

**VISIBILITY OF ROADSIDE
BARRIERS AND KERBS
IN NEW ZEALAND**

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May 2003**

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Glossary Terminology:

Barriers: Include sight rails, guardrails, guide rails, bridge rails, wire rope, concrete barriers (e.g. New Jersey barriers), and metal barriers (e.g. w-beam guardrails) installed deliberately in the highway by road authorities as part of road management. The term also includes bridge, roadside, and median road safety barriers and crash cushions as defined in Transit New Zealand's specification, M/23: 2002.

Bridge barrier: A device placed on the side of a bridge to prevent errant, and possibly out of control, vehicles running off the side of the bridge (TNZ M/23:2002).

Clear zone: The clear zone is an area free of fixed objects adjacent to the roadway providing a recovery zone for vehicles that have left the carriageway. Research indicates that on high speed (>70 km/hr) roads a clear width of 9 metres from the edge of the carriageway permits about 80% of vehicles leaving the roadway out of control to recover. For urban roads the smaller width of 3-4m may be sufficient (Transfund, Issue 5, April 2001).

Delineation: Any method of defining the operating area of the roadway to the driver, in order to convey the route ahead. Examples include edge marker posts, chevrons, and painted edge lines. The term "delineator" is also often used to refer to any road marking device, particularly reflective ones. In this report the term refers solely to marking for the purpose of route guidance, with the term "visibility treatment" referring to the broader definition instead.

Kerb: A raised border of rigid material formed at the edge of a carriageway or pavement.

Median Barrier: A device placed on a road median to reduce the risk of errant, and possibly out of control, vehicles crossing the median and colliding with opposing traffic; and/or to shield a hazard located within the median.

Road furniture: Generally, solid objects located in, or close to the road. In this report it refers to roadside, median, or bridge barriers, guide rails, bridge rails, sight rails, and vertical, and angled kerbs.

Roadside barrier: A device placed on the side of a road to shield errant, and possibly out of control vehicles from a roadside hazard.

Traversable: The ground shape is such that an out of control vehicle can be brought under control (MOTSAM 5.02.02(b)).

Abbreviations

New Zealand Guidelines:

| | |
|---------|---|
| LTSA: | Land Transport Safety Authority |
| MOTSAM: | Manual of Traffic Signs and Markings |
| RTS5: | Guidelines for rural road marking and delineation |
| TNZ: | Transit New Zealand |

FOREWORD

The issue of the marking of roadside furniture along its length has been difficult to unravel because of ambiguities in language and uncertainties of intent. The terms “Hazard marking” and “delineation” can both have different interpretations, and often they are (incorrectly) used interchangeably. While the nature of hazard marking and delineation are prescribed and are to be of different forms, their roles can often blend together as for example, when a row of marked hazards (e.g. power poles) can become also a de- facto delineation of the route ahead, but displaced from the true carriageway. The devices used to mark hazards are often termed “delineators” a generic description for small reflective devices which can be used for either hazard warning or for delineation.

The term “hazards” is applied to objects beside the road, which would cause significant damage and injury if struck. These objects are either marked, or the motorist shielded from them by guardrails that are themselves often not marked, as a guardrail is intended to be a structure capable of being impacted without serious injury occurring. But, if guardrails are struck, damage and minor injury often occurs and in some circumstances serious or fatal injury is still possible. The term “hazards” is also often applied to both geographical features along the route that would be dangerous if the car left the road, such as cliffs, rocky foreshores, or rivers, and geometric features of the route, such as sharp curves. Strong delineation of the route guides drivers round and past these hazards and guardrails near the road edge prevent the vehicle from leaving the road. Markers are often fixed onto these guardrails but it is often not clear whether the intent was to mark the hazard of the guardrail or strengthen the delineation around the hazard from which the guardrail is providing additional protection.

Apart from bridge ends and sides, most of the furniture that is the subject of this report is confined to major roads. For these roads in New Zealand there is a clear and well implemented policy to mark the safe carriageway (where to go). There is also a clear but less well implemented policy to mark dangerous objects in the clear zone away from the road (where not to go). It is the transition between these two zones in the road shoulder area, where most of the road furniture is placed, that both policy and practice are the most ambiguous as to where it is safe to go, and where there is furniture that may be difficult to see.

This report picks through these two main issues of how to illustrate the objects near the road to avoid, and how to mark the safe route ahead. While not providing conclusive solutions it does identify a set of potential solutions for further evaluation.

1 INTRODUCTION

This research reviews practice for improving the visibility of items of longitudinal roadside furniture, such as kerbs and barriers, that extend along the road side.

1.1 Longitudinal Road Furniture

Longitudinal road furniture is generally installed for road safety purposes. Barriers are typically used to reduce the severity of a crash by reducing the chance of a vehicle either crossing the centre line (median barriers) or leaving the road (roadside barriers) where it is hazardous to do so. Sides and raised kerbs on bridges give safety to both cars and occasional pedestrians. Kerbs are used for more varied purposes, including separating pedestrian and vehicular traffic, for drainage, and as a tidy edge around traffic islands and bordering medians.

1.1.1 The Potential Hazard of Unmarked Furniture

Furniture such as guardrails and kerbs are often positioned very close to the traffic lane, even within the roadway. They are usually grey in colour and can be difficult to see, particularly at night and in the wet, because they tend to blend in with the road environment. They can therefore also be a hazard to traffic, though usually a much lesser hazard than the one they are intended to protect drivers from.

Although difficult to see the furniture is often marked only in part. Hazard markers are placed on bridge ends, on the approaches to traffic islands and medians and frequently at the start of crash barriers. In addition delineation in the form of continuous painted lines may also be used to define the edges of the intended vehicle pathway, and if complied with, drivers would safely pass the furniture.

However furniture is not required to be marked along its length even though it can be long, extending up to several hundred metres and even for kilometres. The unmarked length can still present a hazard because:

- After passing the end with the hazard marker, the driver receives only poor information of his position relative to the furniture, which can be difficult to distinguish in the dark. Drivers may be unaware that the furniture is still present.
- New Zealand has no minimum standards of visibility of painted delineation, nor requirements for markings to remain visible in the wet. Paint brightness is low compared to international standards and painted edge lines become difficult to see in wet weather, weakening route delineation and increasing the chance of the motorist straying from the travelled way and towards road furniture.

- There are no rules that state that a motorist cannot cross the painted edge line, and in some cases this is even encouraged. For example, slow vehicles are encouraged to “pull off to the left” to let faster traffic through in holiday advertising campaigns, urban traffic is required to clear the roadway to let emergency vehicles through, and tired drivers are encouraged to pull well off the road and rest.
- Current delineation practice is for it to be consistent along its length, yet the road shoulder beyond the edgeline can be variable with either clear shoulder, or guard rails and kerbs in place. Drivers at night therefore can receive a message of an apparently consistent road environment, which could be misleading.

1.1.2 The Different Concepts of Marking Hazards and Marking the Route

It is noticed that there are attempts in New Zealand to mark furniture along its length and that these practices varied. It is also believed that roading authorities and consultants are not clear in their intent. That is, it is not clear if they are trying to better indicate the hazard of the presence of furniture, or whether they are trying to strengthen the delineation of the route by for example marking the guardrail to give better emphasis to a tight curve. This intent is significant because hazard marking and delineation differ in their purpose.

The purpose of a hazard marking is to demarcate an object that may cause damage or injury if struck, so that the driver can treat the relevant road section with the appropriate level of caution. Delineation serves the purpose of providing route guidance for the driver.

Often a row of hazard markings will also act to show the general route ahead. However, this guidance could also mislead where the row of marked hazards is at a variable distance from the route.

Currently there is no crossover between delineation and hazard marking. That is, in New Zealand use there is no official dual purpose marker for delineation and hazard marking. The regulations specifically state that delineation devices should be used strictly for route guidance, never for hazard marking.

There are two issues in marking longitudinal furniture

- How to continue the same standard of delineation through the affected road section, when the presence of the furniture may make including or mounting the delineation difficult.

- How to provide warnings to the driver where longitudinal roadside hazards exist and the distance of the hazard from the road, but that do not interfere with existing delineation.

1.1.3 Indications of contribution to crashes

The LTSA's Accident Investigation System (AIS) shows that this furniture was associated with crashes in New Zealand – in over a six-year period from 1994 – 1999 this type of road furniture was associated with 1,796 injuries and 164 fatalities. At present the crash reporting would not require an assessment of the contribution that lack of hazard marking along the length may have had on the crash cause so no analysis of the value of improving the visibility of the furniture is possible.

The statistics from 2001, shown below, give an indication of the object struck and the influence of the dark. Care is needed with this data as more than one object may be struck in a crash. However nearly half of the objects struck occur in the dark yet only a quarter of the VKT are in the hours of darkness, providing a quite strong indication that poor visibility of the furniture at night may be a contributing factor.

Objects Collided With in Injury Accidents on Open Road and Urban Roads in 2001

| Object Struck | Urban Areas | | Rural Areas | | Total |
|------------------------------|-------------|------------|-------------|------------|-------|
| | Total | In dark | Total | In Dark | |
| Bridge end or approach rails | 18 | 9 | 69 | 30 | 87 |
| Guard Rail | 27 | 17 | 171 | 67 | 198 |
| Traffic Island or median | 83 | 52 | 21 | 8 | 105 |
| Kerb | 82 | 44 | 17 | 9 | 99 |
| Total | 210 | 122 | 278 | 114 | |

2 SCOPE

2.1 Objectives of This Research

The objectives of this study were to:

- Determine the extent to which inadequate or inappropriate levels of visibility of roadside furniture is a road safety problem (i.e. crash cause) both in New Zealand and overseas
- Identify methods (New Zealand and international) for improving visibility of longitudinal roadside furniture, and the success of these methods.
- Develop guidance for visibility marking of roadside furniture, and estimate the likely impact on safety if implemented.

2.2 Road Furniture Considered

This research considered

- Kerbs and barriers that run parallel to the road.
- “Barriers” include bridge rails, sight rails, bridge guardrails, highway guardrails, and those defined in Transit New Zealand Specification TNZ M/23: 1999 “Specification for Road Safety Barrier Systems”. Examples are: concrete barriers such as New Jersey barriers, metal (w beam) guardrails, and wire rope barriers.
- “Kerbs” include kerbs around culverts, pedestrian footpaths, kerb extensions, and kerb and channelling for drainage purposes.
- Barriers and Kerbs within the road (e.g. median barriers), or at the roadside within the clear zone¹. The typical situation envisaged is where barriers and kerbs are located within 3 metres of the carriageway.
- Delineation/Marking type from the perspective of:
 - Continuing delineation of the route ahead, and
 - Warning the road user as to the presence and proximity of the road furniture.

It does not discuss the construction, installation, or maintenance of the road barriers and kerbs.

There is a rural roads focus to this study as it is these roads that are unlit and usually free of parked vehicles in the shoulder area, or where kerbing is normally not expected.

3 METHODOLOGY

The first stage of the methodology used was primarily a combination of a literature review coupled with direct contact with practitioners, relevant road authorities and road safety researchers so as to identify:

- Current New Zealand requirements specified by the Manual of Traffic Signs and Markings and related documents
- Treatments additional to MOTSAM, trialled in New Zealand, and the need for these treatments.
- The current best international practice for improving the visibility of roadside furniture

¹ (i.e. within 9m of the carriageway and 100 km/hr zones or within 3-4 m in 50 km/hr zones).

- The extent that poor visibility of roadside furniture contributes to crashes in other countries and the extent that the treatments to improve visibility have reduced these crashes.

The intended second stage of the methodology, to review of crash reports held on the LTSA AIS database, was not progressed beyond the preliminary analysis once it became apparent that the data within the records would not contain sufficient detail to determine whether lack of marking on longitudinal furniture was a contributor to crashes. Instead current practice was reviewed to determine whether a credible hazard could exist.

The third stage was to identify treatments for improving the visibility of roadside furniture appropriate to New Zealand, considering the New Zealand setting, and limitations imposed by New Zealand legislation and standards. A selection of preferred treatments was refined by consultation with a group of road safety personnel.

4 NEW ZEALAND REQUIREMENTS FOR MARKING HAZARDS AND FURNITURE

4.1 General

The Manual of Traffic Signs and Markings (MOTSAM) sets out the policy and location requirements for road markings, delineators and hazard markers. It gives mandatory requirements for state highways and is strongly recommended to all local authorities to encourage consistent marking practices nationally” (MOTSAM Preface 1997). New Zealand requirements relevant to the visibility of roadside furniture are described in MOTSAM, Part 2, Section 5 (1994). This states that objects within, or immediately adjacent to the road can constitute a hazard to traffic.

Hazards² include the ends of furniture within the road, or within 9 m of the roadside³.

MOTSAM states that the ends of guide rails, guardrails, handrails, and vertical, or near-vertical, kerbs may constitute a hazard to traffic. It also provides details of how “isolated hazards” should be marked: painted white up to 1.7m above ground and marked with two reflectorised white discs

Furniture ends must be marked except when the furniture is an approved guardrail or a guardrail protects the end. Marking typically comprises, painting the ends white and affixing a hazard marker, or bridge end marker if applicable. Other than in some circumstances approved guardrails on the roadside are not needed to be marked.

² “Objects which may constitute a hazard to traffic include bridge end posts and bridge end kerbs, ends of guide rails and hand rails, piers and abutments at underpasses, ends of vertical or near vertical kerbs, soffits of underpasses with less than 4.4m clearance, service poles and lighting columns, ends of medians and safety zones and trees with trunk diameter of more than 150mm” (MOTSAM 5.01.02).

³ Within 9m from the road if there is no kerb, and within 600mm if there is a kerb (MOTSAM 5.02.02)

The aim of delineating the start of furniture is to alert the road user to the presence and proximity of this potential hazard within the clear zone.

Delineation refers to long range route guidance, which is normally provided by edge marker posts chevrons, road markings and pavement markers. Another document "Guidelines for Rural Road Marking and Delineation : 1992 (RTS5)" advises on marking delineation of local authority roads, which extend to very low daily traffic volumes.

An important concept, indicated in MOTSAM, is that route delineation, and hazard marking are to be treated independently. Delineation is provided to mark the road alignment so the route is clearly visible. Hazard marking is provided to make hazards visible so that the driver is aware of their presence and can take the appropriate care. MOTSAM states that edge marker posts should be used only for route delineation, and never for hazard marking.

This implies that marking the **hazard** of road furniture along its length should be done with hazard markers (possibly a new form of marker) and not with markers normally used for delineation.

MOTSAM section 5 was last revised in 1994, and RTS5 in 1992. Since then the use and range of available road furniture, in particular guardrails and kerb extensions, has increased, as has the availability of high performance materials and the use of reflectorised devices. For example, it is now Transit New Zealand intention to reflectorise all state highway road lines, to ensure good levels of dry-night visibility.

4.2 Furniture Within the Road

Additional signs and delineation are placed on, or prior to, the hazard itself to guide the road user around it. For example: keep left/ keep right (RG17), or diverging traffic (PW5) signs, and height restriction signs (for overpasses).

4.3 On-road Markings and Delineation Associated with Hazards

A process of providing delineation to show the safe path supplements warning drivers of hazards. Markings and delineation on the road and adjacent roadside are used to guide the road user past the furniture where it impinges on the roadway, and may start in advance of the furniture to divert the road user around the furniture. The on road markings are lines, of either paint or specialised products, occasionally supplemented with raised pavement markers. Roadside markers are edgemarker posts. The posts are spaced and placed so as to provide a "smooth flowing pattern of delineation, which defines the trafficable portion of the carriageway" (MOTSAM 5.05.04). They are placed no further than 3m from the side of the adjacent traffic lane.

Often the roadside furniture can make the normal placement of the edgemarkers difficult. Little guidance is provided in MOTSAM on continuing the delineating edgemarker posts

along the furniture with the exception of across one lane bridges, where it suggests the optional use of edge marker posts continued at a 20m spacing (MOTSAM figure 5.6). In practice this same treatment is often applied to guardrails in general. (It is probably this issue of continuing the edgemarker post type delineation along the furniture that is a major driver for practitioners to seek to mark the furniture along its length especially guardrails)

MOTSAM requires advance delineation for the two situations:

- (a) Furniture within the roadway “All objects located within the roadway and constituting a hazard to traffic require (on road) approach markings to guide the traffic past the object...the markings shall take the form of reflectorised yellow lines and stripes”. (MOTSAM 5.04.01) This is re-iterated in section 2.08 in the context of raised islands separating opposing traffic. For islands separating diverging traffic, white lines and bars are used.
- (b) One-lane bridges (where the road narrows to cross the bridge), where the preceding route is delineated with edge marker posts. Here MOTSAM (figure 5.6) requires the edge marker post system to taper into the start of the bridge or if protected by guardrail to the start of the guardrail, (before the guardrail tapers in).

MOTSAM requires ongoing edgelines beside central medians.

- (c) MOTSAM (2.03.04) advises edgelines be fitted to roads with a raised median, one edgeline on the shoulder the other near the central median. These edgelines are permissible on urban roads, recommended for rural roads and are specified for rural median divided roads. These edgelines can be supplemented with red RRPM in extreme cases (2.03.08)

MOTSAM does not specify any performance level of the road markings other than that they are to be reflectorised.

5 SOME METHODS BY WHICH ROAD SIDE FURNITURE IS MARKED ALONG ITS LENGTH IN NEW ZEALAND

Practitioners have investigated a number of treatments for marking roadside furniture along its length, in New Zealand. These are usually treatments applied only in specific areas, often in the course of trial. They have been identified by direct contact with road safety practitioners. The majority of these practitioners were involved with state highways rather than local authority roads.

About 35 people in all from, for example, Opus, Transit New Zealand, LTSA, provided input into this stage.

5.1 General Overview of Practice

The common perception of the road safety groups was that many barriers, particularly concrete barriers, were hard to discern at night. This was perceived as a problem, even when overhead lighting was present. In wet conditions the problem was seen as especially acute, as painted road markings become significantly less visible, thus route guidance becomes correspondingly poorer.

Raised pavement markers, and profiled line markings are touted as possible solutions within existing accepted practice. However, it was noted that for roadside furniture located on the left hand side of the road, these treatments may interfere with the safety of cyclists, an area of concern in recent times.

The majority of practitioners consulted considered that the minimum MOTSAM practice provided an inadequate level of visibility of roadside furniture and gives insufficient advice for the treatment of roadside furniture. Most practitioners stated that there were situations where they were doing more than the minimum requirements of MOTSAM, and had improved night-time visibility of barriers and kerbs along their length. Their rationale for doing so was not based on quantitative crash data, but rather on an intuitive assessment of the need to better mark the route and its potential hazards.

Some practitioners expressed concerns regarding the overall variety of delineation used around furniture, and the national inconsistency that this is likely to lead to. Concerns were also raised about the misuse of delineation and hazard marking; some treatments were over-dominating, causing glare or an imbalance with other delineation. This was commonly due to the treatment being too bright, too large, or too frequently spaced. There is considerable demand for better guidance within documents for the marking of, and delineating along, roadside furniture.

It is also believed that roading authorities and consultants are not clear in their intent in marking this furniture. That is, it is not clear if they are trying to better indicate the hazard of the presence of furniture, or whether they are trying to strengthen the delineation of the route by for example marking the guardrail to give better emphasis to a tight curve. This intent is significant because hazard marking and delineation differ in their purpose.

5.2 Barriers

Practice varied from:

Painting Rails - A number of the highway network managers indicated that they paint at least some of the guardrails in their region, particularly where the guardrail doubles as a sight rail, and on corners.

Trialling the use of delineators and hazard markers (edge marker posts, reflectors, reflectorised sheeting) placed:

- (a) in front of, or flush with, the roadside face of the road furniture. Three practitioners have trialled such systems but only one was still using this treatment, and had done so for at least 6 years,
- (b) on top of the barrier, using chevrons or raised pavement markers,
- (c) edge marker posts above but behind the roadside face of the furniture – so that the furniture face is between the edge marker post and the road (e.g. on the support posts of metal guard rails, or behind a vertical kerb face)

5.3 Specific Barrier Treatments:

The following are specific barrier treatments used by practitioners in New Zealand. They have been categorised into 4 groups: paint treatments; using existing delineation devices; specialised reflectors; and treatments for wire rope barriers.

Group 1 : Paint Type

Treatment 1 Non Reflectorised Paint

Non-reflectorised (usually white) paint applied to guardrails, particularly in urban areas to mark bends. It was hoped that this will achieve the dual purpose of marking the protective barrier and a sight barrier.

Treatment 2 Reflectorised Paint

Reflectorised white paint applied to guardrails to improve night-time visibility. This has been applied to some portions of the state highway network, but has since been ceased because of withdrawal of the paint due to environmental concerns. It is likely that environmentally friendly alternatives (either paint, cloth, or sheeting) are now available.

Group 2 : Existing Delineation Devices

The second group of treatments is the use of existing delineation devices attached to the guardrail. These are primarily attempts to keep the continuity of delineation through the area. They both strengthen delineation of the geometric feature, and their placement on the furniture helps to highlight the presence of the furniture. However they do not do this unambiguously, and the driver may not perceive the section of roadway with guardrail marked in this way as any different from the rest of the road where there is a clear roadside. Placing standard delineation features on the furniture could be construed as contravening MOTSAM, especially if the intent is to warn of the furniture, not strengthen the delineation of the route past the furniture.

Treatment 3 Edgemarker Posts Behind Guardrails

Standard edge marker posts are either driven into the ground behind the guardrail, or sections thereof attached to the reverse side of the guardrail. Post spacing is kept as standard, as per MOTSAM. This is seen as a continuation of standard delineation practice

through the region where the roadside furniture exists. However it makes no attempt to indicate the proximity of the guardrail face to the road user.

MOTSAM states that edge marker posts should define the edge of the trafficable portion of the carriageway. Clearly, being placed behind a barrier on the left hand side of the road, this is not the case, and could potentially mislead motorists to believe that they have more shoulder available than is actually present.

Treatment 4 Chevrons on Face/Top

Chevrons were used on occasional bends both on median and roadside barriers, and were either placed on to or attached to the face of the barrier. There was a noticeable variation in chevron size. Chevrons placed on the face of the barrier appeared to give a better indication of both the curvature and the proximity of it to the road.

Chevrons are a delineation (curvature defining) device, and as such may not be suitable as a part delineation, part hazard marking device.

Treatment 5 Raised Pavement Markers on Face / Top

Standard (red, white, or yellow) raised pavement markers are attached to the top or face of concrete and w-section barriers.

This system is proposed for use on median barrier systems on left hand bends at the same spacing as edge marker posts. However it is being trialled on both median and left hand side barriers.

Group 3 : Specialised Reflectors

These next four treatments use a specialised reflector on the face /top of the guardrail. They represent attempts to find a new marking that combines both delineation and hazard marking.

Treatment 6 Reflector Cut From Edge Marker Post Sections

Small triangular sections of standard edge marker posts applied with a reflector are attached into the cavity of w-beam railing using a single bolt. This treatment is currently in place on sections of the Desert Road. It is reported that this method provides good delineation of the route ahead, as well as indicating the proximity of the guardrail to the lane.

No official costings are available for this method, although qualitative assessments report low installation costs. Also reported is a reduction in damage to roadside furniture, although this will be offset to some extent by the frequent maintenance required. The build up of road film must be cleaned, and as the reflectors are free to rotate about the bolt, regular realignment and replacement are also necessary.

Treatment 7 Proprietary Product: 3M Linear Delineation System (LDS)

3M LDS consists of 1 metre long strips of corrugated reflective sheeting, and is mounted to the face of barriers by bolts at each end. This is currently being trialled in several locations throughout the country (Dunedin, Wellington, Palmerston North). It is designed to provide delineation of the route ahead as well as indicating the proximity of the guardrail to the lane.

No official costings are available for this method. Regular cleaning of the LDS will be necessary, as its close proximity to the traffic will cause rapid build up of road film. Because LDS is essentially flush with the barrier (or recessed in the case of w-beam) it is unlikely to cause a safety hazard unless it becomes detached. For the same reason, it is unlikely to be easily damaged, thus the need for replacement of sheets should be infrequent.

Observations of the trial sites have confirmed that LDS provides a very strong delineating, and hazard proximity effect, however issues have arisen. Because the LDS is particularly bright under headlights, concerns have been raised that a balance needs to be maintained:

- (a) Geographically before and after treatment by LDS to avoid migration of crashes.
- (b) With other delineation and markings present, to avoid LDS from “overpowering” them.

3M are aware of these issues and are currently trialling spacings in an attempt to find a solution.

Treatment 8 Proprietary Product: Reflective Discs

Plastic reflective discs mounted in the cavity of the w-beam section. These were briefly trailed in one area but discontinued as it was an unofficial trial.

Treatment 9 Proprietary Product: RTL Prototype Reflectors

A circular reflector is attached to a flexible base, which is inserted into the cavity of w-beam guardrails at 20-50 metre spacing. The aim is to provide delineation and an indication of the proximity of the guardrail to the lane, while not posing a threat to pedestrians and cyclists

Group 4 : Treatments for Wire Rope Barriers

Wire rope barriers can present some particular difficulties. Unmarked they are difficult to see but the nature of the product limits the opportunity to fix reflective material to them

Treatment 11 Wire Rope Barriers - Pressure Sensitive Fluorescent Reflectors (3M)

Pressure sensitive fluorescent reflectors have been trialled but it is uncertain if this product is still available.

Treatment 12 Wire Rope Barriers: Reflectors on Posts

Small single yellow reflectors are currently fixed to the posts of this system at about 100 metre spacing. These are of low effectiveness but there is the opportunity to increase the density by marking many more of the posts and to select a reflector that will not be confused with edgemarker posts.

5.4 Kerb Treatments

Kerbs pose a particular visibility problem because of their very low profile and are generally made of grey concrete and unmarked. This can make them blend into the roadside, especially at night, or in visually “busy” intersections.

The most common treatment for kerbs was to paint them white with non-reflectorised paint. Continuous marking of kerbs has the danger of appearing to be a road edge line, indicating to the driver that it is part of the traversable portion of the road, therefore consideration should be given to kerb marking which should be discontinuous : dashed or dotted.

Route delineation where kerbs exist has traditionally been achieved by either: (i) mounting edge marker posts behind the kerbing, or (ii) discontinuing delineation altogether; neither of which conveys the true trafficable width of the road to the road user.

Some specific treatments other than ordinary painting have been:

Treatment 13: Painted Kerbs - 3M Cloth or Paint

The top and face of the kerb is painted with white retro-reflective paint.

There are currently issues regarding the availability of the retro-reflective 3M paint that has traditionally been used in similar applications. However, retro-reflective cloth or other suitable paints may be available.

Treatment 14: Edge Marker Posts on Kerb

Edge marker posts are attached flush with the right hand side edge of the kerbing. This is intended to provide delineation along a section of kerbed road, which conveys the true trafficable width of the roadway.

However, this treatment restricts the width of the footpath (if present) for pedestrians. Furthermore, there are potential dangers for cyclists when they get as far left as possible to avoid passing traffic. Posts that have been knocked out of alignment can pose a specific hazard to both cyclist and pedestrian traffic.

5.5 Miscellaneous

Treatment 15: New Jersey Barrier Glass reflectors

115mm diameter glass reflectors are set into the concrete barrier. These have been used in Europe (France and Germany) and have been trialled in Australia over the last 6 months.

Treatment 16: Kerb Studs

Traffic Tech Australia produces 50mm diameter glass studs, which are placed on kerbs, mainly in urban situations. They are not used where people walk, and are typically placed on the bevelled slopes of traffic islands.

Treatment 17: White Reflectorised Concrete

Bridge parapets along the Mon Fayette highway in Pittsburgh Pennsylvania are being constructed of white reflectorised concrete for improved visibility. The use of white concrete in median barriers has been used over the last 20 years for daytime visibility, however in this installation reflective beads have been included in the mix. The cost is estimated at 20% more than standard concrete.

6 INTERNATIONAL PRACTICE FOR IMPROVING THE VISIBILITY OF ROADSIDE FURNITURE

Practices for improving the visibility of roadside furniture in Australia, the USA, Canada, England, Sweden, and Denmark were reviewed. Because there is little literature other than manuals available the methodology for this stage included direct contact with road controlling authorities and consultants.

These countries were selected because they have a similar road and transport environment to ours. Many of our practices are in fact derived from these countries, in particular Australia, with whom we share joint standards and guidelines.

It appears that there are generally two types of treatments in use in these countries.

- (a) Pure delineation, where the only goal is to indicate the route ahead.
- (b) Mixed delineation and hazard warning, where the goal is to indicate the presence and proximity of the longitudinal roadside furniture, as well as to assist with delineation along its length. Often these objectives are not separated in the guidelines or by the practitioner, and the term "delineation" is often used where "hazard marking" would be more appropriate. In the following summaries, these terms have been changed, where appropriate, as inferred from their context.

6.1 Australia

State Road authorities in New South Wales, South Australia, and Victoria indicated that they have their own requirements that incorporate the principle of AS1742.2 in requiring

markers to be attached to guardrail installations that are within 4 metres of the running lane. For roadside furniture situated greater than 4m from the nearest lane edge, no markers are used in order to minimise driver distraction.

Throughout Australia there is a wide variety of practice, some of which is likely to be ineffective. For example, reflective paint on surfaces at angles where it is unlikely to reflect effectively. Some treatments may actually be hazards in themselves, thus careful and considered selection of appropriate treatments is vital (Peter Cairney, ARRB).

6.1.1 New South Wales

The Road and Traffic Authority in New South Wales have guidelines to treat guardrails, concrete barriers, and kerbs, which are derived from AS1742.

Where the guardrails and concrete barriers are within 4m of the running lane, delineators are attached at the appropriate interval. These devices are intended to serve the dual purpose of providing alignment information to the road user and also informing them of the presence of road side furniture.

The treatment comprises of a circular or rectangular reflector, which is made of either sheeting or acrylic material - red on the left hand side and white/yellow on the right hand side. This is attached to the guard rail/barrier/guide-post at a height that (usually) corresponds to the eye-level of the driver (approx. 1m above the road surface).

Inclined faces of the median kerbs are normally painted white. All pavement markings are reflectorised using glass beads. Care is taken to use pedestrian- and bicycle- friendly devices.

6.1.2 Victoria

Victoria's guidelines for the marking of roadside furniture are contained in Vicroads' Traffic Engineering Manual Volume 2. It states that delineation should be continued along the route, and attached to guardrails and bridge rails where they are within 4m of the running lane. Delineator spacing remains independent of the presence of guardrails, with the exception of bridge hand rails and guardrails at the approach and departure of a bridge, where more frequent delineation is required (23.2.3). The same delineator is used for both edge marker posts and for guard rails: red for the left hand side and white for the right hand side, and may be either an 80mm diameter corner cube reflector (type A AS1906.2), or a 100 sqcm rectangle of class 1A retro-reflective material (AS1906.1).

VicRoads generally treats isolated sections of roadside furniture because they are perceived as hazards, not based on accident data.

Companies regularly promote various products, such as 3M's Scotchlite delineators (rippled reflective aluminium sheets), which are trialled subjectively, but have not been adopted as part of standard practice.

6.1.3 South Australia

South Australian practice is essentially identical to that of New South Wales; that is, delineators are placed according to AS 1742.

It is the position of Transport South Australia that road safety barrier systems should either be clearly illuminated or well marked. "The offset cost of collisions with barriers would easily exceed the cost of delineation (hazard marking). Road users may also not appreciate being presented with sudden surprises or poor clarity at close quarters". (Colin Anderson pers. com).

6.1.4 Western Australia

Western Australia currently has limited practice in place for visibility treatment of roadside furniture. However it has identified this area of road safety for further investigation, and is currently trialling stick-on kerb delineators. Circular reflectors, similar to those on Guide Posts, are also being trialled on barriers and walls.

6.1.5 Crash Studies

In South Australia between 1994 and 1996 impact with guardrails resulted in 2 fatalities, 28 hospital admissions, 45 treatment at hospital, and 466 cases of property damage. For the period 1986 and 1995, 13 people were fatally injured when their car hit a guardrail, either by being deflected back into road, or due to the impact with the guardrail itself. These findings were part of a larger study of roadside hazards that included trees, poles, sign posts, bridges, and unspecified fixed obstructions. The majority of the crashes occurred at night, and the authors, Kloeden et al, highlighted the importance of edge delineation to keep the road-user on the road.

However, during the period of the study, the current system of delineation would have been in place, and lack of delineation would not have been a major factor with any of the crashes used in the report. (Colin Anderson pers. com).

6.2 USA

The United States Department of Transportation, Federal Highway Administration (FHWA) has national requirements for delineation and hazard marking in their Manual of Uniform Traffic Control Devices (MUTCD 2000, Chapter 3). The manual states that "Delineators are considered guidance devices rather than warning devices". As this implies, the regulations for delineation along guardrailing follow closely to the standards for road delineation in general. Curves, and un-illuminated road sections may be

delineated, as can barriers lying within 2.4m of the roadside. The delineators are to be mounted behind the guardrail, and have a reflective element with a minimum dimension of at least 75mm, visible from 300m away when viewed under high beam (note that US and NZ standards for car headlamps differ).

In practice, the different states within the USA handle delineation along roadside furniture in a variety of ways. Some states use a reflective tab that fastens to the head of the guardrail bolt as a delineator on guardrails, while others drive a standard delineator post behind the guardrail next to the guardrail post. Engineers from Baltimore, Virginia, and Washington State volunteered information on their practice.

Malcolm Ray of Worcester Polytechnic, Miami, advised that he is unaware of the existence of any specific studies on visibility treatment of roadside furniture, and that the current approaches are likely to have been applied ad hoc.

6.2.1 Baltimore

Most of the state highway agencies require the use of delineation for barrier runs. Old practice was to use “butterfly” reflectors mounted in the valley of w-beam guardrails, or plastic trapezoidal reflectors glued to concrete barriers. Currently, the use of rectangular reflectors mounted on top of guardrail blockouts (or posts where there are no blockouts) and concrete barrier walls is popular. The safety benefit of those longitudinal reflectors has not been studied formally; instead the decision to apply treatment was left to “intuition”, according to William Fitzgerald of the FHWA.

6.2.2 Washington State

Washington State’s treatment practices are given in the Washington State Department of Transportation Design Manual, Chapter 830. This states that barrier delineation is required where guideposts would otherwise ordinarily be required, and that the barrier guidepost spacing should also be standard. However, for *all* barriers within 1.2m of the travelled way, barrier “delineation” is required, with a reflector spacing of no more than 12m.

The latter instruction indicates that the reflectors are to act at least partly as a hazard warning device for when the barriers are closer to the traffic (and thus more likely to constitute a hazard).

Delineation is continued along beam guardrails by guideposts placed behind the rail or attached to the guardrail posts, while concrete barriers are delineated by placing retro-reflective devices on the faces, and occasionally on top.

6.3 Canada

There is currently no standardized roadside furniture marking practice in Canada. Items are examined on a case-by-case basis with the specific treatment left to the particular jurisdiction. Consequently, there are several different treatments for roadside furniture in existence. These include the use of reflection devices, pavement markings, signage, and a newer application involving placing LED's on the obstruction itself.

6.4 United Kingdom

The UK does not treat safety fences as standard practice. However, retro-reflective markers, and raised ribbed thermoplastic edge line (audible) are commonly employed to delineate the road edge.

Paul Forman, of TRL (Transport Road Research) noted while there may be a problem with vehicles hitting safety fences due to poor visibility, it would be very difficult to quantify from accident data.

6.5 Sweden

Road markings and signs are specified in the Swedish roading regulations, but roadside visibility treatments are not. The additional factor of snow covered roads exists in the winter, which may complicate the delineation / hazard marking / road marking issue.

Swedish roads generally have 3 lanes, and are 13m wide. The inner lane alternates as an overtaking lane for opposing directions, and the opposing lanes are separated by wire rope barriers. Crashes into the furniture are common. Sven Olaf Lundkvist, of the Swedish Transportation and Road Institute, considers that improved visibility through the (recent) use of reflectors on barriers may have helped reduce the crash rate.

6.6 Denmark

Current practice is to continue delineation along the length of longitudinal roadside furniture using the same reflectors used for standard route delineation (90x150x200mm white fronted/yellow backed). The reflectors are spaced every 100m on straights, and at less than 50m intervals on curves, similar to New Zealand practice.

7 DISCUSSION

7.1 Current New Zealand Practice

New Zealand guidelines provide no guidance for marking longitudinal furniture along its length. As a consequence, the visibility of the furniture itself, as well as the quality of delineation where longitudinal furniture exists is relatively poor in many instances, especially at night or in poor weather. Many of the practitioners consulted considered that the poor visibility of the furniture in some situations could be a potential danger to road

users. To rectify this, many practitioners in New Zealand have investigated and trialled treatments to roadside furniture to aid in its visibility, and/or to maintain a suitable standard of delineation along its length.

The treatments applied in New Zealand are largely based on the individual practitioner's opinion, and, to some extent, what has been trialled in other parts of the country. The adaptation of existing reflectors, such as raised pavement markers and edge marker posts, is common, and some new technologies have also been trialled, such as 3M's LDS system. This variety in treatments between sites is undesirable from a national consistency perspective. Also undesirable is the variation in treated and untreated furniture. There are instances on some state highways where consecutive barriers are strongly marked, and the next totally unmarked - and thus completely unexpected. Thus consistency of use plays a major role in the effectiveness of any visibility treatment.

7.2 Overseas Practice

No research on the visibility treatment of longitudinal roadside furniture was known of by any of the practitioners contacted. Most implied that the treatments they used came about by consideration of the situation and from informal trials, rather than from a detailed and formal investigation.

Generally, the guidelines consulted and practitioners contacted did not make a clear distinction between delineation (as route guidance) and hazard marking. Australian treatments generally address both purposes, with the emphasis being placed on one or the other depending on the state. New South Wales and South Australian treatments appear to be designed primarily as hazard warnings, while Victorian treatments are based on continuing delineation along furniture in a similar manner to open sections of road.

The USA is one of the few countries to clearly discriminate between delineation and hazard marking in its guidelines, and most of its practice seems to have originated from the former. However, several of the directives within the guidelines are clearly aimed at increasing the visibility of the furniture as a hazard, so this is again something of a mixed approach.

Canada, the United Kingdom, and Sweden are very similar to New Zealand's current situation, where there is no formal treatment for longitudinal furniture. Some practitioners in these countries have attempted to remedy the perceived shortfall of their respective marking guidelines by applying their own visibility treatments, as is the case in New Zealand.

8 COURSE OF ACTION FOR NEW ZEALAND

8.1 General

The presence of longitudinal furniture, either in, or to the side of the road, causes difficulties for continuing delineation along the route. Roadside barriers, bridge railing, tunnel walls, and kerbing, generally cause a narrowing of the traversable roadside area available to the road user. According to the national road marking guidelines (in MOTSAM), edge marker posts must be placed within the trafficable width of the road. Clearly then, to continue edge marker post delineation where longitudinal roadside furniture exists, it is necessary to mount the posts on the near side of the furniture. This certainly may pose a safety hazard for pedestrians and cyclists, and may not even be possible in many situations (such as narrow bridges, tunnels, etc.). Therefore, to safely provide adequate route guidance along roadside furniture, another method of delineation may be necessary.

A closely related, yet distinct, concept is that drivers should be aware that the longitudinal furniture exists, so that they can take the appropriate care (perhaps lowering speed) and so that no confusion exists as to where it is safe, and when it is not safe, to pull off the road. In this respect, barriers and kerbs themselves can be considered hazards, and should be marked as such along their length.

It should be possible to provide adequate solutions to both problems with a single treatment. The treatment would have to indicate to the road user:

- that roadside furniture is present,
- its proximity to the road,
- route guidance, at least to the standard of delineation that would otherwise have existed without the furniture in place.

Thus the design of the treatment must be distinct from the standard delineation devices (such as edge marker posts) to clearly indicate that roadside furniture is present. This distinction is even more necessary now that edge marker posts are made of flexible impact resistant material. The replacement rate of 10 to 15% per annum shows that they are often hit, and because most drivers now know that the posts are flexible they may make less effort to avoid them. (This excludes those who hit them deliberately.)

8.2 Issues to Consider

The visibility treatments applied to the furniture should be at such a brightness level that the driver is aware of the presence and proximity of the furniture, without having to deliberately search for it, so that attention remains focused on the road ahead. Conversely, the treatment should not be so bright or dominant that it 'over powers' other markings present, or that it makes the preceding and following road sections appear poorly delineated by comparison.

The design of the treatment should be done with consideration for the safety of pedestrians and cyclists, who are likely to be in close proximity to roadside furniture in particular. The treatment should also be resilient and secure, as broken or misaligned fixtures may constitute a significant hazard to pedestrians, cyclists, and motor vehicles. The design process would also have to ensure that any furniture to which the treatment is affixed would not be structurally affected. The usual economic concerns of cost efficient materials, construction, placement, cleaning, replacement, and repair of course apply.

Kerbs pose a particular visibility problem, because their low profiles and grey colour make them particularly difficult to identify at night. The same low profile also makes them difficult to treat, and thus the range of treatments available for kerbs is substantially smaller than that for barriers. In New Zealand it is reasonably common practice to place edge marker posts behind kerbs, in contradiction to the regulation for edge marker posts to be placed within the trafficable portion of the road. The need for a kerb based delineation/hazard-warning treatment is supported by the 'kerb overhang' on bridges, where the bridge warning sign is placed 500mm inside the face of the kerb. Any treatment applied to a kerb should not interfere in any way with pedestrian or cycle traffic.

Painting kerbs is a common treatment. However where there are also lane edge lines there may be problems. When brighter edge lines are used they will mask the painted kerb unless it is of a similar brightness. In wet conditions however a white kerb is likely to be more visible than many current road paint types which have poor visibility in the wet and so the kerb may be mistaken for the white edge line. It may be best to continue the common practice of not marking the kerb. Instead a new marking could be developed that conveys the message, "do not cross this line".

8.3 Other Issues : end treatment

This review was directed at investigating the need for marking along the length of roadside furniture, but the review also identified two areas where current end-treatments could be improved. Some provision is made in MOTSAM for treatment of the ends of longitudinal furniture, but it is left as an option, and does not say explicitly how these should be marked. Common practice is to paint the terminals, and/or to affix a sign (left/right arrows, double white dots, and bridge end markers are the commonest). However there are many instances where terminals have not been marked at all. The end of a solid barrier near the road will almost certainly constitute a hazard to vehicles in most situations, therefore regulatory end markings for all guardrails should be considered.

Kerb overhang beyond warning signs is another potential hazard. This often occurs on bridges, where regulations state that the bridge end markers should be 500mm within the (probably unmarked) kerb face. The increasingly popular pedestrian kerb extensions in urban areas also often struck because they can be difficult to see. Trials of reflective treatments suggest that improving the marking of the kerbs can reduce the number of collisions with them.

9 DEVELOPING RECOMMENDATIONS

9.1 Guiding Principles

This review has identified that there is no defined International Best Practice that we can recommend to be used directly in New Zealand. There are a number of examples that are worth pursuing further, but often some specific trials should be undertaken to evaluate the effect of the treatment in the New Zealand context. However the need for guidance on how to mark roadside furniture was clearly apparent from the review of current New Zealand practice.

In formulating guidance we have first identified some general principles to form the basis of recommendations. These are a distillation of current New Zealand practice and our view of how international practice could be included and improved on and fitted to the New Zealand road environment. These general principles are:

- Markings and warnings along the route should illustrate the variability of the close-in roadside environment, that is about 3-4 metres from the edge of the left hand lane, so that a driver at night time has a similar appreciation of this variability in this zone as would a driver in the day time.
- Roadside furniture close to the road edge should be marked along its length to indicate its presence.
- The safe path on the road should be marked where it would be hazardous to stray from the safe path, and this marking should be visible in all weather conditions.
- Delineation of the safe route should be given prominence i.e. the brighter markings, with hazard markings on the periphery being of a lesser brightness so as to be readily discernible without being distracting.
- Markings and warnings should be simple and uncluttered, that is a multiplicity of lines of markers should be avoided.
- There needs to be a balance in the brightness of the markers and road markings also along the road.

9.2 Specific Treatments Proposed

- (a) There should be consistency in marking the start of guardrails. At present only some are marked. This should be extended so that all guardrails are marked at their ends.

- (b) The markings that are currently used to mark the safe route beside roadside furniture should be upgraded to markings which are brighter and which still function in wet night conditions. This will address the problem of many markings being of poor visibility to older drivers and of almost all current New Zealand road markings not being visible in the wet.
- (c) A marking is needed to advise that it is hazardous to cross over the left hand edge line. This is particularly for kerbs in rural areas, and on bridges. The current white line does not have this role in New Zealand unlike Australia where the solid left hand edge line is not to be crossed.

The two candidate line types are:

- A continuous yellow line. This line type already exists for the centre line but its use to the left hand side may require education as to its purpose.

The yellow line has the advantage of being effective both in day light and night time and, if appropriately specified, would not require RRPM's for night or wet night effectiveness. However its use would require other changes to maintain consistency, for example with approaches to medians.

- Red reflective pavement markers fixed onto the left hand edge line. This treatment almost has the "no crossing intent" in rural areas already but this is not explicit and this meaning is corrupted by alternative uses in urban areas.

This no-crossing line type should also be used on the right hand edge line where there is a low profile median adjacent to the lane. In the "RRPM on white line" option, a number of areas in New Zealand are already using red on the left hand edge and yellow RRPM against the median and this appears suitable for a national approach.

- (d) Only furniture close to the road should be marked along its length with hazard markers. Australia marks guardrails up to 4 metres back from the road edge, the USA about 2-4 metres back. New Zealand roads do not always have such wide shoulders. Marking furniture that is 1 metre behind the line of the edge marker posts is proposed, as the EMP positions will already be determined relative to the actual shoulder width at that location. With edge marker posts often being about 3 metres from the road edge, marking hazards that are within 1 metre of the line of EMP's is a close match to the 4 metres used in Australia and the USA.
- (e) A new marker type is needed which can fulfil both functions of marking the hazard of the furniture along its length such as guard rails or sight rails and which continue the route delineation currently provided for the rest of the route by edge marker posts. This type of marker would be used mainly in rural areas where the furniture is intermittent and the roadside environment is therefore variable rather than on urban

motorways where generally the guard rails are continuous, there are generous shoulders marked with diagonal lines, and the roadside environment very consistent.

There are several candidate devices, which include readily available commercial products and some home grown trial devices. Circular prismatic reflectors are used in both Australia and some States in the USA. These are coloured red and so continue, for Australian at least, the use of red reflectors on the left hand side. They are usually fixed to the top of the guardrail posts or concrete barriers.

The alternative approach in New Zealand would be to taper the edge marker posts towards the barrier and continue the posts along the top of the guardrail. We propose that an alternative reflective device be identified for New Zealand use; first because the use of end marker posts at the guardrails does not signal the changed road side environment; and second because the edge marker post is difficult to apply to concrete barriers or bridge sides. These markers need to be balanced with markings on the road, and with the rest of the delineation both before and after the hazard. Specific trials will be needed to identify appropriate devices.

Delineation of the safe road should be given priority with respect to the brighter markings and hazard markings should be less intrusive. Where the furniture is close and parallel to the road edge then it can be used to reinforce the delineation around, for example, a tight curve. This could be achieved by increasing the marker density and if necessary the brightness, or size.

10 RECOMMENDATIONS

- a) The current practice of marking the end of some guardrails should be extended to the ends of all guardrails.
- b) Road marking used to mark the safe route beside roadside furniture in rural areas should be brighter and function in wet conditions (Retroreflectivities, based on 100mm wide lines, of $100\text{mcd.m}^{-2}\text{Lux}^{-1}$ in the dry and $50\text{mcd.m}^{-2}\text{Lux}^{-1}$ in the wet are recommended.
- c) A new marking type that denotes "do not cross" is recommended for the left hand lane edge line (equivalent to the yellow centre-line), for use where it would be hazardous to do so such as kerbs in rural areas and against kerbs on bridges. Possible markings that should be further investigated are; a solid yellow line or a solid white line with coloured reflective raised pavement markers.
- d) Furniture within 1 metre of the line of edge marker posts should be marked along its length with hazard markers.

- e) A new marker type that can fulfil both functions of marking hazards and providing delineation should be further investigated for use in rural areas where the furniture, such as road edge guardrails or sight rails, is intermittent, and marking it warns both of the hazard and strengthens the delineation of the road.
- f) Delineation of the safe route should be a priority and be brighter than for hazard marking.

11 REFERENCES

Appleton I: "Safety Management Systems" Transit NZ and NZHIT: Engineering for road safety symposium 2000

Boyle J: (1998) Clear the Way to Roadside Safety" Traffic Safety September / October. pp12-13.

Croft, D: (2000) "Using Crash Statistics to Improve Road Safety". Roadmarking Industry Association of Australia Conference 2000.

Elvik, R (1995): "The Safety Value of Guardrails and Crash Cushions: a Meta-Analysis of Evidence From Evaluation Studies". Accident Analysis and Prevention Vol. 27 no 4, pp. 523-549, a995. Elsevier Science Ltd, USA.

FWHA MUTCD (2000) Manual of Uniform Traffic Control Devices Ch. 10 Other delineation devices.?? P148 barrier delineators. US Dept. of Transport.

Hammond, J: Wegmann, F: (2001): "Daytime Effects Of Raised Pavement Markers On Horizontal Curves" ITE Journal August 2001 pp. 38 - 41

Jenkins S "Risk Management In The Clear Zone" Transit NZ and NZHIT: Engineering for road safety symposium 2000.

Lienau, K: (1996): "Safety Effects Of Barrier Curb On High Speed Suburban Multilane Highways". Texas Transport Institute report TTI-04690-6. August 1996. Texas Transport Institute.

LTSA: (2001) "Installation of Guardrails". Land Transport Safety Authority Crash Reduction Study Monitoring. December 2001. LTSA, Wellington

LTSA (2001) "Roadside Hazard Management" Land Transport Safety Authority Traffic Standards and Guidelines 2000/2001 Survey RSS 15. November 2001. LTSA, Wellington.

LTSA: (2000) "Motor Accidents in New Zealand"

LTSA: (2001) Traffic Standards and Guidelines 2000/ 2001 Survey RSS 15 *Roadside Hazard Management*. Nov 2001

LTSA: (1992) "Guidelines For Rural; Road Marking And Delineation"

LTSA: (2000) "Travel Survey Highlights 1997/1998"

LTSA: (2000) "Travel Survey Report 1997/1998".

LTSA: (2001) "Installation of Guardrails". Crash reduction study monitoring December 2001

LTSA and Transit N Z: (1997) "Manual of Traffic Signs and Markings"

McDevitt, C: (2000) "Basics Of Concrete Barriers" (tfhrc.gov/pubrds/marapr00/concrete.htm)
Transit NZ (1999) "Specification For Road Safety Barrier Systems". TNZ M/23: 1999. Transit New Zealand Wellington.

Ogden, K: (1996) "Safer Roads A Guide To Road Safety Engineering". Avebury Technical Hants England

Opus International Consultants/ Transit NZ "Road Markings - Effect on Cycle Safety" paper presented to Road Safety Conference, Canberra

RNZRMF and RIA Safety through Engineering And Education 1997 Conference

Spowat T and Oppenhaus M: "Safety Management Systems" Transit NZ and NZHIT: Engineering for road safety symposium 2000.

Standards Australia: "Manual of Uniform traffic Control Devices". Australian Standard AS 1742.2 - 1994

Transfund NZ: 1998 "Median Barriers - How The Safety Benefits Measure Up" Transearch August 1998 Issue 32 pp16-17. Transfund NZ, Wellington.

Transfund NZ: 2000: "RCA'S Need To Get Edge- Wise". Transearch February 2000 issue 2 pp2-3. Transfund NZ, Wellington.

Transfund: 2001 "More Attention Needed To Roadside Hazards". TranSafe April 2001 issue 5

Transit N.Z, Opus: (1999) "Performance of Thermoplastic Markings and Cyclists Safety Stage 2: Line Thickness and Skid Resistance Studies". Transit New Zealand/Opus International Consultants, Central Laboratories Report 99-527550.02. Transit NZ, Wellington.

Transit N.Z, Opus: (2000) "Performance of Thermoplastic Markings and Cyclists Safety Stage 1: Review of Current Practice". Transit New Zealand/Opus International Consultants, Central Laboratories: Report 00-527550. Transit NZ Wellington.

Transit N.Z, Opus: (2000) "Performance of Thermoplastic Markings and Cyclists Safety Stage 3: Further Line Thickness Studies". Transit New Zealand/Opus International Consultants, Central Laboratories: Report 00-527559.00. Transit NZ, Wellington.

Transit NZ: 2000 "State Highway Safety Management System Manual". Edn. 2 June 2000. SP/M002

Transit NZ: 2000 "Bridge Manual". 2000 SP/M/104

Transit NZ: 2002 TNZ M/14: 2002 Specification For Edge Marker Posts (available on their website)

Transit NZ: TNZ M/23:2002 Specification For Road Safety Barrier Systems (available on their website)

Zuckier, G, Lenworth, J Thibeault, L: 1999. "Using Linked Data To Evaluate Severity Of Outcome Of Injury By Type Of Object Struck (First Object Struck Only) For Motor Vehicle Crashes In Connecticut Crash Outcome Data Evaluation System" (CODES). US Dept of Transportation National Highway Traffic safety administration DOT HS 808 973 NHTSA rep