to school and residential areas. Not appropriate for high volume main roads.		
Speed humps	Moderate to High	High	Reduce the number of child injuries in residential streets.
Kerb extensions (road narrowings)	Moderate to High		Rated High in both urban and rural areas. O/seas – most effective when combined with no stopping parking restrictions.
Pedestrian refuge islands	Moderate to High		Extensively used in NZ. Increase driver awareness, best when combined with kerb extensions (o/seas).
Raised platforms	Moderate		O/seas – also used as part of pedestrian crossings.

Other devices	Comments from NZ and overseas
Conspicuity aids for children	Safety jackets: High (NZ). Sashes/dangles: Recommended (o/seas). Visibility of child pedestrians and cyclists: major safety concern; O/seas view: more can be done in this area.
Railway level crossings	Problem worldwide. Most warning devices aimed at motorists, not pedestrians. Safety gates, mazes, limit lines on footpaths, fences and warning lights used o/seas.
Buses	Recessed bus bays: Moderate (NZ). Most crashes occur in afternoon when a child has just alighted from a bus.
School safety programmes	Safety programmes are a growing area of safety opportunity, with programmes often resulting in engineering safety devices being installed.

6.4 Influence of cost

Cost is an important factor in the choice of an appropriate engineering safety device. The support from RCAs and municipalities is essential, along with the political will to improve safety, and to ensure that adequate funding is dedicated to the task. Of equal importance is the need for RCAs to provide relevant policy documents and guidelines for their officers and the community.

Supportive legislation and a willingness to fund engineering safety improvements have a direct influence in the best examples of children's safety in traffic used by other countries.

6.5 Gaps in knowledge

The literature review has identified some important gaps in knowledge that the authors believe are worthy of further investigation. These include:

- Safety measures for pedestrians crossing railway lines; guidelines and an audit process that focus on safety for pedestrians are essential, although lacking in New Zealand.
- Mid-block crossings – the need is for a 'controlled' study in New Zealand as overseas research highlights safety concerns regarding non-compliance and the severity of injury. New Zealand practitioners nevertheless considered this type of crossing to be effective, and they are increasingly being used.
- Pedestrian safety audits – guidelines that specifically focus on safety for pedestrians appear to be lacking in New Zealand, whereas the overseas literature has highlighted the need for such audits, particularly to include the child's perspective of pedestrian safety.
- Long-term evaluation study of safety in school catchment areas.
- School bus safety.
- Conspicuity of school buses.
- Legislation – the study highlighted the importance of a legal framework and the political will for addressing safety issues for children on the school journey.

6.6 Developing the toolbox

So that the findings from the literature review and survey of engineering devices are useful (to practitioners and the community), the knowledge gained needs to be transferred into a practical guide or toolbox. Several options for a decision-making process, and a toolbox for selection of appropriate engineering devices, have been put forward for consideration.

The suggested process is in the form of a flowchart which highlights the need to match the device to the individual situation, and to make reference to national and local policies, standards, and guidelines.

6.7 Conclusions

Conclusions from the research are that:

- No one 'magic bullet' or 'quick fix' can be applied.
- Devices need to be tailored for individual situations and user groups.
- Addition of complementary devices and design detail enhances safety gains.
- Differences between urban and rural impact of devices should be recognised.
- A document providing a range of best practice engineering treatments is needed in New Zealand.
- Development of best practice guidelines needs to incorporate findings in the literature.

6.8 Recommendations

To follow on from this research, the recommendations are that:

1. The development of a toolbox to aid practitioners and the community to improve child pedestrian safety should be further developed, and that key stakeholders be involved during its development.
2. The toolbox should provide:
 - a process for identifying individual needs for specific environments;
 - a fit with national standards, guidelines and policies;
 - a guide of 'best practice' devices appropriate to address real and perceived problems (matrix).
3. The gaps in knowledge identified in this research are addressed.
4. A long-term study is initiated to evaluate area-wide effectiveness of devices used to improve safety on the home-to-school journey.

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Glossary of terms

Chicane:	offset road narrowing that force vehicles to drive an 'S' shaped path.
Close to school:	the area directly surrounding a school with high concentrations of school-related activity.
Controlled crossing:	a crossing point at which pedestrians have priority over vehicles but does not use changing signals.
Cycle track:	parts of the roadway that are dedicated for the use of cyclists.
Device:	physical part of a traffic control and management system.
Drop-off and pick-up:	the act of dropping students off at the beginning of the day and picking them up at the end.
Gate:	a narrow opening into an area, e.g. town gate.
Grade separation:	dividing the pedestrian facilities from roads by height, either through underpasses or over-bridges.
Home-to-school journey:	the return journey between home and school.
Intersection signals:	pedestrian signals that form part of the cycle for normal traffic lights.
Kea crossing:	a crossing point used around a New Zealand school, which is active only when school wardens are in attendance.
Kerb extension:	extension of the footpath into the roadway to increase the footpath width at a point.
Median island:	a raised part of the median between two lanes of traffic.
Mini roundabout:	small diameter roundabout used as a traffic-calming device.
Paved shoulder:	paving used on the side (shoulder) of the road.
Physical measure:	measure that is neither spiritual nor mental.
Pinch point:	a narrowing of the roadway used as a traffic-calming device.
Raised junction:	intersection that is raised to the level of the footpath.
Road closure:	closing a road to eliminate traffic.
Road narrowing:	a reduction in the width of the road at some point.
Road paving:	alternative materials used on the surface of the road.
Rumble strip:	raised part of road surface that causes noise inside a vehicle.
School zone:	area surrounding a school that has been specially marked designating its use by school children.

Signalised crossing:	a crossing point which has pedestrian-operated traffic signals.
Speed hump:	a narrow vertical deflection used as a traffic-calming device.
Speed monitoring trailer:	a portable system that displays the speed of traffic to motorists.
Speed table:	a wide vertical deflection used as a traffic-calming device.
Storage area (for pedestrians):	the area of footpath provided where pedestrians wait for crossing signals.
Traffic calming:	use of engineering devices to slow vehicles down by changing the roading environment.
Traffic volume:	number of cars passing a point in a given length of time.
Uncontrolled crossing:	a crossing point that has no priority for a pedestrian over traffic.
Wombat crossing:	a zebra crossing on a raised platform used around Australian schools.
Zebra crossing:	a crossing point on a street marked by black and white stripes where pedestrians have priority.

Appendix 1 Questionnaire A



School Journey Safety – A Comparative Study of Engineering Devices

Questionnaire A

Introduction

This questionnaire is intended for traffic engineers and road safety officers for road controlling authorities or organisations that implement engineering devices or traffic intervention measures on the roads in their region. In the questionnaire, can you please describe what engineering intervention measures or devices are used to improve safety on the home-to-school journeys in your area, along with the information requested in the set of questions included in this document?

Below is an example of some of the engineering devices we use in New Zealand. We are also interested in your opinion of how effective you consider each type of device to be with regards to improving safety, and any comments you may have on the strengths and weakness of each.

An example of engineering intervention measures or devices:

• Speed humps to slow traffic	• Pedestrian barrier fences
• Road narrowings	• Cycle lanes
• Marked pedestrian crossings (zebra crossings)	• Speed reduction devices such as 40 km/h speed zones
• Flashing lights	• School zones
• Fluoro discs	• Special road markings
• Pedestrian refuge islands	• Special treatments for bus travel or at bus stops
• Special signage	• Other

Assessment of each type of device

In assessing each type of device, we would ask you to consider the following issues, and rate them on a scale of 1 – 10, where 1 is the least effective and 10 the most effective. (Please send just one response that typically reflects your overall view of the device for urban and rural areas.)

- Effectiveness in improving safety
- Effectiveness in encouraging children to walk or cycle
- Ease with which the device can be installed, with regards to process
- Cost issues (is funding a barrier to getting the device installed)
- Encouragement from local council or road controlling authority
- Encouragement from school

In the last part of the survey, we ask that you to please provide some information on typical locations for the type of device being assessed, and typical usage. Estimates only for a typical situation are expected.

Completing the questionnaire should only take around an hour if you are familiar with your area, and please feel free to combine responses for each RCA or region. We have found that getting road safety officers and traffic engineers together for a combined response works well.

Please send the completed questionnaire to: Brenda Wigmore, 41a Ewen Alison Avenue, Devonport, Auckland, NZ; or email to bwigmore@ihug.co.nz as soon as you can, as we will be collating results in January 2004. Thanks you for your help, it is very much appreciated.

QUESTIONNAIRE A Summary Sheet

Name:

Road Controlling Authority:

Position:

Contact details: Ph. Email

Address

Device	Brief description and estimated cost per device (if available)	Urban Areas		Rural Areas	
		Estimate of number used	Effectiveness of device on a scale of 1-10*	Estimate of number used	Effectiveness of device on a scale of 1-10*
Zebra crossing					
Kea crossing					
Speed humps					
Flashing lights					

* Where 1 is the least effective, and 10 is the most effective

Please fill in this summary as you complete your evaluation for each type of device used.

Questionnaire A – Safety improvement devices

Please use a separate sheet for each type of device. Just one response for urban or rural areas (if necessary please)

Type of device being assessed:

Please give a brief description

Effectiveness of the device:

These questions are aimed at determining what the overall level of effectiveness your experience with this type of device has been. Please scale each question from 1 through to 10, with 1 being the least effective, and 10 being the most effective.

Safety

How do you rate this type of device with regards to improving safety for the children?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to slowing vehicle speeds?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to making children more conspicuous to motorists?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to making motorists more aware of the children?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

Encouragement

How do you rate this type of device with regards to encouraging more children to walk to school?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to encouraging more children to cycle to school?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to encouraging children to use other non-motorised modes of transport to school?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

Support for the type of device used:

The following questions are aimed at determining which devices solicit the most support from interested stakeholders. Please rate each question on a scale from 1 through to 10, with 1 being a minimal amount of support (or the greatest barrier to installation), and 10 being the most enthusiastic support.

How do you rate the degree with which funding for this type of device influenced its installation?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate the support given for this type of device from the Policy & Standards Organisations (similar to Land Transport Safety Authority in NZ)?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate the support given for this type of device from the Police?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate the support given for this type of device from the Road Controlling Authority or TLA, in terms of approval for the device and ease of implementation?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate the support given for this type of device from the school?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

Location/s where device is typically used:

This set of questions is aimed at determining the most appropriate location for this type of device to be used. Please tick the appropriate box that reflects the overall typical location of the device (more than one box may be ticked).

Type of road: <input type="checkbox"/> Highway <input type="checkbox"/> Regional Arterial Road <input type="checkbox"/> District Arterial Road <input type="checkbox"/> Collector Road <input type="checkbox"/> Local Road <input type="checkbox"/> Other	Typical Speed Limit: <input type="checkbox"/> 50km/h <input type="checkbox"/> 70km/h <input type="checkbox"/> 80km/h <input type="checkbox"/> 100km/h <input type="checkbox"/> Other
Estimate of distance from school this type of device is typically located: <input type="checkbox"/> 0 – 30m <input type="checkbox"/> 31 – 100m <input type="checkbox"/> 101 – 400m <input type="checkbox"/> > 400m	Predominant surrounding land use: <input type="checkbox"/> Residential <input type="checkbox"/> Shopping area <input type="checkbox"/> Industrial <input type="checkbox"/> Rural <input type="checkbox"/> Other

Typical usage of this type of device:

This set of questions is aimed at determining the most common usage for this type of device. Please tick the most appropriate box, and more than one box may be ticked. Please just estimate the number of child pedestrians or cyclists using the device (we do not expect you to undertake special counts).

Hours device in operation: <input type="checkbox"/> Full time - 24h, 7days/week <input type="checkbox"/> Part time – school hours only <input type="checkbox"/> Part time – school start and finish times only	Estimate of the number of child pedestrians typically using the device: <input type="checkbox"/> 1 - 10 <input type="checkbox"/> 11 - 20 <input type="checkbox"/> 21 - 50 <input type="checkbox"/> >50
Estimate of the number of child cyclists typically using the device <input type="checkbox"/> 1 - 10 <input type="checkbox"/> 11 - 20 <input type="checkbox"/> 21 - 50 <input type="checkbox"/> >50	

Comments:

Please add here any comments that you have on this type of device that has not been covered in the above set of questions, or where you would like to expand on the strengths or weaknesses of the device. Your input is extremely valuable, and we appreciate your assistance with this research project.

Thank You

Your assistance and support for this important safety issue is very much appreciated.

Appendix 2 Questionnaire B



School Journey Safety – A Comparative Study of Engineering Devices

Questionnaire B for Major Stakeholders

Introduction

This questionnaire is for major road safety stakeholders such as Policy or Standards organisations (such as Land Transport Safety Authority in NZ), Police, and other injury-prevention groups interested in improving safety for children on their home-to-school journey. In this questionnaire we would like to hear your views and assessment of the effectiveness of each type of engineering intervention measure that you are familiar with, and in particular the strengths and weakness of each.

An example of engineering intervention measures or devices includes:

- Speed humps to slow traffic
- Road narrowings
- Special signage
- Flashing lights
- Fluoro discs
- Special road markings
- Pedestrian refuge islands
- Cycle lanes
- Pedestrian barrier fences
- Speed reduction devices, such as 40 km/h speed zones
- Special warning cones
- Marked 'zebra' pedestrian crossings
- Special treatments at bus stops
- Other

Assessment of each type of device

We would like your assessment as to the effectiveness of each type of device, and ask you to consider the following issues, and rate them on a scale of 1 – 10, where 1 is the least effective and 10 the most effective. (Please send just one response that typically reflects your overall view of the device for urban and rural areas)

- Effectiveness in improving safety
- Effectiveness in encouraging children to walk or cycle

QUESTIONNAIRE B

Summary Sheet

Name:

Organisation:

Position:

Contact details: Ph. Email

Address

Device	Brief Description	Urban Areas		Rural Areas	
		Estimate of number used	Effectiveness of device on a scale of 1-10*	Estimate of number used	Effectiveness of device on a scale of 1-10*
Zebra crossing					
Kea crossing					
Speed humps					
Flashing lights					

- Where 1 is the least effective, and 10 is the most effective

Questionnaire B – Safety improvement devices

Please use a separate sheet for each type of device (just one response for urban and one for rural areas please)

Type of Device being assessed:

Please give a brief description

Effectiveness of the device

These questions are aimed at determining the level of effectiveness your experience with this type of device has been. Please scale each question from 1 through to 10, with 1 being the least effective, and 10 being the most effective.

Safety

How do you rate this type of device with regards to improving safety for the children?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to slowing vehicle speeds?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to making children more conspicuous to motorists?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to making motorists more aware of the children?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

Encouragement

How do you rate this type of device with regards to encouraging more children to walk to school?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to encouraging more children to cycle to school?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

How do you rate this type of device with regards to encouraging children to use other non-motorized modes of transport to school?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7	8	9	10

Comments:

Please add here any comments on a separate sheet that you have on this type of device that has not been covered in the above set of questions, or where you would like to expand on the strengths or weaknesses of the device. Your input is extremely valuable, and we appreciate your assistance with this research project.

Thank You

