

# **Pavement Markings Role in Enhancing Road Safety Strategies**

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## **Abstract**

Almost universally it is agreed that the fundamental needs for all road users include the provision of safer roads & driving conditions. Most road safety strategies however are built on the premise that visibly-safe road markings already exist. As evidence however proves that this premise is often not the case many of our road safety strategies are being compromised at this most basic level.

What role can pavement markings play in improving road safety?  
Are the levels of retroreflectivity currently being used by Road Authorities sufficient to provide adequate preview time for safe driving?  
How can you accurately determine the standard of your current markings?  
What are the minimum levels of retroreflectivity required to ensure visibility of the markings 24 hours a day, wet or dry?  
What strategies involving pavement markings are being adopted internationally to enhance road safety?

The recommendations contained in this paper, if adopted, will substantially improve the quality of pavement markings both on local and rural roads. The resultant road safety benefits will result in fewer motor vehicle accidents, fewer deaths, fewer injuries, and definite savings, human and monetary.

## **Keywords**

Road Safety; Older Drivers; Visibility; Preview Time; Retroreflectivity.

## **Body of Paper**

### **WHAT IS THE CURRENT ROAD SAFETY SITUATION IN AUSTRALIA?**

As highlighted in the abstract for this paper, it is almost universally agreed that the fundamental needs for all road users include the provision of safer roads & driving conditions. It is therefore not surprising that in today's safety (and litigation) conscious society inordinate amounts of money are invested annually into important road safety strategies seeking to stem the tragic loss of lives on our roads. Even with these important strategies in place, what is the current situation in Australia?

Former Tasmanian Premier, the Hon. Tony Rundle MP has stated that for every road death in Australia, at least 30 people are seriously injured in motor vehicle accidents. These injuries include paraplegia, loss of limbs and serious brain damage. Not surprisingly then he termed that this "the hidden disease".

In her article, "A Sign of The Times: fixourbloodyroads.com", which was published in December 2005, Dr Jacqui Murray quoted the NRMA as saying that in Australia in the 'next 24 hours', five people will die, 539 will be injured and 4,800 crashes will occur on the nation's roads at a cost of \$41 million a day".

As these statistics remain generally constant the next 12 months will likely see 1,752,000 motor vehicle accidents on our roads nationally, resulting in 1,825 deaths and 200,000 injuries. The total monetary cost of this carnage? Some \$15 billion+.

More than one-half of the total cost of crashes (56%) are 'human' costs related to the 55,000 individuals suffering "serious" injuries (paraplegia, loss of limbs, serious brain damage etc).

\$8.4 billion dollars per annum (or \$23 million per day) is directly attributable to the lost output, long-term care, rehabilitation and lost quality of life of these unfortunate individuals.

## **PAVEMENT MARKINGS ROLE IN MEETING THE ROAD SAFETY CHALLENGE**

What role can pavement markings play in improving road safety?

Please consider the following:

- Linemarking is the most fundamental countermeasure ever introduced into road safety. (NSW StaySafe)
- Centre lines and edge lines reduce all accidents by 20%. (Miller, 1992).
- Centre lines and edge lines reduced single vehicle accidents by 34%. (Moses 1986).
- Road marking treatments have the potential to reduce the percentage of crash types by up to 40%. (Australian Automobile Association)
- Linemarking is the most cost-effective safety measure..... it can reduce car accidents by as much as 60%. (AITPM)

You will notice from these quotes that pavement markings can potentially reduce all accidents by between 20 and 60%. What effect would this have on reducing the human and monetary costs that we have just considered?

Each year **pavement markings** could potentially deliver the following positive road safety benefits:

- Between 350,400 and 1,051,200 fewer motor vehicle accidents.
- Between 365 and 1,095 fewer deaths.
- Between 40,000 and 120,000 fewer injuries.

- Between 11,000 and 33,000 fewer individuals suffering "serious" injuries.
- An overall monetary saving of between 3 and 9 billion dollars

Many of you may be thinking at this point though that as centre lines and edge lines have in many instances already been installed on our road systems that we have therefore surely already achieved these potential savings, both human and monetary? Sadly this is not the case. Why not? Because many of the specifications that are currently used by State and Local Road Authorities throughout Australia ***simply do not deliver the performance characteristics*** required to ensure safe driving 24 hours a day, seven days a week, 365 days a year.

If the recommendations contained in this paper are adopted for use on all of our paved roads, the resultant quality pavement markings will contribute to road safety by significantly reducing motor vehicle accidents, deaths and injuries. This will also result in definite savings, both human and monetary.

But before we consider the recommendations that can potentially improve the effectiveness of pavement marking in this country, let us first consider the need for a nationwide change in thinking and attitude on the part of every person who considers themselves to be dedicated to the provision of safer road & driving conditions.

For too long now existing pavement markings have been viewed and budgeted as a road maintenance issue, to be considered only when and/or if the budget allows for maintenance to be performed. This erroneous view coupled with a poor understanding of what constitutes effective pavement markings, has resulted in ***much of the markings on our roads being ineffective and therefore unsafe***. Remember, most road safety strategies are built on the premise that visibly-safe road markings already exist. As this is often not the case our road safety strategies are being compromised at this most basic level.

All of us must embrace (and act upon) the realisation that ***the uncompromising delivery of high-quality, well maintained pavement marking systems are key road safety measures, fundamental to the success of any serious road safety strategy***.

I sincerely hope that this prelude has highlighted to each of you the genuine need that exists in this country for action in implementing the recommendations that are featured in the following section of this paper. These recommendations, if adopted, will definitely improve the quality of pavement markings (and by default positively impact on road safety)!

## **VISIBILITY FACTORS FOR CONSIDERATION:**

**Firstly let us consider the road safety needs of older drivers**, which should be of great concern to all of us as statistically we live in a rapidly ageing population.

Please consider the following few quotes:

- End of line detection distances can be 55% higher for the younger driver than the older driver, (Zwahlen & Schnell, 1998).
- “In 30 years, 22% of Australians will be aged 65 & over, compared with 12% today.”

(Sydney Morning Herald “Prepare for the amazing greys bent of reinventing old age” Jan, 2002).

- Over the next 40 years the number of people aged 65-84 years will more than double, while the number of people aged 85 and over will increase by more than 4.5 times. (Wayne Swan, Treasurer, 2009)

Visual deterioration is a natural ageing process; studies suggest that after age 21, we require 20% more light for each 13 years we age, in order to be able to see as well as we did at age 21.

All drivers interact with environment clues whilst driving. Indeed driving is a series of decisions based 90% on visual clues. As we age therefore it becomes increasingly important that our road systems incorporate sufficient tolerances that will cater for deteriorating light perception and also for the longer time it takes for the elderly to react to these all important visual clues whilst trying to safely navigate our roads.

Older drivers, therefore, need brighter road markings in order to navigate their way safely on our roads at night. In an aging population, which wants to and frankly needs to maintain its mobility, the need for quality line marking has become a critical issue requiring the attention of road owners and specifiers alike.

**Consider too the importance of preview time:**

- A driver must be able to see pavement markings at a certain distance down the road in order to receive adequate information to safely guide the vehicle. This distance allows the driver adequate time to perceive, process, and react to the information that the pavement marking presents. Since the required distance increases as the speed of the vehicle increases, it is often expressed as a constant preview time. (U.S Department of Transportation, Federal Highway Administration).
- “It has been established that for night time low-beam conditions, a driver requires a minimum recommended preview time (comprising both eye fixation time and driver reaction time) of 3.65 seconds at 80km/hr, of oncoming road geometry to enable safe negotiation without the driver requiring to shift attention away from the road, to look for other clues” - (Zwahlen and Schnell, Transportation Research Board, January 1998, Washington DC).

With this in mind, it is critically important that the pavement markings on our roads be visible in day & night conditions. They must remain visible even when the road surface has become wet because of rain. If pavement markings are not visible under these conditions, most drivers will have great difficulty in safely negotiating the road on which they are travelling, (the ramifications for this should be obvious).

Can you identify in your mind a stretch of road with which you are personally familiar, that exhibits any of the following symptoms of ineffective markings?

- A multilane lane road wherein the linemarking has deteriorated significantly; to the point that the lanes are not clearly defined.
- A road that, during the day, appears to be well marked, but at night the lines are barely visible.

- A road, that normally appears to be well marked, enabling good vision in both day & dry night conditions; and yet on nights of even moderate rainfall the lines become invisible.

Sadly I am sure that each of us present at this conference has personally experienced these exact conditions, and it's a sad indictment on the effectiveness of many road safety strategies when we can all identify roads in and around the areas that we regularly travel that are clearly dangerous.

## HOW TO ENSURE PAVEMENT MARKING VISIBILITY:

The primary performance criterion that delivers visibility of pavement markings, especially at night, is **retroreflectivity**. Essentially, retroreflectivity of pavement markings can only occur if the markings are incorporated with glass beads specifically designed to provide retroreflectivity\*.

\*For further information see: AS/NZS 2009 Glass beads for pavement-marking materials. (available from [www.saiglobal.com](http://www.saiglobal.com))

The basic mechanics of this process are that the beam of light emitted from the headlights of a vehicle enters into glass beads that have been imbedded 60% into the pavement marking materials surface; the light will then retroreflect back to the driver at a sufficient level of brightness as to complete the safe guidance system that markings are meant to deliver. When measuring units of retroreflectivity the value is expressed as  $\text{mcd/m}^2/\text{lx}$  (millicandella/per square metre/lux).

Of course the big questions are:

1. What is the ideal minimum level of retroreflectivity to ensure the visibility of markings 24 hours a day, in wet and dry conditions?
2. Are the levels of retroreflectivity currently being used by Road Authorities sufficient?

Of Australia's eight States and Territories, four have absolutely no specified minimum levels of dry retroreflectivity. One specifies a level of  $100 \text{ mcd/m}^2/\text{lx}$ , (the internationally accepted level at which a line becomes invisible at night) and another even allows a level as low as  $90 \text{ mcd/m}^2/\text{lx}$ .

The situation for minimum wet retroreflectivity values is even worse, with six of our States and Territories not having any requirements that would ensure safe driving in wet-night conditions.

No doubt many of you will be alarmed by these facts, especially as many Local Authorities and private road owners will automatically use their relevant State or Territory's pavement marking specification to formulate their own pavement marking strategies.

So again the question - what is the ideal minimum level of retroreflectivity to ensure visibility of the markings 24 hours a day, in wet and dry conditions?

To answer this, please consider the following research from Australia and around the world:

- Traffic fatalities are 3 to 4 times higher at night, than day. (Boyce 1981).
- Improved night-time visibility for drivers can be a major factor in reducing accidents. (Boyce 1981).
- Retroreflectivity has more influence over end of line detection distances than head lamp illumination. (Zwahlen & Schnell, University of Ohio USA 1998).
- Larger (1mm) sized glass beads provide more effective wet night visibility. (Kalchbrenner, USA 1989).
- Large glass beads are used to add wet weather retroreflectivity to conventional markings. The beads need to be at least 1mm in size. (CIE International Commission on Illumination, 1999).
- For roads with an AADT of 5,000, the minimum retroreflectivity required is 150 mcd/m<sup>2</sup>/lx (30m geometry). (Dravitzski, Laing & Potter, Opus Labs NZ. 2004).
- For highway speeds above 80km/hr, a minimum RL value of 150 mcd/m<sup>2</sup>/lx was recommended. (Migletz, Graham, Bauer & Harwood, 1998).
- For night time wet-pavement conditions, a minimum RL value of 180 mcd/m<sup>2</sup>/lx was recommended. (Migletz, Graham, Bauer & Harwood, 1998).

Note: When considering that last quote which recommended 180 mcd/m<sup>2</sup>/lx for wet-pavement conditions, please bear in mind that this is a measurement of the minimum dry retroreflectivity values required to deliver sufficient levels of retroreflectivity (brightness) in wet conditions.

**Based on these reports alone, the recommended levels of retroreflectivity for roads exhibiting either an AADT of 5,000 vehicles or highways speeds greater than 80km/hr are:**

- A minimum 150 mcd/m<sup>2</sup>/lx dry
- A minimum 100 mcd/m<sup>2</sup>/lx wet

Notice how these recommended minimum levels of retroreflectivity are reflected in the following excerpt of Australian Standard AS 4049.4—2006 Paints and related materials—Pavement marking materials Part 4: High performance pavement marking system (available from [www.saiglobal.com](http://www.saiglobal.com)):

**TABLE 3**  
**DRY RETROREFLECTIVITY**

Classification	Retroreflectivity mcd/m <sup>2</sup> /lx		
	Initial	Interim(s)	Final
RD0	No requirement	No requirement	No requirement
RD1	>250	>200	>150
RD2	>350	>250	>150
RD3	>500	>350	>250

**TABLE 4**  
**WET RETROREFLECTIVITY**

Classification	Retroreflectivity mcd/m <sup>2</sup> /lx		
	Initial	Interim(s)	Final
RW0	No requirement	No requirement	No requirement
RW1	>80	>80	>80
RW2	>160	>130	>100
RW3	>240	>180	>120

*(Note: Australian Standard AS4049.4 – 2006 is highly recommended for anyone interested in setting performance parameters for pavement marking systems.*

*The performance parameters featured in this document include:*

*Colour; Colour Change; Luminance Factor; Volatile Organic Compounds; Dry Retroreflectivity; Wet Retroreflectivity; Degree of Wear; Slip Resistance and Skid Resistance.*

*The aim of this Standard is to provide users with the ability to specify requirements for high performance pavement marking systems.)*

Of course it must be remembered that **150 mcd/m<sup>2</sup>/lx dry** and **100 mcd/m<sup>2</sup>/lx wet** are the recommended **absolute minimum** levels of retroreflectivity, below which they should never fall. Therefore when these figures are used within a specification they should be considered as **the intervention levels at which the re-marking must be instigated**.

It is recommended that the initial levels of retroreflectivity required by new markings be substantially higher than those shown here in order to realise reasonable service life expectations.



## ASSESSING THE VISIBILITY OF ROADMARKINGS?

Equipped now with a clear understanding of what the minimum levels of retroreflectivity should be, how can you determine the standard of the markings on your road system?

The first thing you need to be aware of is that the  $\text{mcd/m}^2/\text{lx}$  figures quoted herein are those shown when testing with a retroreflectometer that utilises a 30 metre geometry as it's angle of measurement. In Australia 30 metre geometry hand held retroreflectometers (used for spot checking retroreflectivity) are available. There are also companies that provide retroreflectivity measuring services utilising truck mounted retroreflectometer systems that can measure any length of road at any interval that you could possibly want at highway speeds (and provide you with computer generated reports for your analysis).

It must be stressed however, that the only way for you to ensure the veracity of the readings of these instruments is to ensure that they have been calibrated using Secondary Standards that are traceable to the requirements of the National Measurement Laboratory (NML).

In direct response to increased performance expectations, and with the total support of industry and every Road Authority throughout Australia and New Zealand, Secondary Standards have been developed. The use of traceable Secondary Standards provides protection for contractors and road owners alike, eliminating any dispute as to the real standard of works performed.

Also, beware of the dangers inherent in the reliance on daytime visual assessments of pavement markings as a tool for assessing the quality of your markings. REMEMBER: for a marking to be visible 24 hours a day, in both dry and wet conditions, it MUST have sufficient glass beads in-situ to deliver this most important of safety features - retroreflectivity. It is simply not possible to determine from within a car, travelling at speed, during the day if this is the case or not.

If you must perform a visual assessment then this should at least be performed at a time when retroreflectivity is both important and apparent – AT NIGHT (and maybe even a wet one at that).

*(Note: Also available from [www.saiglobal.com](http://www.saiglobal.com) is AS 4049.5 Guidelines for the performance assessment of pavement markings.*

*This document standardises procedures for the assessment of the field performance of pavement markings, including the development of sampling plans and strategies for the use of gathered data).*

## **OTHER EFFECTIVE ROAD SAFETY STRATEGIES INVOLVING PAVEMENT MARKINGS THAT ARE BEING ADOPTED INTERNATIONALLY:**

### **CENTRELINE AUDIO TACTILE MARKINGS**

The 'Insurance Institute for Highway Safety' in the USA recently published a report on the findings of trials in that country utilising what we call audio tactile markings (known as rumble strips in America). The report was entitled: "Crash Reduction Following Installation of Centreline Rumble Strips on Rural Two-Lane Roads" (Persaud, Retting & Lyon September 2003).

Notice the following findings from this report:

*The results of this research demonstrate that centreline rumble strips are an effective countermeasure on rural two-lane roads. As expected, they had larger effects on frontal and opposing direction sideswipe crashes, a 25 percent reduction in injury crashes, but the effects on other more numerous crash types also was large. The overall reduction in rural two-lane crashes attributable to centreline rumble strips was 14 percent. ....Consideration should be given to wider application of centreline rumble strips on rural two-lane roads"*

Whilst on the subject of centreline audio tactile markings, you should be aware that the Roads and Traffic Authority of New South Wales (RTA) is currently trialling the use of this marking system in that State. These trials are also seeking to significantly enhance the retroreflectivity of audio tactile markings by utilising larger glass beads of around 1 mm (AS/NZS 2009 Type D) to enhance wet-night visibility.

The RTA is to be applauded for taking this pro-active stance in the field trialling of innovative marking systems with a view to enhancing road safety.

### **WIDER MARKINGS**

In it's report entitled: "The Use of Wider Longitudinal Pavement Markings -Research Report 0024-1", the 'Texas Transportation Institute' reported *strong evidence that wider markings provide the following benefits to drivers, suggesting improved roadway safety:*

- *improved long-range detection under night time driving conditions (older drivers benefit the most),*
- *improved stimulation of the peripheral vision,*
- *improved lane positioning and other driver performance measures, and*
- *improved driver comfort.*

In regard to longitudinal markings, the report stated that: *"it is clear that longitudinal markings must be at least 4 inches (100mm) in width"*. The report further showed that 34% of State Road Authorities in USA are now using 150mm lines and some other States are even using 200mm lines.

## **OTHER FACTORS FOR CONSIDERATION:**

### ***AusRAP Australian Road Assessment Program***

Reports released by the AusRAP Australian Road Assessment Program have indicated that most national highways have not been delivering acceptable safety standards.

This program sought to institute a 'Star Ratings' classification system; rating roads from 1-star (least safe) to 5-star (safest). The report considered for this paper revealed that of the some 19,000km of our national highway network that were rated, the majority of roads rated just 3 stars.

AAA Executive Director, Lachlan McIntosh has been quoted as saying that those roads achieving the 3-star rating (the majority of roads assessed) were below those expected of a national network of roads.

"We should expect that, with increasing traffic, we can have a national network which has low risk and hence a low crash rate. Five people die every day on Australian roads and 61 are seriously injured – these tragic statistics could be significantly lowered if more attention is paid to incorporating simple safety features in all road design and maintenance. Research confirms that improving roads can contribute more to reducing road deaths than improving driver behaviour and vehicle safety".

## **CONCLUSIONS:**

Embrace (and act upon) the realisation that the uncompromising delivery of high-quality, well maintained pavement marking systems are key road safety measures, fundamental to the success of any serious road safety strategy.

If you are not already doing so, work towards specifying **150 mcd/m<sup>2</sup>/lx dry** and **100 mcd/m<sup>2</sup>/lx wet** as the absolute minimum levels of retroreflectivity, below which your markings must never fall. And then ensure that you use effective assessment techniques to ensure that this is the case.

The RIAA also encourages the adoption of new technologies (i.e. audio tactile centrelines where necessary and the use of wider lines) that will enhance road safety. We are committed to remaining actively involved in the promotion of awareness and professionalism throughout all levels of the Australian pavement delineation industry with a view to realising road safety outcomes.

We therefore welcome the opportunity to work along with any and all concerned parties in facilitating an environment wherein all road users can travel our roads in maximum safety.

To this end we would encourage you to contact us here at the Roadmarking Industry Association of Australia for any further information or assistance in enhancing road safety through the utilisation of enhanced marking systems. My contact details are shown below.

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