The Usability and Safety of Audio Tactile Profiled Road Markings

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Abbreviations and acronyms

ATP	Audio tactile profiled
AADT	Annual average daily traffic
B/C	Benefit cost ratio
CAP	Cold applied plastic
DYC	Double yellow centre line
MOTSAM	Manual of Traffic Signs and Markings
NZAA	New Zealand Automobile Association
TP	Thermoplastic
ROR	Run off road
VPD	Vehicles per day
RRPM	Raised reflective pavement marker
TERNZ	Transport Engineering Research New Zealand

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Foreword

Audio Tactile Profiled (ATP) road markings (also known as rumble strips) have been used at selected locations on New Zealand roads for a number of years. However, a recent Land Transport Research report established that more extensive use of these markings, over a wider range of traffic volumes and roadway situations would result in cost-effective crash reductions. Land Transport New Zealand therefore commissioned TERNZ to investigate possible impediments to the wider use of ATP road markings and to consider whether the existing guidelines for their use need to be reviewed.

Of the available range of road improvements, ATP road markings are identified in KiwiRAP 2008 as able to bring about one of the greatest potential reductions (20% to 45%) in injury crashes, and can assist with the management of driver fatigue and inattention. KiwiRAP is the New Zealand Road Assessment Programme, the New Zealand Automobile Association's partnership with government transport agencies dedicated to helping achieve the government's Road Safety to 2010 strategy through driver awareness and road improvement measures.

This project was conducted in 2 stages. The first stage was the preparation of a discussion paper which identified issues and potential solutions requiring further consultation. The discussion paper was reviewed in detail at an expert's technical workshop and at a series of three industry-based road safety workshops held at Auckland, Christchurch and Wellington in April 2008. These involved representatives of local government, Transit New Zealand, road marking contractors and suppliers, road users and researchers. The second stage of the project used the results of the above consultation processes to prepare this report to present findings and recommendations.

The report makes a number of recommendations, which when adopted as policy in guidelines, standards and procedures, will help to ensure the application of best practice and the consistent use of ATP road markings. NZ Transport Authority (NZTA) believes that the results of the project will provide a significant opportunity to improve New Zealand's road safety outcomes by enabling ATP road markings to be used more extensively and more consistently than at present.

NZTA acknowledges TERNZ and their associates for undertaking this project, and thanks the New Zealand Automobile Association, Transit New Zealand, the New Zealand Road Markers Federation and the many organisation and individuals who contributed to the identification and analysis of the issues, the consultation process, and the preparation of the recommendations.

Executive summary

Audio Tactile Profiled (ATP) edgelines and 'no overtaking' centrelines generate audible and tactile vehicle responses when driven over, making drivers less likely to inadvertently leave the lane that they are travelling in. A research report prepared by TERNZ (Mackie and Baas 2007) established that the increased use of ATP road markings or rumble strips, as they are also referred to by road users, would result in crash reductions on New Zealand roads and would be economically justified. Land Transport New Zealand commissioned TERNZ to undertake this second project to investigate the current operational requirements for ATP road markings, and to prepare recommendations on policy and technical matters to enable their use to be increased.

Mackie and Baas (2007) found that cost-effective crash savings could be achieved if ATP road markings were used on up to 70% of New Zealand's highways. Current estimates suggest that only 3% to 5% of New Zealand's highways have some form of ATP road marking treatment. On State Highways, Transit New Zealand acknowledges that there are potential safety benefits from increasing this proportion and is currently developing a strategic approach based on KiwiRAP high risk routes, high personal crash risk areas, and other locations where low cost engineering treatments such as ATP road markings are likely to provide a good safety return.

A discussion paper was prepared based on input from a wide range of interested parties including road users, highway managers and engineers, researchers, and suppliers of road marking services. It identified 20 main issues (reduced to 18 in this report) which were considered in detail at 4 workshops involving road user representatives, central and local government road owners and providers, the road marking industry, highway and road safety managers, researchers and consultants. This report presents the outcome of the consultation on the discussion paper and workshops.

A key conclusion, strongly supported through the consultation process, was that to be most effective ATP road markings should be used as a continuous treatment to help establish the safety environment of a significant length of highway, rather than as a series of localised or spot treatments at crash black spots or specific high risk locations. This is because the alerting safety intervention created for drivers by ATP road markings may occur some distance before the location of a potential crash. Furthermore, a consistent road environment will in itself yield safety benefits. This conclusion was considered to be of central importance as it shapes the approach needed for the assessment and evaluation of proposed ATP road marking installations, and also informs some of the practical and standards related issues which this paper addresses. A number of other recommendations have also been made which are intended to clarify best practice usage and promote consistency, if implemented as policy, in the appropriate standards and guidelines.

Implementation of the results presented in this report would help to further improve the safety of the road environment by encouraging the use of ATP road marking where this technology is appropriate, and enable them to be used more effectively with greater uniformity and consistency.

The installation and maintenance of ATP products remain more expensive than other high performance long life road markings, but the cost differential is expected to reduce as their use increases. Careful attention to installation details and technical specifications is required

to ensure that the expected trade-off between cost and safety is achieved. It was recommended that, as at present, each ATP road marking installation should remain subject to appropriate cost benefit evaluation and technical assessment procedures. The cost evaluation tool previously developed by TERNZ is available for this purpose.

The conclusions and recommendations in this report represent current best practice concerning a relatively new road safety treatment, based on the collective experience and consensus of practitioners. This body of knowledge is now available to inform amendments to standards, guidelines and procedures, but should also continue to evolve as the pool of experience and evidence increases.

Abstract

Audio Tactile Profiled (ATP) road markings (also known by road users as rumble strips) have been used at selected locations on New Zealand roads in recent years. However, a recent Land Transport Research report established that more extensive use of these markings over a wider range of traffic volumes and roadway situations would result in cost-effective crash reductions. The potential benefit of ATP road markings is recognised by KiwiRAP, the New Zealand Automobile Association's New Zealand Road Assessment Programme partnership with government and transport agencies, dedicated to helping achieve the government's Road Safety to 2010 strategy through road driver awareness and improvement measures. Land Transport New Zealand (now NZTA) therefore commissioned this project to investigate possible impediments to the wider use of ATP road markings and to consider whether the existing guidelines for their use need to be reviewed.

Based largely on consultation, the report provides an overview of practice and technology currently applied to the use of ATP road markings in New Zealand. It recommends best practice guidelines and changes to decision making processes, technical standards and some further research.

The project provides information needed by highway managers and ATP road marking installation contractors. The recommendations inform the development of changes to rules and decision making procedures and, when adopted, should result in significantly increased usage of ATP road markings and a corresponding increase in crash savings.

1. Introduction

The purpose of this project is to support the development of best practice guidelines for the safe and effective use of Audio Tactile Profiled (ATP) road markings, also known as rumble strips, in New Zealand to help facilitate their wider use.

ATP road markings are a type of long life road marking product which have raised ribs orientated perpendicular to the longitudinal direction, and are closely spaced at regular intervals along or adjacent to the line. If a vehicle's tyre runs on or over an ATP road marking it provides an audible and tactile warning to the driver, improving safety by making the driver less likely to leave the traffic lane unintentionally. Furthermore, the raised ribs can provide superior visibility to a conventional flat line in wet-night conditions and during rain. As such, ATP road markings are potentially a very powerful and cost effective road safety intervention. The driver stimulus generated by ATP road marking are considered to assist with driver fatigue management and to help reduce driver inattention.

ATP road markings belong to a wider group of long life road marking products each with particular performance characteristics best suited to certain applications. For example, some long life road markings are designed for enhanced visibility in wet night-time conditions, although all long life road markings, including ATP, contain reflectivity treatments to help improve night-time delineation. Typically, ATP road markings are used in conjunction with other types of road marking and delineation treatments and as such should be regarded as part of a complete road marking and delineation system. New and improved products of this type are continually being developed and tested; their selection for particular installations requires consideration of the highway's operational characteristics and drivers' requirements. However, the distinctive performance characteristics of ATP road markings, and their established road safety benefits appear to strongly justify their increased usage.

This project follows Land Transport New Zealand Research Report 322, *The cost effectiveness of delineation improvements for safety*, (Mackie and Baas 2007). A spreadsheet-based cost management tool was developed to enable convenient and rapid calculation of the benefit/cost ratio (B/C) for a given road segment (e.g. mid-block or curve) or a complete route. This tool was used to assess B/C ratios for a range of typical road marking situations. ATP road markings were found to provide significant safety benefits that outweigh the cost of the treatment even at relatively low traffic volumes, and the report established that ATP road markings should be installed on a much more widespread basis where road conditions allow.

Based on the findings of previous literature (Baas et al 2004), a default crash reduction setting of 25% was used in the cost management tool as a representative value, based on the application of ATP edgelines and 'no overtaking' centrelines (Mackie and Baas 2007). Subsequently, of the available range of road improvements, ATP road markings were endorsed by KiwiRAP 2008 as able to bring about one of the greatest potential reductions (20% to 45%) in injury crashes. KiwiRAP is the New Zealand Road Assessment Programme, the New Zealand Automobile Association's (NZAA) partnership with government transport agencies dedicated to helping achieve the government's Road Safety to 2010 strategy through driver awareness and road improvement measures.

The project aims to identify the full range of issues which have emerged from the current use of ATP road markings in New Zealand, and to resolve issues already identified by Mackie and Baas (2007).

The purpose of the recommendations in this report was to assist Land Transport New Zealand and Transit New Zealand (now the New Zealand Transport Agency) in the adoption of best practice guidelines to enable those responsible for highway management and safety, and road marking service providers to make better decisions when installing ATP road markings. It is also expected that the best practice guidelines will be used to inform the development of future amendments to the Traffic Control Devices Rule (2004), the Manual of Traffic Signs and Markings (MOTSAM), and Transit New Zealand's contract specifications.

2. Methodology

This project was largely consultation based. It complements the work previously undertaken by TERNZ to evaluate the effectiveness of ATP markings as a road safety treatment, and complements research currently being conducted by Opus International Consultants Ltd for Transit New Zealand to review technical details concerning ATP rib profiles.

Four phases of consultation were used. Firstly, a large number of roading professionals currently or previously engaged in installing ATP markings, and a sample of road users representing the NZAA, cyclists, motorcyclists, and truck operators, were canvassed to identify current practices, issues and any problems experienced with ATP road markings. These sources were the main input for a Discussion Paper which invited comment on 20 main issues which were distilled from the above process. The Discussion Paper was circulated for comment and was used as the basis for a technical workshop. The Technical Workshop findings were in turn discussed in a presentation by TERNZ at each of 3 Road Safety Workshops hosted by the New Zealand Road Markers Federation. Finally, this report, whose recommendations were informed by each of the above consultation phases, has been circulated for further comment and reviewed accordingly. Overall, about 70 people contributed to this report comprising road users, central and local government road and safety engineers, researchers, consultants and highway managers, and the road marking industry. Appendix 1 lists individuals and organisations who participated in the above consultation processes.

This report's recommendations are expected to be used for the preparation of amendments to Transit New Zealand specifications, MOTSAM or its replacement (i.e. the proposed new Traffic Control Devices Manual), when further opportunities for formal discussion will be available.

3. Background

This section provides a summary of essential reference documents and, for the reader's convenience, a brief review of the literature and the findings of the previous TERNZ research.

3.1 Conclusions from the Research Report 322

The main purpose of Research Report 322 (Mackie and Baas 2007) was to develop a cost management tool that would assist Road Controlling Authorities and their consultants to prioritise delineation treatments to achieve added safety benefits compared with standard road markings.

Currently, ATP edgelines and 'no overtaking' centrelines tend to be installed at specific locations where there is an obvious history of injury accidents. Additionally, there was the potential to treat a larger proportion of New Zealand's rural roads with safety measures such as wider line markings, or ATP edgelines and 'no overtaking' centrelines. However, the cost-effectiveness of these safety improvements needed to be calculated before a recommendation for their more widespread use could be justified.

A tool was developed that calculated a benefit/cost ratio (B/C) for a given road segment (rural mid-block, rural curve, and rural bridge) based on road parameters, delineation improvement details and an associated crash reduction factor based on the delineation improvement. A "Route Builder" was also developed where the B/C for an entire route of a specified length could be readily determined.

In general, favourable B/C's were found to result from ATP treatments on roads with relatively modest traffic counts and much higher B/C's from higher traffic counts. Using the cost management tool, a typical ATP edgeline and 'no overtaking' centreline treatment resulted in a B/C of greater than 1 at approximately 1300 vehicles per day for mid-block applications. Changes in individual variables did not greatly affect the resulting B/C's, however changes in a combination of variables such as region, daily traffic, crash reduction factor, treatment costs and treatment life were found to collectively have a large affect on the B/C of a project.

The results of a limited number of analyses of the effect of ATP road markings on crashes in New Zealand were in agreement with overseas literature and provided validation for the cost management tool.

Using Transit New Zealand's vehicle count data, the proportion of the state highway network that has a given annual average daily traffic (AADT) was estimated. Using the cost management tool the report showed the proportions of the State Highway network that might conceptually qualify for delineation upgrades to ATP lines for B/C's of 1.0 and 4.0. This was intended to give a rough estimate of the proportion of the State Highway network that might be upgraded based on the B/C analysis. Refer to Table 3.1, from Mackie and Baas 2007.

Table 3.1 Approximate percentage of the State Highway network that could be treated with ATP lines at B/C's of 1.0 and 4.0. - From Mackie and Baas (2007)

	B/C ratio > 1.0	B/C ratio > 4.0
Treat all	70% (>1300 AADT)	26% (> 5000 AADT)
Treat curves	21% (> 600 AADT)	44% (> 2200 AADT)

Using this approximation, Mackie and Baas (2007) stated that there would be a net benefit in treating a substantial amount of the State Highway network with ATP road markings. Even if a B/C ratio of 4.0 was used as the minimum criteria for treatment, 70% of the network would qualify for some degree of ATP road marking treatment. Currently only 3% – 5% of State Highways have any form of ATP road marking treatment.

While Mackie and Baas (2007) concluded that there would be a net benefit in treating a much greater proportion of the State Highway network with ATP road markings than at present, they noted that there are many operational factors that need to be considered prior to the installation of ATP road markings. These factors include the possible dangers of using ATP lines with narrow or non-existent road shoulders, the relative merits of other products that have excellent wet night retroreflectivity but little or no audio-tactile response, the merits of the different ATP road marking products available, variations in ATP road marking designs and cost variations. The usability of ATP road markings by motorists, motorcyclists and cyclists, together with the effects on nearby residents, also needed to be more fully considered prior to increasing their use. This project addressed these and other issues.

3.2 Literature review

A comprehensive literature review was reported in a previous project, Baas et al (2004) sourced from published journal articles, local and overseas transport engineers, and a search of reports posted on worldwide web sites. Twenty four key reports (citing more than 500 source documents) were then independently reviewed and summarized, and an annotated review of each article was prepared and included in the review document. This reported a survey of 43 States in the US (Agent et al. 1996) which found a large variation in crash reductions due to wider edgelines, with an average crash reduction of 5%. Reports of rumble strips' effectiveness ranged from a 2% reduction to a 44% reduction across all types of crashes, with an average reduction of over 27%. When considering only run-off-road (ROR) crashes, shoulder rumble strips had been found to be very effective in reducing crashes by 20% to 80% (an average of 32% for all ROR crashes, 42% for fatal ROR crashes). According to the literature, the greatest benefit may occur for high-speed road segments associated with horizontal curvature (which is also associated with a higher ROR crash rate). Similarly, centreline rumble strips were reported to produce significant reductions in head-on and sideswipe crashes ranging from 21% to 37% of reported crashes.

An ongoing Road Safety Engineering Risk Assessment (RSERA) project by ARRB, which is still to be published in full, has carefully evaluated reported crash savings from studies of audio tactile treatments, weighting the results of each study according to the quality of the data and methodology. On this basis, ARRB has selected a 23% reduction and has a medium level of confidence in this figure. In an earlier report on this project ARRB's Road Safety Risk Reporter 6, a newsletter giving crash reduction estimates for road safety treatments indicated a crash reduction of 20% for shoulder (ARRB 2006) treatments.

While it seems clear that improved delineation technology, especially the use of ATP road markings, is effective in reducing crashes, there is less overseas information on the cost effectiveness of such treatments. One study reported the B/C ratios for profiled line treatment, based on a literature review, a survey of 68 road engineers, and a simulator study conducted at the University of Minnesota (Corkle et al. 2001). Benefit/cost ratios from treatments in New York, Nevada and Maine in the US were found to range from 30:1 to 182:1 depending on the location.

It should be noted that the rumble strips reported in North America usually consist of transverse grooves 300mm to 500mm wide either pressed or milled into the road surface and placed a similar distance from the edgeline where wide shoulders are present on freeways and turnpikes. As such, they technically are quite unlike the ATP edgelines used in New Zealand and as they are applied in a different highway environment under a different cost structure; the North American findings must be used with caution in New Zealand.

3.3 New Zealand evaluations of delineation improvements

Recently, the Traffic and Road Safety Research Group (Waikato University) and TERNZ Ltd participated in a study titled *South Waikato and Taupo Target 2010 Remediation Treatments Monitoring*. (Charlton 2007), known as the SWATT 2010 Corridor Study. In response to design and operational problems that have led to high crash rates on State Highway 1 between Piarere (near intersection with SH 29) and the Desert Road summit, trial treatments were installed and 4 sites were evaluated. The treatments were installed progressively. The first treatment involved improved painted delineation including the addition of 'no-overtaking' centrelines at sites where they did not previously exist. A second treatment stage included the addition of ATP edgelines and centrelines and at a fifth site, with no other treatment, raised domes were installed on the white dashed centreline. In order to assess the success of the delineation treatments, drivers' lane-keeping, speeds, and overtaking were monitored at 5 sites in the study corridor as the treatments were progressively introduced throughout 2005 and 2006. The 'no overtaking' lines eliminated overtaking at the monitoring sites. The ATP centre and edgelines had the effect of significantly reducing the number of vehicles with wheels over the lane lines, eliminating observed centreline crossings at the site where they most often occurred. The ATP lines appeared to have their greatest positive effect in reducing the proportion of vehicles traveling at the extreme right or extreme left of the lane just prior to, or after a curve.

Prior to the study, roading officials (the SWATT 2010 Corridor Study Team) identified two key problem areas on this section of State Highway 1. These were:

- drivers losing control and failing to stay on the road, and
- a high incidence of crossing centreline and head-on crashes.

The observed improvements in these behaviors suggested that the ATP edge and the 'no overtaking' centrelines may significantly contribute to reducing the crashes within the study area; however a more extensive study was required to verify this.

There were also some less formal New Zealand examples of the effectiveness of ATP edge and 'no overtaking' centrelines. These were discussed as case studies in Mackie and Baas (2007).

One conclusion reached from the literature and local reports is that, at least in road environments such as New Zealand's, there is relatively little scientifically-based evidence available to guide engineering judgement about practical matters when installing ATP markings. This means that pending the results of the current work by Opus International Consultants Ltd regarding certain technical specifications, and further work recommended in this report concerning road shoulder provisions for cyclists, improved guidelines for using and increasing the use of ATP road marking in New Zealand must come from consensus based on practical experience.

3.4 MOTSAM and TNZ Specification M/24

The current operational requirements for the use of ATP line markings on State Highways in New Zealand are set out in the following two Transit New Zealand (Transit) documents:

- Manual of Traffic Signs and Markings (MOTSAM), Part 2 Markings, Section 4.08 Profiled Line Marking, and
- Specification for Audio Tactile Profiled Road Markings, Transit M/24.

MOTSAM sets out Transit's requirements for the location and arrangement of ATP line markings, while the M/24 Specification lists type-approved products and designs. In addition, Transit has granted provisional approvals based on results of overseas trials, and various installations have been made on the basis of 'trials' of products and marking formats. M/24 is primarily a performance specification for supply and installation contractors.

Research is also underway by Opus International Consultants Ltd to look at the effectiveness of various formats for block heights, inter-block spacing, block shapes, angles etc, and the effect of these parameters on the audio tactile impact. The above two Transit documents will be updated when the results of this Opus project are available.

The above Transit documents are intended to ensure that the location and arrangement of ATP road markings and their performance is consistent throughout the country, and reliable over the period of their design life. On roads which are not State Highways, Road Controlling Authorities (RCAs) may also adopt the Transit requirements or may use other standards, provided they do not conflict with provisions of the Land Transport Rule: Traffic Control Devices Rule (TCDR). This Rule regulates and gives authority for the provision of traffic signs and markings on all roads in New Zealand. The TCDR is not specific about ATP road markings but the rule's general provisions concerning safety and the arrangement of road markings apply to them.

It should also be noted that Land Transport New Zealand has a project underway to review and revise MOTSAM. MOTSAM's reviewed requirements will then be moved to two new documents entitled Traffic Control Devices Specifications and Traffic Control Devices Manual, supporting the TCDR, in order to clarify their application to the entire road network as distinct from State Highways only. This project report is intended to provide input to the Road Marking Specification section of the new manual.

The main requirements contained in MOTSAM and the provisions of M/24 are summarised in Appendix 1 and Appendix 2 respectively.

3.5 Current practices

3.5.1 ATP product materials

ATP lines are currently applied using thermoplastic (TP) or poly methyl methacrylate (PMMA) commonly known as cold applied plastic (CAP), with ribs consisting of the same product. Technical installation requirements, such as the road surface texture or cost would normally determine which product is used. The ribs may be placed either with or without an interconnecting continuous line.

One variation is to first place TP or CAP ribs and then spray a painted line, either over the top of them or alongside, in a second run. This process reduces the amount of TP or CAP material required potentially saving cost, and can also be used to retro fit ATP on or adjacent to an existing edgeline. However, as two passes may be required to complete the installation the cost of temporary traffic management may be doubled, and this is a significant proportion of the cost in most road marking installations. It is understood that processes have recently been developed to allow any permitted combination of line and ribs to be applied in one vehicle pass. This would significantly reduce the overall time taken to install ATP road markings.

Many factors determine the service life of an ATP road marking installation. These include:

- The type of ATP product and how it is installed.
- The age, material and condition of the road surface before the ATP installation.
- Traffic composition and highway usage that the lines are been subject to.
- Placement of the ATP lines in relation to the road geometry which may determine the frequency of vehicle encroachment.

MOTSAM provides guidance on the use of ATP road markings which are consistent with its other provisions and the TCDR. However MOTSAM does not cover every situation, and over recent years there has been some experimenting with ATP applications. This has resulted in a variety of ATP designs which have been informative to their use by highway safety managers. The following section shows some of the different ATP treatments that have currently or recently been in use.

3.5.2 Centreline arrangements

In accordance with MOTSAM ATP centrelines are generally used only where there are double yellow no-passing lines. There appear to be few exceptions to this rule, but the following variations were observed:

1. The ATP line may be 100 mm or 150 mm in width, with ribs the same width as the line. Ribs are normally spaced at 250 mm but 500 mm spacing is also sometimes used. See Figure 3.1.

Figure 3.1 CAP ATP centre and edgeline treatment near Bombay; 100 mm wide line with 100mm ribs spaced at 250 mm

2. The profile ribs may cover only one half of the width of each yellow line resulting in a composite line in which the outer edge only is profiled. See Figure 3.2. This arrangement reduces the amount of TP or CAP material required, and can be retrofitted against existing double yellow no-passing lines without reducing either the audio-tactile effect or the retroreflective performance of the line.

Figure 3.2 ATP Double yellow centreline on two lane road with ribs on outer edge only. Edgelines are non ATP.

3. Profile ribs have been installed between normal long-life double yellow lines and coloured black so that they are not visible, See Figure 3.3. This arrangement reduces the amount

of ATP product required to install the line, but has the disadvantage that, in comparison to other ATP centrelines, a vehicle must diverge further towards the opposing lane before an audio-tactile response is generated. The rib's lack of contrast with the road surface is necessary to comply with TCDR requirements, but this lack of visibility could be a surprise for any motorcyclists who stray over the yellow line. The need to mix a darker colour material for this application would be an additional cost which would at least partially offset any saving in material volumes. The additional service level offered through effective wet night visibility provided by the ATP line is also lost where a black ATP line is installed between double yellow centrelines. This arrangement of ATP centrelines is not recommended.

Figure 3.3 ATP double yellow centreline with black ribs and ATP edgelines, together with CAP composite edgeline and narrow shoulders

ATP double yellow no-passing centrelines are used in conjunction with either standard edgelines or ATP edgeline treatments.

3.5.3 Edgeline arrangements

ATP edgeline installations consist of 100 mm or 150 mm TP or CAP.

At some locations, TP or CAP ribs have been placed immediately to the left of a painted or long-life material edgeline instead of on the edgeline (Figure 3.4).

This process effectively doubles the width of the edgeline without using more material, but does reduce the shoulder width available for use by cyclists. However, advantages for cyclists are that the ribs are more clearly visible, and (at least on one side of the line) there is no continuous raised edge. Cyclists consulted and those who attended the workshops advised that they can safely negotiate the transverse ATP ribs provided they can see them, whereas the longitudinal raised edge of long life road marking is more likely to cause a more significant stability problem for them.

This arrangement has other advantages; the rate of wear of the ribs is reduced, cheaper painted edgelines or high performance reflective products such as wet night visible markings can be used together with the ATP product and retrofitting of ATP treatment is easier.

An obvious disadvantage is that a larger degree of shoulder encroachment is required before the audio- tactile response is generated.

Figure 3.4 ATP edgelines placed adjacent to a painted continuous edgeline, ATP lane lines and ATP double yellow lines on SH 2 near Bombay

As per MOTSAM, ATP edgeline installations are normally terminated at intersections and other access points where vehicles may be required to cross edgelines or centrelines.

3.5.4 Lane lines

ATP markings have been used on both continuous and dashed lane lines separating traffic travelling in the same direction. An example is on SH 2 at Bombay near the intersection with the Auckland – Hamilton highway (Figure 3.4). This use of ATP is unusual in that traffic may be expected to routinely drive on these markings, and is therefore not currently provided for in MOTSAM.

3.5.4 Other applications

Short lengths of ATP have been installed on lines separating traffic travelling in the same direction both approaching and departing from intersections. These applications include departure markings for right turn lanes (Figure 3.5) and at diverge and merge areas on motorways and other high-speed intersections.

Figure 3.5 Example of right turn lanes with ATP solid lane line on the departure

3.6 Existing examples of ATP treatments

It has been difficult to accurately establish the extent of existing ATP road markings throughout New Zealand because new installations are constantly being applied, and from time to time existing installations are removed and replaced with other line marking treatments. There is no central database. Mackie and Baas (2007) suggest that up to about 5% of State Highways (300 km to 500 km) may have some form of ATP treatment and a consensus of highway engineers and road marking contractors agreed with this figure.

Table 3.2 represents examples of locations of ATP installations which the authors have observed or have been informed of through a survey of highway engineers and road marking installation contractors.

Although this list is not complete, it is considered to provide a fair indication of the current usage of ATP markings on New Zealand roads. A clear conclusion can be drawn that the current use of ATP road marking is minimal and there is considerable scope to increase it.

Table 3.2 Location and description of current examples of ATP road marking installations

Location	Notes
North Island	
SH1 Northland Ruakaka Straights Brenderwyn to Ross	29 km CAP edgeline and centrelines. 17 km CAP.
SH 1 Auckland, North Puhoi – Hatfields Beach	
SH 1 Auckland Southern Motorway / Waikato Expressway	ATP on left hand edgeline, and diverge/merge areas. Limited distance only. Auckland Motorways 52 km CAP.
SH1 Waikato Meremere safety upgrade	
SH 1 Putaruru - Tokoroa	Edgelines, DYC, (DYC not at passing lanes).
SH 1 Tokoroa - Wairakei	Occasional edgelines and DYC.
SH1 Wairakei - Taupo	DYC.
SH1 Taupo - Turangi	Edgelines (sporadic), DYC.
SH 1 Manakau – Te Horo	DYC at 3 lane passing lanes only. Not at 2 lane DYC areas.
SH 1 Waikanae – Te Horo	Lane lines on right turn bay at Pekapeka Rd.
SH 1 Waikanae - Paraparaumu	DYC, 1 km. 1.9 km DYC CAP Ribs/ 3M paint.
SH1 Pukerua Bay – Paekakariki	Turning lanes, DYC, edgelines. 4 km.
SH 1 Bulls - Sanson	DYC (stops at right turn bays). 2.6km CAP.
SH 1 Wellington –Johnsonville Motorway	Left and right hand edgelines, 1 km. Off and on ramp. Approach and departures.
SH 2 SH 1 to SH25, Maramarua	Edgelines and DYC, adjacent to flush median and 20km CAP and TP.
SH 2 Tauranga - Katikati	Edgelines and DYC. 27 km CAP.
SH 2 Tauranga – Te Puke	Some edgelines and DYC CAP.
SH 2 Kaitoki Hill	1.8 km CAP.
SH 5 Rotorua –Rainbow Mountain (SH 38)	Occasional edgelines (CAP).
SH 27 Wahatoa	Edges of painted median.
SH 58 Haywards - Judgeford	DYC, 3 km.
Alfriston – Ardmore Manakau City	Rural non-State Highway. 3 km. AADT 2600.
Hamilton City	Urban. ATP centrelines on Victoria St and Claudelands Bridge.

Table 3.3 (continued) Location and description of current examples of ATP road marking installations

Location	Notes
South Island:	
SH 1 Christchurch Templeton – Rakaia Bridge	29 km – ATP TP edgelines on 2 lane sections only, 1.5 m shoulder.
SH1 Kaikoura	Edgelines.
SH1 Dunedin South	Edgelines.
SH 8 Omarama – Twizel	35 km edgeline. 750 mm shoulder. AADT approx 1050.

3.7 Product technical considerations

New Zealand Road Markers Federation document *NZRF Roadmarking Materials Guide* gives users practical information regarding the use of the different products.

The cost management tool developed by Mackie and Baas (2007) does not differentiate between all of the performance measures that might be associated with different products. For example, both TP and CAP ATP lines may be attributed with a 25% crash reduction, based on previous studies, yet individual formulations and use of different surface applied bead and aggregate mean they may differ in terms of their wet-night retroreflectivity, service life, skid resistance and overall cost. Anecdotally it appears that there may be differences in the performance of TP and CAP ATP lines depending on the environment, installation details and other factors. However, until information regarding other factors such as the safety benefits of retroreflectivity, treatment life, environmental and health considerations are determined, it is difficult to objectively consider the merits of the different products.

4. Issues for discussion

Current practice for the use of ATP markings as part of a road marking and delineation system clearly varies from place to place and on some issues the views of experienced ATP road marking users are still changing. However, it was acknowledged that the variations in current practice or uncertainty of how to use ATP in certain situations could result in less than optimal solutions, and could limit the wider up take of this technology. Through the initial consultation process, the discussion paper identified 20 main issues for review. These issues were put forward by many people who have been responsible for arranging the installation of ATP road markings, suppliers of line marking installation and maintenance services, and representatives of road users. For the purpose of the workshops, the issues identified were arranged into three loosely related areas as follows, and the discussions and results are reported below under the same headings:

- Strategic and funding related issues,
- Road user issues,
- Standards and installation issues.

The remainder of this section discusses these agreed issues and reports the consultation-based conclusions. For convenience, the consultation conclusions are summarised in a highlighted box at the end of each section.

Recommended actions drawn from the conclusions are stated in section 6.

4.1 Strategic and funding related issues

This section covers the following six issues.

- Continuous and isolated ATP road marking treatments.
- Threshold traffic volumes for ATP installations and installation at new road works and road improvement works.
- Processes for approval and funding of ATP installations.
- The cost of ATP installations and maintenance.
- Increasing the use of ATP on local government owned roads.
- Product selection, performance and maintenance.

4.1.1 Continuous and isolated ATP road marking treatments

Early ATP edgeline installations were generally (although not always) spot treatments at selected locations where there was an increased risk associated with run-off-road crashes. As such, these installations tended to be installed over relatively short sections of highway (e.g. a few kilometres) or single locations such as the approach to a specific roadside hazard, rather than installed continuously along a route between major destinations or throughout a connected area of the highway network. Even when installed over a large section of the road

network, ATP edgeline were sometimes not continuous and covered only a proportion of the total distance treated.

This project's consultation process resulted in strong and unanimous agreement that ATP edgeline treatments, where used, should be largely continuous, allowing only for gaps where necessary such as at intersections, narrow shoulders, and for noise management or other technical requirements. The use of sporadic treatments only at high-risk locations along a route was not supported.

The need for ATP treatments to be regarded as continuous was seen as a fundamental principle that impacted upon options for dealing with a number of the other issues discussed in the remainder of this report. These include the requirements for road shoulders, treatments at intersections and driveways, noise mitigation and other issues. One commenter said the question should be "where not to put them", rather than the opposite.

The rationale supporting this position was supported by consideration of the following principles:

- Road safety engineers considered that ATP lines have a generalised effect as well as a local effect. An ATP edgeline generates a warning, or several warnings, to a driver over a period of time or distance, that a vehicle is wandering out of its correct lane. This can alert the driver to take appropriate action (such as stopping to rest, or to pay more attention) before a more serious incident occurs. To deliver this more general effect, ATP lines would need to be installed continuously along a route rather than just at a few high-risk locations. Short, isolated, sections of ATP road marking treatments were considered to not provide very effective assistance for the management of driver fatigue and inattention. However, a number of short isolated gaps in ATP lines (as required by technical and practical requirements discussed later) were not considered to diminish the beneficial effects of lines installed otherwise continuously along a route.

- As with all traffic management devices and road safety engineering treatments, consistency and uniformity are essential for road users' understanding and correct response. In a uniform highway environment drivers need to know whether a safety treatment upon which they might depend is either present or not present. ATP markings, where used, should therefore be a consistent part of the safety environment for routes of a certain functional hierarchy and safety standard.

- ATP road markings provide an instant warning that a driver has encroached onto a line marking at a specific place enabling corrective action to the vehicles' lane position to be taken over the next few hundred metres. If there is a gap in an ATP line at the point of encroachment, the driver's warning will be reduced or not received, and the immediate benefit of the facility is diminished. Clearly the requirement to leave gaps in ATP lines or to terminate them at various places should be minimised in advance of high-risk locations.

- On the basis of this hypothesis then ATP markings installed on narrow shoulders may not, as previously thought, have substantially diminished safety value compared to installations with wide shoulders (i.e. where more recovery space is available). Shoulder width requirements and the closely related issue of lane width are further discussed below in section 4.3.1.

The TERNZ economic evaluation tool (Mackie and Baas 2007) has been designed to evaluate both isolated and route treatments. The Route Builder facility allows ATP proposals to be readily evaluated for complete routes by linking up sections of road which need to be separately assessed because of physical and functional characteristics.

Conclusion 1:

ATP markings are considered to have a generalised safety benefit along the length of a route, as well as at high risk locations, and should therefore be regarded in principle as a largely continuous treatment along a route, i.e. corridor treatment, rather than as a series of isolated safety treatments. Continuous ATP road marking treatments can help assist with the management of driver fatigue and inattention, which is unlikely to be achieved with short isolated treatments. ATP road markings should be used consistently along routes with similar functional status and road environment.

4.1.2 Threshold traffic volumes for ATP installations and installation at new road works and upgrades

The objective of this project is to remove impediments and to facilitate the increased use of ATP line markings. The issue addressed under this heading was whether there is a case for this objective to be achieved by requiring ATP markings to be installed as a standard feature (i.e. without further evaluation) on all rural highways above certain traffic volumes, or as treatments to be added to all highway upgrades such as shape correction, road widening and other road geometry improvements. Another suggestion was that ATP lines should be installed as a standard feature on all new work and major remedial work, including shape correction, above a specified minimum traffic volume.

Previous research has established that ATP road markings have a cost-effective safety impact at much lower traffic volumes than are currently recommended, and roads with an AADT greater than 1000 vehicles per day could qualify for some form of ATP treatment on a B/C basis. In contrast, MOTSAM suggests that to remain effective ATP line markings should be used sparingly and where there are high traffic volumes, although no minimum volume is specified.

The consultation did not support the concept of effectively mandating, or making standard, any form of ATP treatment on the basis of certain predetermined highway-related criteria such as those mentioned above. Firstly, it was considered that in many cases the technical and operational requirements necessary to support ATP installations may not be achievable, or that other treatments may be more appropriate. Secondly, each proposed ATP installation should be subject to appropriate economic and technical assessment, taking account of crash risk, traffic volume and the road hierarchy. Furthermore, it was considered that requiring assessment for ATP treatment of new work or upgrades separately from the remainder of the corridor would result in an inconsistent patchwork effect. However, it was agreed that MOTSAM guidelines should be relaxed to encourage consideration of ATP line markings at all locations where B/C evaluation criteria are met, rather than its current requirement to use them sparingly. Perceived risks of overuse of ATP markings are referred to again in section 4.3.3.

It was noted that the TERNZ cost management tool is available as a means to readily and easily support the economic analysis of ATP proposals.

Conclusion 2:

There was no case to require the installation of ATP line markings on all highways with traffic volumes over a minimum specified number of vehicles per day, or as a standard treatment on all new work and highway upgrades. Instead all ATP road marking proposals should be subject to appropriate economic and technical assessment. Guidelines should be amended to require that all highways, not just new work and upgrades, are subject to periodic assessment for treatment with ATP, or other long life road marking products, to provide them consistently in the majority of highway corridors.

4.1.3 Processes for approval and funding of ATP installations

It was reported that under some circumstances, project funding approval procedures for new works do not always enable ATP markings to be included as an integral part of the project. Separate funding application and approval is required, rather than this being seen as part of the package for new works. The requirement for a separate funding application and approval for ATP road marking for a highway project has been seen as an impediment to the consideration of ATP marking for new works. This problem was considered to result from the structure of certain highway safety management and project contracts where, unlike the consideration of other measures like centrelines, edgelines and clear zones, ATP was not a standard part of the package.

It was agreed that, while all ATP road markings proposals should be subject to assessment, this should be considered as 'mainstream' so that requirements for such assessments should be an integral part of project packages applying to all parts of the network, not just new works.

There was limited support for the establishment of a dedicated funding source to support ATP treatments. If the installation of ATP treatment was assessed as appropriate during the course of an existing highway safety management contract, then arrangements for the additional funding required should be put in place. There was some concern that lack of suitably flexible contract and funding procedures could block ATP installations.

Conclusion 3:

It was agreed that a requirement to carry out an assessment for ATP treatment together with other standard safety treatments should become standard in road safety management and project contracts so that, where appropriate, ATP treatment would be an integral part of highway projects. Provision is required to enable existing contracts to be adjusted to enable ATP installations to proceed during existing contracts.

4.1.4 The cost of ATP installation and maintenance

ATP markings are currently significantly more expensive to install than non-profiled long life materials. For example, one recent installation of ATP edgelines (consisting of a long-life edgeline product with ribs placed outside it) and centre lines, cost around $52,000 per kilometre whereas the cost of the resealing was $40,000 per kilometre. Other ATP road marking arrangements and product combinations may cost more or less, but in this example

the inclusion of ATP markings effectively doubled the cost of the project. A range of actual costs, as recently estimated, are detailed in Mackie and Baas (2007). These high costs are attributable to the current relatively small demand for ATP products resulting in under utilisation of the costly specialised equipment required. Sources in the road marking industry expect the costs to decrease significantly if ATP marking becomes more widely used, and the continuity of available work increases. Road marking contractors are currently investing in additional ATP installation plant to reduce the cost of moving it between locations such as between the North and South Islands.

Cost provision for the removal of old ATP markings when refurbishment is due can be a significant factor in the additional costs compared to other road marking products.

The various different products available are also prone to price fluctuations which can affect the rationale for their selection and use.

In Australia, laying ATP thermoplastic in the 1990's has been reported as costing $5,400 per line kilometre, based on a 150 mm wide edgeline. Currently, in South Australia, thermoplastic audio-tactile marking costs approximately $1500 to $1800 per line kilometre to install on larger projects (Wooley and McLean 2006). This also suggests that the cost of installing ATP in New Zealand may be expected to decrease.

Post installation costs and practical issues also need to be considered. Attempts were made to determine some of the on-going maintenance costs and issues such as line removal, but much of this information could not be obtained. This is at least partly due to some of the products that are used being relatively new, so many of these issues are still being worked through. Over-spraying and removal of ATP lines are examples of areas where more information is needed. The consensus based on experience to date was that, depending on a range of factors including the products used and traffic conditions, the annual maintenance cost for ATP road marking installations is around 20% to 25% of the initial installation cost. This includes the total refurbishment cost after a number of years.

The consultation revealed a general view that the cost of new ATP installations was tending to decrease, and this trend was expected to continue as the amount of ATP marking installations increased. An example was given in which a previous installation cost of $44,000 per kilometre for double yellow centrelines and edgelines had now come down to between $20,000 and $30,000. It was also noted by member of the road marking industry that some of the costs quoted here could also include other components of the complete road marking system.

Conclusion 4:

It was agreed that the cost of installing ATP markings was a mitigating factor in the level of take-up, but this should decrease over time as the use of these products increases. Annual maintenance costs are expected to remain a significant proportion (currently around 20% to 25%) of the initial installation cost. The cost of removal of ATP markings and decisions concerning replacement were considered to be significant factors in determining the lifetime costs.

4.1.5 Increasing the use of ATP installations on local government owned roads

It is clear that based on the benefits and costs, ATP edge and 'no overtaking' centrelines could be applied more widely on New Zealand's State Highway network. However, of the approximately 90,000 kilometres of road that exist in New Zealand, only about 11% is designated as State Highway and owned by central government, with the remaining majority of roads being owned almost entirely by local government. Some local authorities operate a large number of high volume rural roads that are functionally little different from State Highways. There is clearly a view among road users and engineers that there may be a net benefit in treating many non-State Highway roads with ATP lines.

It was noted that whilst traffic volumes on rural local authority roads are usually lower than on State Highways, the risk factors are generally higher, and this is not always obvious to road users. It was argued that for this reason, and due to the need for consistency, ATP road markings on local authority roads could be highly cost-effective, and assessment for treatment should be given some priority. A case was also recognised that ATP markings may be appropriate on certain special local roads e.g. tourist routes or where there are special environmental characteristics, even though the standard State Highway criteria for ATP road markings may not be met. In these situations a road user's personal risk may be high, although due to lower traffic volumes the reported crash numbers may not be. KiwiRAP documentation explains that 'Personal Risk' is a measure of the danger to each individual using the section of highway being assessed taking account of the traffic volume, unlike 'Collective Risk' which is measured in terms of the number of crashes per kilometre and which can also be described as 'Crash Density'.

For non-state highway applications, there appears to be no reason why funding approval and assessment criteria and technical standards should remain different from those which apply to ATP installations on State Highways. Funding and approval processes discussed in section 4.1.3 were considered applicable to local government roads as well as to State Highways.

Consistency between State Highways and local roads carrying similar traffic volumes was seen as important. It was agreed that technical requirements and other decision-making criteria for the installation of ATP markings on local roads should not differ from those for State Highways. Funding such proposals would be problematic for local government, some of which are struggling to meet basic roading requirements and have not yet been able to develop a road safety management plan in which an ATP policy could be incorporated.

Any requirements for ATP line marking installations proposed to be included in the new Traffic Control Devices Manual, mentioned in section 2.4 of this discussion paper, will be applicable to both State Highways and non-State Highways.

Conclusion 5:

The consultation agreed that the requirements for the use of ATP road markings on state highways and non-state highways should generally be the same and that, subject to these requirements, the strategic use of ATP road markings on non-state highways should be encouraged. Drivers may have little perception of whether or not they are on a State Highway, and there is a higher but sometimes less obvious personal risk profile for users of some local roads. However, it was also recognised that many local authorities would find funding of the higher costs to be a major impediment to increasing the use of ATP markings on local roads.

4.1.6 Product selection, performance and maintenance

Compared to other long life road markings, ATP markings may be more difficult to reinstate when worn out, because new lines cannot be successfully laid on top of old ones while ensuring the required rib profile and spacing is retained. Prior to reseals and for replacement, existing ATP lines ideally need to first be removed by grinding, water cutting or abrasive blasting, adding significantly to the reinstatement cost. In some cases CAP ribs have been applied over existing ATP materials, but this in effect changes the spacing of the ribs and can result in unacceptable rib profiles (Figure 4.1). Painting over existing ribs and applying retro reflective treatment has been used effectively to reinstate reflective performance. Coarse seals have been placed over worn ATP markings with some success, but generally they need to be removed prior to resealing. ATP edgelines with ribs outside the edgeline are reported to be easier to maintain.

Figure 4.1 New ATP ribs installed on top of an existing ATP centre-line resulting in inconsistent rib profile and spacing which fails to meet specifications

In some regions of the country, for example throughout the South Island, there were no ATP machines readily available so repairing and reinstatement of ATP sections removed by road works was not economically feasible. This situation is gradually being rectified as contractors gain confidence that their heavy investment in new plant is likely to be justified as the volume of work increases.

Mackie and Baas (2007) reported that a four-year life for ATP treatments appears to be reasonable. However, there seems to be considerable variation in the product life that is achieved, depending on who is providing the information, the road environment and traffic volume, product type, seal type and condition, application thickness, maintenance issues and the criteria that are used to determine the need for re-marking. Some ATP lines may remain adhered to the road surface for four or five years but lose a significant amount of their audio tactile effect after only three years. All of these factors need to be considered when determining the treatment life. However, it was agreed that with improved products and applicator experience product life is increasing.

Because of the many factors that can affect product life, the cost management tool developed in Mackie and Baas (2007) provides an easy mechanism for adjusting the assumed product life. The tool does not include a maintenance cost function, but this can be covered by adjusting the assumed service life value, for example from 5 to 4 years, or adding a factor to the initial cost values. Some ATP lines have required maintenance work after 3 or 4 years, but they are generally expected to last the reseal life on main highways. It was noted that, referring to the discussion in section 4.1.1, it may not be necessary to reinstate short lengths of ATP lines that have been damaged.

Transit New Zealand suggests allowing one quarter to one-fifth of the initial installation cost to provide for annual maintenance costs, on the assumption that an ATP installation would typically require full replacement every 4 or 5 years.

There is a wide range of maintenance practices and experiences informing the use of ATP road markings, and this body of knowledge is rapidly expanding. A suggestion that an ATP maintenance guideline for practitioners, which would also include information about the removal of ATP road markings, should be prepared gained wide support.

Conclusion 6:

There is a wide range of maintenance practices and experiences informing the use of ATP road markings, and this body of knowledge is rapidly expanding. A suggestion that an ATP maintenance guideline for practitioners should be made available gained wide support. In particular, ATP application contractors felt an urgent need for information and education.

4.2 Road user issues

This section of the report provides a summary of the discussion and consultation outcome of the following six issues. These generally concern the effects, or potential effects of ATP road markings on road users, and how these may be addressed.

- Effects on vehicles and steering
- Considerations concerning cyclists
- Considerations concerning motorcyclists
- Considerations concerning heavy vehicles
- Environmental noise generation

- Publicity and communications requirements.

4.2.1 Effects on vehicles and steering

One existing ATP edgeline installation has an installed profile such that there was a report of a vehicle's steering being affected to an extent that was distinctly noticeable to the driver and disconcerting to passengers in the vehicle at speeds of up to 100 km/h. However, this effect had not been documented or reported at other locations. While any such effects may be considered marginally acceptable on an edgeline with a wide shoulder, in other circumstances - particularly if installed on centrelines, such a profile would be potentially hazardous. At the location detailed above, the ATP treatment was 100 mm wide, and the rib height was considered to be at the upper limit of the acceptable range. The consultation consensus was that 150 mm wide ribs were therefore preferable to 100 mm, and that the specification should be reviewed accordingly. Also, the 150 mm ribs are not crossed as quickly as 100 mm and hence the audio-tactile stimulus to drivers appears to be more effective.

Strict adherence to a profile approved according to Specification M/24 is essential. If ATP line markings come into more widespread use, the installed profiles should be checked as part of post construction and ongoing safety reviews.

It was noted that a current research project by Opus International Consultants Ltd, Central Laboratories is expected to further address the impact of different rib profiles on road users. Opus International Consultants Ltd, Central Laboratories is conducting measurements of the noise and vibration effects from traversing a range of ATP road marking profiles. The data will inform development of numerical models to link the dimensions and shape of ATP road markings to the physical effects they can generate. Other work will test drivers' subjective responses to noise and vibration cues to determine the effective thresholds for noise and vibration from ATP road markings. A further stage of work is investigating the effect of ATP road markings on stability for cyclists. Overall the outputs will ensure that ATP road markings are established and maintained at dimensions which ensure optimal performance while avoiding untoward effects on other road users. The work will also facilitate industry innovation of new improved forms of ATP road markings by establishing a reliable process by which their performance can be determined.

Conclusion 7:

The potential for ATP marking to affect the steering of four wheeled vehicles was not considered to be a major issue, but it was noted that 150mm wide ribs were preferred over 100 mm wide ribs. It was also noted that installed rib profiles should be checked against the approved standards and corrected if they do not comply. These standards would be reviewed when the results of a current research project being undertaken by Opus International Consultants Ltd is available.

4.2.2 Considerations concerning cyclists

An important distinction needs to be made between road space intended as a dedicated cycle facility (such as cycle lanes), and road space that is generally available for use by both cyclists and motor vehicles, such as road shoulders. Recommended requirements for cycle lanes and

other cycle facilities are set out in the provisional Transit document, New Zealand Supplement to the Austroads Guide to Traffic Engineering Practice Part 14: Bicycles. (Transit, 2008). The ATP road marking issues concerning cyclists discussed in this report generally relate to traffic lanes and road shoulders in rural areas which may be used by both cyclists and motor vehicles, and where speed limits up to 100 km/h may apply. MOTSAM's recommendations also apply.

Lane width and shoulder width as they affect cyclists in areas with ATP edgelines are discussed in section 4.3.1.

It has been suggested that ATP lines may represent a hazard or be inconvenient for cyclists. Walton et al. (2005) stated that 'The concept of locking cyclists into a cycling space and locking motorists out of this same space with a continuous raised profiled marking, or another type of restricting device (e.g. close-spaced raised pavement marker) is strongly not recommended'. However, the authors also found that a line marking as low as 0.5 mm can induce a similar level of cycle instability as that of an ATP line, and therefore perhaps more consideration needs to be given to the instability caused by ATP lines. Recently, Charlton (2006) has found that ATP lines are associated with improved lane keeping and less instances of line crossing among motorists. Given these findings, it would be prudent to compare the risk of accidents associated with cyclists losing control when riding over ATP lines with the benefit that ATP lines bring by improving the separation between motorists and cyclists. If the benefits associated with improved separation outweighed the risks associated with the presence of an ATP line, then their use should be promoted rather than discouraged. Clearly, a reasonable cycle lane width or road shoulder would need to be present in order to justify the use of ATP lines between cyclists and motorists. Shoulder width requirements for ATP edgeline are discussed in section 4.3.1.

As summarised in Appendix 1, MOTSAM contains specific provisions for cyclists' safety by specifying a minimum shoulder width, and the provision of gaps to enable cyclists to cross the lines when necessary. These provisions recognise that like some other long-life road markings, the raised profile of ATP markings potentially affects the stability of cycles, especially when crossed at an acute angle. In trials carried out by Opus International Consultants Ltd, cyclists conducting a secondary task while negotiating an ATP line were not noticeably affected by the presence of the ATP line. However, some non-ATP thermoplastic lines had been shown to create a longitudinal ridge that could be a problem for cyclists, and the addition of ATP ribs on top of such lines could be problematic. Opus International Consultants Ltd is currently testing a range of simulated ATP profiles, but the results are not yet available.

The benefits for cyclists are that where suitable shoulder width is provided, ATP improves the lane discipline of motor vehicle drivers and reduces the number of unintended incursions over the edgeline. Some State Highway managers advised that cyclists have reported they feel a higher level of security riding on a road shoulder with ATP markings, although perceived increased safety level is not necessarily the same as an actual reduction in crash risk. However, cyclists also emphasise that for this potential benefit to be achieved the shoulder must be relatively smooth, clean, free of physical obstructions and of consistent width; these attributes being more important than the existence or not of ATP markings.

Where suitable shoulders are not present and cyclists are required to ride within the traffic lane, ATP may be seen as unhelpful to cyclists by limiting the extent to which they can keep to the left. In these circumstances adequate lane width is vital.

Some of the improvements in ATP road marking design that have been suggested include variations in the gaps between the ribs and the depth and width of the ribs themselves. Another cycle friendly approach that has been suggested is to create frequent gaps between the ATP treatments so that cyclists can navigate between them periodically if they need to leave the shoulder and enter the traffic lane. The Colorado Department of Transportation suggests that rumble strips should not be used when the road shoulder is less than 1.2 m wide. However, it must be remembered that the rumble strips can be up to 400 mm or more wide in the US, with a similar gap between the edgeline and the rumble strip. This would be equivalent to a 600 mm or 700 mm minimum riding space, plus a similar clearance from the traffic lane when New Zealand style ATP lines are considered (although 1 m is generally accepted as a minimum cycle lane design envelope). The recent practice of placing audio tactile ribs outside a line may reduce the available shoulder width to cyclists, which may become problematic when the shoulder width is already marginal.

In the UK, ATP road markings (called 'raised rib' markings in the UK) are essentially the same design that is used in New Zealand, with thermoplastic being mostly used. The London Cycling Design Standards, applicable to urban areas states that:

> *Additional protection of cycle lanes from motor traffic on the rest of the carriageway by physical features will increase cyclists' comfort and encourage use. Protection to cycle lanes can be provided by the following methods:*
>
> · *Hatched road markings outside the cycle lane*
>
> · *Intermittent traffic islands (which should not reduce the cycle lane width)*
>
> · *Reflective road-studs (authorised for advisory but not mandatory lanes)*
>
> · *Raised rib markings (requires transport department authorisation).*

This suggests that in London, ATP lines are considered to be an effective way of separating traffic and cyclists. A difference is that the height of the ribs that are recommended for cyclists is 6 mm (maximum 8 mm) instead of the target 7 mm ribs (11 mm maximum overall height) that are specified in New Zealand.

According to the Taupo District Council, ATP edgelines were installed on some sections of the route that is used for the 'Lake Taupo Cycle Challenge' (a 160 kilometre ride/race that circumnavigates Lake Taupo). It was considered that this event could provide a test of the usability of the ATP lines by cyclists in an open road setting. Responses to the ATP lines by cyclists were expected to be more negative in this example than in an urban commuting environment, as speeds are likely to be faster, most of the bicycles would have narrow racing tyres and there would be more cyclist fatigue in the Taupo cycle ride. However, Transit advised that in the two years following the installation of ATP road markings on part of the route, no negative response was received from participants or organisers of this annual event. Some individual participants also confirmed that they did not perceive the ATP markings as a problem. However, it is recognised that as the event takes place under special traffic management arrangements allowing riders more lane use freedom, neither the riders nor the circumstances of this event should be considered representative.

None of the highway managers consulted for this project reported complaints from cyclists about ATP road markings. One cyclist in the Northland region advised the State Highway manager that the ATP edgelines in the area provided greater security for cyclists in open road environments. Cyclists consulted for this report advised that generally they prefer to avoid

the need to cross any longitudinal road markings, but felt that ATP lines were less of a potential bump hazard than RRPMs and ceramic discs, and could be beneficial in helping to differentiate the riding area from the traffic lane and thus increase their separation from other traffic.

The research currently being undertaken by Opus International Consultants Ltd at their Central Laboratory includes investigation of ATP rib profiles on cyclists.

Conclusion 8:

It was acknowledged that ATP road marking installations are of potential concern for cyclists when travelled on, but that the issues can be managed. Conversely, ATP road markings have been reported as offering a degree of separation between cyclists and motorists and may therefore promote cyclist safety. Careful consideration must be given to the impact on cyclists, especially where they are expected to be present in large numbers. The provisions in MOTSAM for cyclists' safety and convenience should be carefully observed. ATP road markings should be installed with a 20 m gap in advance of any location where cyclists are required to cross from the shoulder to the traffic lane (such as before bridges) and at other frequent intervals particularly where road shoulders are narrow and where cycle numbers are high. The current research by Opus International Consultants Ltd is expected to identify ATP profiles suitable for use where cyclists may be present.

4.2.3 Motorcyclists

The consultation recognised that, as in the case of cyclists, ATP markings may have some potential to adversely affect motorcyclists who may be required to, or choose to, ride over them. However, there are no reports of motorcyclist accidents attributed to ATP road markings, and highway managers have reported no complaints from motorcyclists concerning ATP installations, although at one of the Industry Workshops a motorcyclist expressed a contrary view.

MOTSAM and Specification M/24 contain specific provisions to address any potential safety risk that ATP road markings could cause for two wheeled vehicles. The limitations on the use of ATP road markings as set out in MOTSAM are such that they may not be placed where they may be legally driven or ridden on. As for cyclists, the profile ribs would have less effect on comfort and stability than RRPMs and ceramic markers.

Conclusion 9:

Provisions already in place in MOTSAM to help ensure that ATP line markings should not form a hazard or inconvenience for two wheeled vehicles were considered to be sufficient to address potential issues affecting motorcyclists.

4.2.4 Heavy vehicles

The need for specific consideration of the effects of ATP line marking on heavy vehicles was identified by some stakeholders questioning whether the stiffer suspensions of trucks could unduly amplify the audio-tactile response, causing annoyance and fatigue to truck drivers if

used more extensively, or alternatively whether truck drivers might gain particular safety benefits.

Officers of the New Zealand Road Transport Federation advised they were not aware of truck driver complaints about existing ATP marking installations. An Austroads report, Safety Benefits of Improving Interaction between Heavy Vehicles and the Road System, (Styles et al 2007) reports a US study which found rolled or milled longitudinal rumble strips had little impact on heavy vehicles. However, these treatments are unlike the ATP product used in New Zealand so the effects may differ.

The consultation consensus was that, due to truck's relatively large tyre diameter, ATP road markings do not usually generate a very strong audio or tactile response to alert truck drivers, although it is usually able to be detected. It was noted that due to the greater length and width of trucks, and their wider swept path or 'cut-in' on sharp curves, maintaining correct lane position requires more driver vigilance than for other vehicle types. On this basis, ATP markings should be of at least as much assistance to truck drivers as to the drivers of light vehicles, and any level of audio-tactile feed-back to truck drivers would benefit their safety.

Excessive external noise generation by trucks crossing ATP lines were not reported as a specific problem, but these would be addressed by the noise mitigation measures discussed below in section 4.2.5.

Instances of premature wear of ATP edgelines, or damage such as the ribs being punched into the road surface, has been reported where they are frequently run over by truck tyres. This is likely to occur on small radius left hand curves where there is a high proportion of heavy vehicles in the traffic stream. It was considered acceptable to address this problem by removing and not replacing the ATP edgeline over short lengths at locations where this has, or is likely to occur. As discussed in section 4.1.1, isolated gaps in ATP treatments were not considered to diminish the overall effectiveness of a treatment applied continuously over a significant section of highway.

Conclusion 10:

It was not considered that heavy vehicle drivers require any special consideration when ATP road marking are installed, although the proportion of heavy vehicles in the traffic stream may affect ATP placement and maintenance requirements. However, as is always the case, care is needed to ensure the standard state highway lane width is not reduced when installing ATP edgelines on truck routes. On truck routes ATP edgelines may be installed with short sections on left hand curves omitted (in the short term) to help address maintenance or road damage problem that the ATP ribs could cause, until longer term measures to address a truck lane keeping problem at the location are implemented. In the context of treating entire highway corridors with ATP road markings, short gaps in the edgelines for the above reason (or for the other operational reasons discussed in this report) are not considered likely to reduce the crash reduction outcomes.

4.2.5 Environmental noise generation

ATP markings are intended to generate noise and vibration inside vehicles to alert drivers to lane incursions. Unfortunately there is currently no ATP technology that does not also

generate noise outside the vehicle, and this noise is sufficiently loud to create a potential nuisance to people living and working nearby. There are some formats of long-life high performance line marking products that produce substantially reduced noise outside vehicles and still provide some audio feed-back for drivers, but these products do not have the strong audio tactile impact available with ATP ribbed markings.

The safety benefits potentially achievable by the application of ATP road marking on a section of highway was not considered to be sufficient justification to create an environmental noise nuisance in the area, especially for nearby residential properties. Steps are available, and should be taken, to mitigate any potential or reported noise problems. This may require discontinuing some of the ATP markings where a road passes close to residential property. As discussed in section 4.1.1, the safety benefits of an ATP installation in a highway corridor are not considered to be significantly reduced by short gaps in the treatment. MOTSAM suggests that ATP should not be installed near residences, but is not specific about the distance required and does not refer to work places.

Highway managers advised they have received a small number of noise complaints resulting from new ATP installations. Responses from nearby residents to environmental noise from ATP installations have not been consistent or predictable, and appear to depend on a number of variables including the sensitivity of the individuals concerned. Factors determining the acceptability of ATP markings near residences appear to include traffic volume, characteristics of the road surface, the ATP product and how it has been applied, distance from the premises, ambient noise levels, land contours and other factors. The combined effect of these factors is variable, making the resident's response difficult to predict. Noise problems are more likely to result from edgelines installed on left hand curves on high volume roads. These have generally been addressed by removal of sections of ATP edgelines at selected locations, and this solution was confirmed as acceptable.

State highway managers in Auckland have found the removal of ATP edgelines on curves within 100 m clear line of sight of residences has been sufficient to eliminate ATP generated traffic noise problems, or reduce it to levels acceptable to the residents. In Queensland and South Australia, guidelines recommend that ATP markings are not placed within 500 m of residences, although this distance may be reduced to 200 m if the property owner agrees. ATP markings on straight sections of road and on double yellow centrelines have not generated any reported complaints in New Zealand even where the lines are much closer to residences than 100 m, because these lines are rarely crossed over by vehicles.

While the practice on State Highways in some areas is to terminate ATP lines within 100 m (measured from the building frontage) of residences, in other instances ATP edgelines have continued past residences that would be within 100 m without any noise complaints.

It was considered that noise is less of an issue in relation to ATP double yellow centrelines because it is rare for traffic to encroach on these lines, and it is not legal to do so.

There has been little use of ATP road markings in urban areas, and urban applications would more likely be on centrelines rather than edgelines, which in rural areas are the most likely source of any ATP noise nuisance. If ATP road markings are used in urban areas, placement only in positions where they should not normally be driven on, together with lower speed limits, should sufficiently mitigate noise problems. If this is not achieved, as also recommended for rural ATP installations, the relevant section of the markings should be removed.

Overall it was considered that a universal fixed distance exclusion zone for the installation of ATP edgeline near residences would not be an appropriate solution to a potential environmental noise problem. Each situation requires individual consideration. Based on discussion with affected residents, ATP edgeline should be removed where necessary to eliminate any actual noise nuisance.

Conclusion 11:

It is not appropriate or necessary for ATP road marking to be the cause of a noise nuisance, in either rural or urban areas. The current guidance in MOTSAM that ATP markings should not be installed near residential properties is appropriate. There is a wide variation in both the noise level generated and residents' response to similar ATP edgeline installations, so a fixed exclusion distance is not a recommended solution. Instead each situation where there is a noise problem or potential problem should be treated on an individual basis. This may involve removal of a section of an ATP edgeline particularly on left hand curves. The provisions in MOTSAM to mitigate the noise impact of ATP road markings were considered to be appropriate and sufficient.

4.2.6 Publicity and communications

In some parts of New Zealand, road users are not yet familiar with ATP line markings, to the extent that Transit and highway managers still occasionally receive complaints from drivers who think there is a problem with their vehicle or the road when new ATP markings are installed. While this is unlikely to be a direct safety issue, drivers could stop at inappropriate places to check their vehicles, or waste money having them unnecessarily inspected. This is more likely to be an issue with ATP edgeline profiles with ribs that are not very visible.

While there has been very limited adverse feedback from the public and they generally support the use of ATP road markings, it appears desirable that some local information is provided to the public when ATP edgelines are first used in a region. This could explain the function and purpose of ATP road markings, such as the relationship between the audio-tactile vehicle response generated and the appropriate drivers' actions. Where appropriate, the information could link the installation to other road improvement safety programmes such as KiwiRAP.

It was also considered that increased nationwide publicity about the benefits and purpose of ATP marking would be appropriate. Experience has been that road users do not always understand the benefits of ATP markings, and many feel they would be better placed on centrelines than edgelines. Some observers considered that the availability of appropriate information for road users could also help address a perceived risk that road users might demand the use of ATP road markings where they are not appropriate.

Temporary signage should also be considered at locations with new ATP installations. A suitable temporary warning sign had been developed by Transit in the Tauranga region and used successfully for a period of approximately 3 months when ATP marking was first installed.

Conclusion 12:

Where ATP road marking is used for the first time in a region, consideration should be given to temporary signage and other means of informing the public and road users of the purpose and function of the markings, including how they link to any relevant road improvement safety programme in the area. Some nationwide communications explaining the overall benefits of ATP marking was also supported. This could be linked to communications about the KiwiRAP project, as an early tangible outcome of that project.

4.3 Standards and installation related issues

This section considers six issues concerning standards and installation details:

- Shoulder and lane width
- Reflective performance
- Additional uses for ATP
- Snow conditions
- Motorways
- Standards and specifications.

4.3.1 Shoulder and lane width

Road shoulders have multiple functions, and their presence significantly reduces crash rates. Their functions include enabling vehicles to stop clear of the traffic lane, provision for broken-down vehicles and emergency services, clear space for safer recovery of control or reducing impact severity in the event of run-off road crashes, provision for animal and other non-motorised traffic, and to provide facilities for cyclists. The presence of ATP edgelines, by assisting the clear demarcation of the shoulder, can enhance each of these functions, provided they are used correctly.

Early installation of ATP edgelines were limited to locations where a wide sealed shoulder existed e.g. 1.5 m. This was based on the understanding that drivers would require wide shoulders to provide sufficient recovery space after running on to ATP edgelines and being alerted by the audio tactical response, and to ensure sufficient space for cyclists. For these reasons MOTSAM limits ATP edgelines to use only where there are wide shoulders although a measure is not specified.

More recently, a move towards the use of ATP edgelines on roads with narrower sealed shoulders has been informed by the thinking explained in section 4.1.1 i.e. that wide shoulders, previously considered necessary to allow appropriate driver response to ATP stimulus, are not essential for ATP edgelines to be effective. In relation to ATP edgelines, shoulder width considerations are now driven by other considerations, including the road space required to provide for cyclists, the need to provide the required minimum traffic lane width, and the need for a consistent surface suitable to support and maintain the ATP markings.

There is now a range of experience on the issue of shoulder width as ATP edgelines have been installed with a wider range of shoulder widths. Shoulder widths of between 850 mm and 1 m were reported by highway engineers to be acceptable when used by cyclists. Indications from research by Opus International Consultant Ltd (Walton et al 2005) were that shoulders that reduced to 600 mm to 700 mm wide at the narrowest points, such as at bridges and near other obstructions, appear to be reasonable for use by cyclists. However, this indication was not a specific finding of the above report and Opus is now addressing the issue further in a current project, Minimal Design Parameters for Cycle Connectivity. For cyclists, clearly an important consideration was that shoulders are continuous and consistent. Further experience reported at the workshop consultation was that ATP edgelines have been acceptable where shoulders are used by cyclists provided a minimum consistent clear shoulder width of 500 mm to 700 mm is available. ATP markings were reported as also being effective at locations with effectively no sealed shoulders, provided there is a very low level of cycle traffic or where cyclist are able to ride in wider than normal traffic lanes.

Having considered the above factors, the consultation consensus of highway managers, engineers and cycle users who attended the workshops, was that ATP edgelines could be used effectively provided at least 600 mm of clear usable shoulder is retained to allow for the possible presence of cyclists. Where larger numbers of cyclists are expected to be present the availability of sealed shoulders much wider than 600mm were considered necessary where ATP edgelines are used. If this cannot be achieved, then an alternative may be that the width available for cyclists should be included in a wider traffic lane by shifting the ATP edgeline to the edge of the seal, providing more space for cyclists in the traffic lane.

An alternative view, rejecting the above advice that a minimum shoulder with of 600 mm is adequate, was subsequently expressed by cycle advocates and traffic engineers concerned about cycle safety. They advised the generally accepted cycling design envelope is 1.0 m wide and noted that on rural highways with a speed limit of 100 km/h the provisional New Zealand Supplement to Austroads Part 14: Bicycles (Transit 2008) recommends a desirable minimum width of 2.5 m for cycle facilities, with an acceptable range from 2.0 m to 2.5 m. Currently few highways have shoulders in the above range, and it was accepted that ATP edgelines would be acceptable with 1.5 m wide road shoulders and that a lower value may also be reasonable. This could avoid losing the potential safety benefits of ATP edgelines, for both motorists and cyclists, on a large proportion of highway and the rural highway network. One cycle advocate stated that 1.0 m wide shoulders would be an absolute minimum. Shoulders on rural highways are not generally regarded as designated cycle facilities, therefore it was not clear whether the supplement was intended to apply to all road shoulders because they are available for use by cyclists.

It has not been possible, with the information obtainable by this project, to determine an exact minimum shoulder width below which ATP edgelines are not acceptable for cyclists. On the one hand, cycle advocates suggest the range could be from 2.5 m to 1.5 m or marginally less, and on the other hand, highway managers recommend a minimum of 600 mm. It is recommended that further research is undertaken on this difficult issue. Trials of ATP edgelines with varying shoulder widths with monitoring of crash rates were suggested.

The consultation also investigated whether there were circumstances (such as the presence of a continuous obstruction, for example a cliff face or a drop near the road edge not able to be protected by a barrier) where ATP edgelines could be considered with shoulders between zero and 600 mm wide but without the lane widening as mentioned above. This suggestion was rejected as impractical and of no likely safety benefit.

The consideration of the minimum shoulder width necessary for ATP edgeline installations also requires careful consideration of clear lane width requirements. It must be recognised that, due to the presence of the ATP ribs not intended to be driven on, lane width must be measured between the ribs rather than from the crown of the road to the middle of the edgeline, as is the case for non-profiled markings.

On this basis MOTSAM recommends a standard State Highway lane width of 3. 5m, although in practice lanes may be 3.4 m or even down to 3.25 m. In Australia 3.35 m is recommended. Because ATP lines are not included in the measured lane width, the effective width of a lane is reduced by 200 mm to 300 mm (depending on the width of the lines) to only 3.2 m wide if existing edge and centrelines are marked. This width is less than the recommended minimum, if existing markings are converted to ATP without repositioning them. The placement of ATP ribs outside the existing edgeline (shown above in Figure 3.4) is a method used successfully to help retain recommended minimum lane width when ATP is retrofitted without seal widening, provided sufficient shoulder is available.

The consultation outcome was that a minimum 3.3 m clear lane width is acceptable with ATP markings in cases where the standard 3.5m cannot be achieved.

Conclusion 13:

ATP edgelines can enhance the functionality and safety benefits of road shoulders. However, ATP road markings are not acceptable on highways where there is insufficient clear road shoulder to ensure cyclists safety. Although not trialled, increasing the lane width where ATP edgelines are used where shoulders are insufficient for cyclists, to provide for cyclists within the traffic lane, may be satisfactory provided the requirement for shoulders to meet the needs of other road users is also considered. Wider shoulders, or increased lane width, may therefore be required where ATP edgelines are used on roads which are expected to be used by large numbers of cyclists.

It has not been possible to determine the exact minimum shoulder required with ATP edgelines to ensure the safety of cyclists. Further research on this issue is recommended, together with clarification of the intended application of the New Zealand Supplement to the Austroads Guide to Traffic Engineering Practice Part 14: Cycles.

The provision of minimum shoulder width to facilitate ATP edgelines should not be achieved by reducing the traffic lanes to less than a minimum of 3.3 m measured inside the ATP lines.

4.3.2 Reflective performance

All long-life pavement markings (including ATP) are reflectorised, and some products are designed for enhanced visibility in wet conditions at night and while rain is falling. While there may have been an assumption that the ribs in ATP profiles might function like raised reflective pavement markers (RRPM) and thus enhance the night time visibility of ATP lines, suppliers of the product advise that this is not necessarily correct under all weather conditions. This effect is said to be due to the profile effectively shadowing part of the line and presenting a reduced surface area to reflect light. As a demonstration, the composite ATP line, shown in Figure 3.2, showed only a marginal difference in retro-reflective performance between the two sides of the line when viewed under car headlights at night.

While ATP lines may be marginally less reflective than some non-ATP products, the ribs are less likely to be obscured by surface water under very wet conditions.

The consultation agreed that, if required, ATP line markings may be used together with RRPMs, but that ATP products should not be considered to supersede RRPMs. Red RRPMs could be placed to the left of an ATP edgeline or on the edgeline (in gaps provided for the purpose) where necessary, to ensure the required clear shoulder width is provided. In the latter case, experience confirmed the ATP installers had been able to easily create the gaps in the ATP edgeline required for the placement of the RRPMs.

Conclusion 14:

ATP edgelines do not supersede RRPMS and other forms of positive delineation for left and right hand road edges. Where appropriate, RRPMs may be used together with ATP road markings and may be placed on or outside the ATP lines depending on space requirements. Their use to replace ceramic domes on lane lines is discussed in section 4.3.3.

4.3.3 Additional uses for ATP Markings

From time to time road users and road safety advisors have made suggestions for widening the range of applications for ATP markings and some innovative uses have been installed at a few locations on highways. The following ideas for new applications of ATP road markings were included in the consultation process.

4.3.3.1 Single no-passing lines

MOTSAM does not provide for the use of ATP markings at single no-passing lines or dashed no-passing line advance warning lines, on the grounds that these markings are required to be driven over during certain legal passing manoeuvres. However, there was an argument that encouraging drivers not to cross single no-passing lines is as important as for double yellow lines; indeed, the visibility restriction at single no passing lines is likely to be more deceptive than at most other highway locations. It was argued that the risk of crossing a single no-passing line is at least as great as that of crossing a double yellow line, and the availability of ATP lines to provide extra warning should therefore be no less. ATP road markings at other locations (i.e. edgelines) may also be legally driven over, so it was not obvious why this should be unacceptable in the case of single no passing lines.

While the consultation process identified several potential options for ATP treatments at single no-passing lines and no-passing line pre-warning zones where they are not currently used, this application was not supported. Further research was considered necessary for an agreed position to be reached on this issue.

4.3.3.2 Median barriers and roadside barriers

MOTSAM does not encourage the use of ATP markings adjacent to protective roadside barriers (but does not prevent this usage) and is silent with respect to their placement adjacent to median barriers. It is not obvious why ATP should not be used to alert drivers who have inadvertently drifted to the edge of their lane and could be at risk of striking a safety barrier, provided that the standard lane width is maintained. ATP edgelines could be used more frequently on the right hand lanes of motorways and other highways where a

median barrier is installed. An example of where ATP edge-lines could be used with a median barrier is shown in Figure 4.2.

Figure 4.2 A situation where ATP edge-lines could be considered in association with a safety barrier

Right hand ATP edgelines are installed adjacent to the median guardrail over a distance of about 1 kilometre in both directions on the Wellington – Johnsonville Motorway (SH 1). There are no reports of this being problematic. Wide shoulders were not considered to be a necessary pre-condition for the of ATP right hand edgelines adjacent to median and central barriers.

The consensus of the consultation was that accepting the principle discussed in section 4.1.1 (i.e. that wide shoulders providing recovery space are not a critical factor for the effectiveness of ATP road markings) then ATP edgelines should be considered in these situations.

4.3.3.3 Dashed centrelines and lane lines

From time to time road users have suggested the use of ATP on white broken (dashed) lane lines and centrelines. One example of these treatments (a dashed lane separation line) is shown in Figure 3.4, and a trial of ATP white dashed and solid white centrelines is currently proposed on State Highway 27 north of Matamata, due for completion by the end of 2008. If it is accepted that ATP markings may be safely driven on (particularly by motorcyclists) in other than exceptional circumstances, then guidelines for ATP lane lines and centrelines could be developed. This could provide for the use of ATP lane separation lines in circumstances where good lane keeping is considered very important and where centrelines need more emphasis. In these circumstances, ATP markings could have better audible impact on road users than RRPMs and ceramic discs, and less negative effect on two wheeled vehicles. They could be more cost effective particularly with respect to maintenance, but further experience is needed to confirm this.

The consultation agreed that standards should be developed for the arrangement of ATP road markings for these applications, subject to further research. However, it was noted that the continued impact of ATP markings and loss of clarity of their intended function may be at

risk if they are placed where they may be crossed intentionally, and this question should be further investigated.

4.3.3.4 Lane separation at intersection approach and departures and merging areas

Examples of these applications of ATP marking exist mainly on motorways and at a few major intersections on State Highways (Figure 3.5). The intention is to encourage correct lane keeping and merging behaviour. It was noted that a single solid white line has no particular legal standing under the Road User Rule. It was suggested that ATP marking could be used to reinforce the impact of a solid white line where crossing it is not recommended, and that in due course this meaning for a solid ATP line could be considered for inclusion in the Road User Rule. ATP markings at right turn bays and left turn lines, and their associated diagonal markings, were not supported because traffic is expected to drive over these markings. There was a strong view that the continued impact of ATP markings and loss of clarity of their intended function would be at risk if they were placed where they may be crossed intentionally.

ATP markings are already used extensively at merge and diverge areas on motorways near Auckland and Wellington, and at a few other locations on State Highways. Consultation agreed that these intersection and merge area treatments were appropriate, and could be considered in isolation from continuous ATP line marking treatments.

4.3.3.5 Transverse ATP road marking

Although outside the scope of this project, some road users wished to state that ATP road marking products should be available for use in transverse applications. CAP and TP products have been used transversely, but in the form of raised lines rather than profiled. Transverse lines are used to warn motorists of the presence of blind intersections, for example, they have been used in Papakura to warn motorists of a roundabout that is on the far side of a humpback bridge over a railway line, and as rumble strips progressively more closely spaced to help drivers to slow down on high speed approaches to intersections and railway level crossings. It was suggested that ATP markings could also be used to enhance diagonal markings approaching right turn bays and on flush medians, but as mentioned in the above sub-section, possible loss of clarity of their intended purpose would be a concern. It was agreed that the issue of transverse ATP road markings should be the subject of separate consideration, as further debate is required and evidence for their effectiveness is not clear from the literature.

4.3.3.6 Use in urban situations

It was considered that ATP lines are generally not suitable for urban use (except on some sections of motorways and expressways within urban areas) as the noise that is generated when a vehicle travels over them can be annoying for residents. Edgelines and double yellow centrelines, which have been the main applications of ATP markings to date, may be found on major routes in urban areas. In South Australia, the Department of Transport, Energy and Infrastructure practice is to avoid installing profiled lines within 500 m of a residence. In New Zealand, MOTSAM states that '*…care must be exercised when considering the use of profiled line markings in urban situations, e.g. urban motorways and rural township bypasses'.* However, at urban speed limits (50 to 70 km/h) the noise impact may be less, and there could be applications where the beneficial effects of ATP markings installed near residences are justified, particularly in applications where they are unlikely to be driven on.

ATP centrelines have been used in urban environments in Hamilton on centrelines in Victoria Street and on the Claudelands Bridge, without reported noise problems.

Conclusion 15:

The strongest response of the consultation on the above six issues was to reject the suggestion of using ATP road marking at single no passing lines, pending further research. The remaining five proposals (listed below) obtained some support as being potentially available on a case by case basis for further consideration, but were not seen as pressing issues. However, any consideration of these potential applications should address the general concern that the continued impact of ATP markings and loss of clarity of their intended function would be at risk if they are placed where they may be crossed intentionally:

Adjacent to roadside barriers and median barriers.

Solid and or broken single white centrelines and lane lines between lanes in the same direction of travel.

Intersection approaches and departures.

Transverse applications.

Urban applications.

4.3.4 Snow conditions

The consultation reported varied experience with the use of ATP markings on roads subject to snow conditions. In the South Island they had been used successfully, provided the height of the rib profile was half that normally required by Specification M/24, to ensure that they remain undamaged during snow clearing operations. It was also found in this area that, in addition to the normal benefits of the audio tactile warning, the raised ribs of the profile enable the lines to remain visible when painted lines and non-profiled long life markings have been temporarily obliterated by anti-icing grit treatments. The reduced profile height of the ribs in snow prone areas was reported to not greatly affect the audio tactile effect or the normal operational life of the ATP markings, but further research would be required if reduced height rib profiles were to be used more generally, or for other reasons such as reduced noise impacts or reduced product material requirements. Standard ATP road markings were not recommended where snow clearing operations were expected.

Conclusion 16:

The consultation considered use of ATP road marking in snow prone areas as acceptable, but care is required to ensure damage to the marking does not occur during snow clearing operations. ATP markings have been used successfully on some snow prone roads in the South Island with the rib height reduced by half.

4.3.5 Motorways

ATP road markings have been installed on parts of the Auckland and Wellington motorways. These have been placed at a limited number of locations covering a proportion of the length

of these motorways, but would not be considered as continuous corridor treatments. The main ATP treatments are on left hand edgelines and merge/diverge areas. There is also a short length of right hand edgeline adjacent to a median barrier on the Wellington – Porirua Motorway.

In Auckland a trial is being undertaken on motorways using ATP lane line markings to replace the raised ceramic domes, primarily to reduce the maintenance cost of replacing the domes. This is the accepted practice in New South Wales, Australia.

Cyclists' needs, such as minimum acceptable shoulder width, are not a consideration since cyclists are not permitted to use motorways, therefore the main technical constraint on the use of ATP lines would be the potential noise problem where motorways pass close to residences. This is largely an issue on left hand edgelines on left hand curves, where edgelines may be more likely to be routinely driven on. Right hand edgelines (i.e. on the right of the outer lane) are rarely crossed in normal driving, and ATP treatment in these areas should not generate a noise problem. This could also be said of merge and diverge areas.

A possible requirement that ATP left and right edgelines should be installed where possible on all motorways, and also at all merge/diverge areas on motorways was discussed. The consultation concluded that whilst in many instances ATP road markings would be suitable and beneficial on motorways, the use of other line marking products and delineation treatments should not be excluded. As discussed above in section 4.1.2 each proposal for an ATP road marking installation should remain subject to economic and functional evaluation.

Conclusion 17:

ATP road markings are available as a line marking treatment for motorways, but the consultation did not agree that it should be used automatically. Instead all potentially suitable products should be evaluated in each instance, and economic evaluation undertaken.

4.3.6 Standards and specifications

There is currently a considerable variation in the design of ATP lines in New Zealand, some of which are discussed and illustrated in previous sections of this report. Such variation is sometimes warranted to allow ATP installations to be adapted to suit the conditions found at different locations. For example, more separation between ribs might be needed in rural open road situations than the lower speeds that might be encountered on a motorway on-ramp. However, currently line width, rib height and spacing often differ for no obvious functional reason. Over time, the use of wider ATP lines have generally been found to be more satisfactory. Although MOTSAM and Specification M/24 specify requirements for ATP line markings, many of the lines that are currently being laid do not comply. For example, MOTSAM states that ATP lines should be 100 mm wide with ribs at 250 mm centres, yet one of the most common ATP lines currently being laid (and accepted by road authorities) is 150 mm in width with ribs at 500 mm centres. Certain specifications for ATP road markings are essential for safety, such as the rib profile height which can affect steering and, in the case of 2-wheeled vehicles, could affect stability. Some of the non-compliant installations could pre-date the release of the M/24 or the requirements of MOTSAM.

The consultation process acknowledged the research currently being undertaken by Opus International Consultants Ltd, Central Laboratories on ATP road marking profiles, but noted

that this work is not yet completed. However, pending the result of this project two clear views were revealed. The first was that, at least for edgelines, 150 mm wide ATP line markings were strongly preferred to 100 mm and that the standards and specifications should now be amended accordingly. The second view was that the general configurations of ATP road marking arrangements should be standardized.

For DYC lines the standard treatment for yellow lines is 100 mm CAP or TP ribs be placed on the full width of the yellow lines; the arrangement as shown in Figures 3.2 and 3.3 are not recommended. Where a wider traffic separation was desired 150 mm ATP double yellow centreline have been used to increase the median space where sufficient lane width was available. There was support for the two different ATP edgeline treatment types currently in use, i.e. 150mm wide lines and ribs with the ribs placed either on or to the left of the solid line. In the former case the use of either 150 mm or 100 mm edgelines was also considered acceptable, but the ribs on the outside should always be 150 mm wide. Both options were considered acceptable, with the choice being determined in some cases by the available clear traffic lane width and available shoulder width and the need for consistency within a region of the country, or at least along corridors.

The issue of whether to stop ATP markings at intersections and other intersecting access ways was considered, as there is variation in how these situations are currently treated. The alternatives are to either continue the ATP markings or to stop them. The consultation recommendation was that a break in ATP markings should be provided at all road intersections but not at driveways and smaller access ways. This practice needs to be clarified in MOTSAM.

Conclusion 18:

The range of ATP marking profiles and marking arrangements that are currently used should be rationalized to one standard treatment for DYC and two options for edgelines. The appropriate edgeline treatment would be determined by the available clear lane width and shoulder width. The width of all ATP line and ribs on edgelines should be 150 mm, although 100 mm edgelines are acceptable where the ribs are outside the line and the required shoulder and lane width cannot otherwise be achieved. ATP markings on DYC may be dual 100 mm wide lines, or dual 150 mm lines where space is available to achieve the required lane width.

5. Summary of conclusions

The outcome of the analysis of issues, discussion and the consultation was strong agreement that the usage of ATP road markings should be substantially increased compared to the present level of about 5% of State highways. This to be achieved primarily by clarification of policy that ATP road markings be regarded as a continuous treatment along significant lengths of road as part of a consistent safety environment, rather than as a series of spot or short treatments, and the guidelines be amended accordingly. There was no dissention from this view.

It was also agreed that each ATP installation remain subject to economic evaluation on a case-by-case basis in order to justify funding, and that existing evaluation procedures were appropriate. Alternative proposals for various automatic or blanket treatments, e.g. to install ATP on all highways above a certain traffic volume, or on all motorways or roads meeting certain criteria without further economic evaluation, were not supported. However, the option of ATP markings should always be considered alongside the assessment of other appropriate marking and delineation technologies. Minor updating and enhancement of the TERNZ ATP economic evaluation tool was supported. It was further agreed that potential ATP treatments on local government roads should meet the same technical standards and be assessed on the same basis as State Highways.

MOTSAM and Specification M/24 provide standards to ensure the effectiveness, durability and safety for vulnerable road users. Some amendments to these documents are required to ensure consistency and compliance with current best practice. These amendments address shoulder width and lane width, and the setting out and arrangement of the markings. Guidance is also provided on how any potential noise nuisance should be addressed. Provisions to meet the needs of cyclists where ATP markings are installed need further research, particularly regarding the provision of adequate shoulder width for cyclists. The results of research projects currently being undertaken by Opus International Consultants Ltd on rib profiles and clearances required by cyclists, will assist with a review of the relevant specifications as they may affect cyclists' and vehicle stability, and the relationship between the provision of ATP road markings and road shoulder width.

Current applications of ATP markings and additional uses recommended by this project are that they generally be placed so as not to be intentionally driven over by vehicles travelling longitudinally with the direction of the line. Proposals to extend the use of ATP marking to locations where they are intended to be traversed were treated with caution because the continued impact of ATP markings and loss of clarity of their intended function would be at risk if they are placed where they may be crossed intentionally. Any such proposals should be subject to research. Crossing ATP lines in the transverse direction, such as may occur when vehicles enter or leave driveways, is not of concern because an audio tactile stimulus is not generated.

Recently commenced research on ATP solid white centrelines and dashed centrelines was noted, and a suggestion for their use at single no-passing lines was not supported at this stage.

6. Main recommendations

The discussion paper and consultation addressed a wide range of issues, the results of which are reported in the 18 conclusions stated above in the highlighted boxes. In a number of cases the consultation found that existing practice was appropriate or that current provisions could be endorsed, with either minor changes or clarification to existing policy or practice. Areas where the need for significant changes in policy or standards were agreed are summarised in the following seven main recommendations:

Recommendation 1:

- That the New Zealand Transport Agency endorses the view that, to be fully effective as a road safety engineering improvement, ATP road marking be used as a continuous treatment over the full length of the relevant highway section. Gaps in the treatments at isolated locations as determined by practical requirements are not considered to diminish the overall safety benefits.

Recommendation 2:

- All State Highways and strategic local government owned roads be considered for ATP treatments. The decision be based on standard economic evaluation and technical appraisal for each proposal.

Recommendation 3:

- On local government owned roads the technical standards and assessment requirements be the same as for State Highways.

Recommendation 4:

- ATP rib profiles and spacing be standardised when the results of the current Opus International Consultants Ltd research projects are available. As well as audio tactile performance, this research needs to continue to address the stability effects on cars and two-wheeled vehicles.

Recommendation 5:

- ATP edgeline marking arrangements be standardised and 150 mm wide ATP ribs and lines are recommended. For ATP double yellow centrelines, 150 mm wide lines are preferred where sufficient lane width is available; otherwise 100 mm wide ATP marking are acceptable for double yellow centrelines.

Recommendation 6:

- ATP marking be available for roads where a minimum clear lane width of 3.3 m and shoulder width sufficient for the safety of cyclists can be provided. Where wider lanes are provided to allow space for cyclists within the traffic lane, ATP edgeline may be considered for use with a minimal sealed shoulder.

Recommendation 7:

- Further research is required to establish the minimum shoulder width required to ensure the safety of cyclists where ATP edgelines are installed.

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APPENDICES

APPENDIX A – Acknowledgments

APPENDIX B – MOTSAM requirements for ATP markings

APPENDIX C – Specification M/24 requirements for ATP road markings

APPENDIX A – Acknowledgments

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APPENDIX B – MOTSAM requirements for ATP markings

The following requirements have been summarised for convenience; MOTSAM should be referred to if the exact wording of its provisions is required.

AB.1 General Requirements:

- ATP line marking may be used in order to reduce run-off-the road crashes and to help reduce overtaking (head on) crashes where no-overtaking lines are violated, and to improve lane discipline.
- To ensure they retain their effectiveness, ATP markings should only be used on rural roads and motorways and, on other roads if the operating speed is over 60 km/, provided certain other specified requirements are also met.
- Special attention is paid to the needs of cyclists and motorcyclists.

AB 2 MOTSAM requirements for edgelines

- Traffic Volumes are high and/or there are a significant number of crashes related to fatigue or driver inattention, and/or there are specific problems such as poor visibility, frequent heavy rainfall, or a night time crash history etc.
- The desirable minimum length of ATP edgeline marking is 1 km, and should be continued through the whole section of road and extended approximately 500 m on either side of that section.
- ATP edgeline markings should be discontinued at intersections, private access ways and the entrance/exit areas of motorways.
- Extra wide ATP edgeline markings may be used on rural roads to enhance their audio tactile effect, e.g. at curves where drivers' deviation from the traffic lane is likely to be at a high angle.
- ATP edgeline markings should not normally be used in conjunction with roadside safety barriers, unless it is a short barrier protecting an isolated roadside hazard.
- ATP edgeline markings are reflectorised to improve night time visibility.
- Width 100 mm; however it is also noted that experience indicates that 150 mm minimum width is necessary for ATP edgelines to be effective.
- To preserve the minimum required lane width, where necessary an ATP edgeline may be installed immediately to the left of the existing edgeline, subject to review when the road is resealed.
- Full standard lane width must always be provided where ATP edgelines are installed, and any lane widening on curves must not be diminished by the ATP edgeline installation.

- A minimum sealed shoulder width of 0.5 m is required to ensure the durability of a profiled edgeline marking.
- A minimum shoulder width of 1.5 m is needed where a significant number of pedestrians and cyclists use a sealed shoulder, in order to reduce and allow recovery from the aerodynamic effects of high speed vehicles.
- Where there is a permanent feature in a sealed shoulder that could require cyclists to cross an edgeline, a minimum of 20 m of standard edgeline should be provided in advance of the permanent feature.
- ATP edgeline markings should not be used where motorcyclists will frequently need to cross them.

AB.3 MOTSAM requirements for ATP no-overtaking lines

- ATP centreline markings may only be considered where two parallel yellow no-overtaking lines define the road centreline. This is to reduce the risk to vulnerable road users, particularly motorcyclists, should they drive legally over a centreline that incorporates a no-overtaking line in one direction only.
- ATP no-overtaking lines may be used to discourage drivers crossing the centreline only where there are double yellow no-passing lines, long-life materials are used for both line markings, an increasing number of drivers cross the no-overtaking lines, and there is a continuing occurrence of overtaking crashes; or where the no-overtaking lines are not readily visible due to a specific site condition.
- To reduce costs ATP may be installed on only one of the parallel no passing lines.
- RRPMs must be used in conjunction with ATP no-overtaking lines.
- Colour is reflectorised yellow; width 100 mm, noting that 150 mm is desirable.
- ATP should not be used for no-overtaking advance warning lines.
- Clear lane width of 3.5 m should be provided.

AB.4 MOTSAM requirements for intersections and property access:

- ATP line markings must not be used near intersections and major access points because cyclists and motorcyclists are likely to need to cross line marking at these locations.
- ATP lines should end 20 m in advance of intersections and access points, and the markings for a merge or diverge lane.

AB.5 Other considerations discussed in MOTSAM

- Road noise generated by ATP markings may cause problems in residential areas, requiring care to be exercised if ATP lines are near residences.

- Drainage gaps should be provided at 10 m intervals to prevent the accumulation of surface water and the channelling of runoff water which could erode roadside slopes. Drainage gaps of 100 mm to 150 mm are recommended.
- Materials and profile designs must conform to Transits M/20: Specification for Long-life Roadmarking Materials, and M/24 Specification for Audio Tactile Roadmarkings and their Notes.

APPENDIX C – Specification M/24 requirements for ATP road markings

The following requirements have been summarised for convenience; Specification M/24 (5) should be referred to if the exact wording of its provisions is required.

- Specification M/24 specifies the materials and profile designs that may be used to ensure safety (particularly cycle and motorcycle stability), and performance with respect to the three functions - audio, tactile and visual, and design life of the products used.
- Approval processes for plant and equipment for applying ATP are detailed.
- Quality assurance and testing procedures before and after installation and ongoing monitoring together with remedial steps are set out.
- Requirements for site preparation and installation for new and previously trafficked road surfaces, and clean-up are given, including allowable limits for variation in line and block (bump) placement and dimensions.
- Ongoing maintenance and defect correction requirements are specified.
- Procedures for approval of materials used to manufacture ATP road markings.
- Procedures for the type-approval of profile designs. This includes the provision of 'evidence that the profile design and material combination does not create any adverse effect for road users (including road users such as cyclists and motorcyclists) greater than any affect produced by the profile design in MOTSAM on a particular and stated type of road surface'. LTNZ Research Report 273: *Balancing the Needs of Cyclists and Motorists* is referred to in M/24 as providing one method by which cyclist stability may be assessed.
- Methods to establish evidence of skid resistance, audio, tactile and visual effects of proposed products in a high-wear situation including methods for making these measurements.
- Subject to ongoing satisfactory performance product type approval may last for 10 years.