

Poor Road Markings Contribute to Crash Rates

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Abstract

The majority of traffic fatalities in Australia occur at night. The death rate is estimated to be between three to four times higher at night than during the day.

In recent a survey across Australia (D. Brown 2004), it has been noted that the standards for road-marking, in the area of night time visibility, are either set at very low performance levels or are non existent. There have been many studies and experiments that demonstrate that accident rates can be significantly further reduced if the road markings were to be maintained to safer standards.

This paper presents some of the results from this and other recent global research, and looks at how road-markings can figure in reducing crashes. It suggests that the measure of road-marking performance for both day and night, and in both wet and dry conditions, should be used as a tool in future accident investigations. The statistics would then become more meaningful, the fatalities and serious injuries could be reduced, and the cost benefit of safer performing road-markings may then be realised.

1.0 Introduction

Following are some recent media quotations made by professionals who know their business:

1.1 The Australian Institute of Traffic Planning and Management (AITPM) says that line marking, which is described as “an essential element of a modern road system”, is the most cost effective road safety measure. Line marking can reduce car accidents by as much as 60%, the report says, and with correct levels of contrast and brightness the reflective lines can prevent crashes on bends, at night on rural roads. (D. Brown 2004 www.aitpm.com)

1.2 Mr Paul Gibson, chairman of the NSW State Government’s StaySafe committee, says that the simple white reflective lines dividing a road were just as important safety measures as speed cameras and random breath tests. “I believe line marking is the most fundamental counter-measure ever introduced into road safety”, Mr Gibson said. “It is not just about dividing a road, but it is the delineation of the edge of the road that has saved lives”. (Sydney Morning Herald, 12 May 2004)

1.3 The NRMA's President, Mr Ross Turnbull, says that in the next 24 hours, five people will die and 550 people will be injured on our roads. If this many people were killed in aviation crashes every day, every plane in Australia would be grounded.

So what are we doing about it?

2.0 Road Marking Is Road Safety, Not Just Road Maintenance

A great deal of work has been done over the past twenty years to prove the worth of the humble painted pavement marking. A summary of some of the finding were presented in a paper at the AUSTROADS Road Safety Researching, Policing and Education Conference, held in Perth in 2004, entitled, 'Road Marking - High Priority Road Safety, or Just Road Maintenance?', and another at the 2003 Conference entitled 'Road Marking - Cosmetic or Crucial?' These papers present a collage of documented evidence of studies from around the world that demonstrate what effect an injection of funding to basic roadmarking can have on road safety. Both are available from the Web (www.rsconference.com).

3.0 The Public Does Notice

The Royal Automobile Club of Tasmania (RACT) believes that the standard of painted roadmarkings in their State is not being maintained to an adequate level. They are lobbying the State Government to provide more funding for roadmarking. To assist with their argument, they have a survey on their website (www.ract.com.au) which is continuously being updated. The status of the poll, as of February 2005 is displayed below:

- 3.1 Do you believe that some road line markings on rural roads are misleading?
- 84% have answered yes.
- 3.2 Do you believe that some of the road line markings on State highways are misleading? - 80% have answered yes.
- 3.3 Do you believe that some road line markings on National Highways are misleading? - 35% have answered yes.
- 3.4 Do you believe that some road line markings on metropolitan roads are misleading? - 84% have answered yes
- 3.5 Do you believe that the overall condition of road line markings on rural roads is poor? - 88% have answered yes.
- 3.6 Do you believe that the overall condition of road line markings on State Highways is poor? - 72% have answered yes.
- 3.7 Do you believe that the overall condition of the National Highways is poor? - 23% have answered yes.
- 3.8 Do you believe that the overall condition of road line markings on metropolitan roads is poor? - 84% have answered yes.

4.0 Safer Roads

Extracts from the Australian Automobile Association's (AAA) Report:

Over the last 10 years billions of dollars have been spent on significant road improvements in Australia. Yet there is a backlog of viable unfunded road projects throughout the country of over \$10 billion, with a benefit cost ratio (BCR) of up to 5:1 on many of these projects.

According to comprehensive research, fixing the roads has a greater potential to save lives than most people think. The Federal Government's National Road Safety Strategy estimates that by 2010 around 332 lives could be saved each year through improved roads, 175 because of safer vehicles, 158 by better driver behaviour and 35 by the use of new technology.

With regard to how Roadmarking fits into road safety, AAA goes on to explain that 'average standard' roadmarking treatments have the potential to reduce the percentage of crash types as follows:

- ✓ Off road, on straight - 10 to 20%
- ✓ Off road, on curve - 10 to 30%
- ✓ Out of control on curve - 10 to 20%
- ✓ Rear end - 10 to 20%
- ✓ Head on - 30 to 40%
- ✓ Hit permanent obstruction - 10 to 20%
- ✓ Overtaking - 30 to 40%
- ✓ Lane change - 10 to 20%



Source - Royal Automobile Club of Victoria (RACV) 'Lifeline: Situation Critical' - 2003. (www.aaa.com.au)

- ✓ "Crash severity on the open road is on average 3 and a half times higher than that on roads in built up areas in terms of serious crashes as a proportion of all reported crashes. Serious crashes are defined as fatal plus hospital admission". (B Kidd, MRWA - Road Safety Conference 2001. www.rsconference.com)

NOTE: It is not widely known 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. This is being termed 'the hidden disease'. (Hon. Tony Rundle MP. Tas Aust - 2004).

5.0 Our Safety Nets are Below Safe Standards

In a paper presented by Ross Walsh (ex RTA Traffic Engineer) at the Roadmarking Industry Association of Australia Conference in 2004, entitled, 'Raising the Safety Levels of Linemarking on State Roads and National Highways', he says:

"A number of reports conclude that a driver's preview time of 1.8 seconds to the visibility of road markings ahead should be regarded as an absolute minimum for safe driving. This equates to the driver being able to see the road markings up to about 44 metres ahead at 80 km/hr and up to about 60 metres ahead at 100 km/hr".

"The current intervention level for retroreflectivity of 100 mcd/lux/m² for dry linemarking that has been set by the RTA allows for visibility on a **dry night** of up to about 50 metres. This barely satisfies the "absolute minimum for safe driving" requirement for 80 km/hr and fails that requirement for 100 km/hr".

"The current intervention level for retroreflectivity of 70 mcd/lux/m² for wet linemarking (i.e. 70% of the dry values) set by the RTA completely fails to satisfy the "absolute minimum for safe driving" requirement for both 80 km/hr and 100 km/hr at night in the wet".

“Prior to the introduction of water borne paint with large glass beads, no such objective intervention levels were used by the RTA. These intervention levels were set in accordance with commonly accepted international practice current at that time. Since then, the international trend has been to increase these levels to somewhere in the range 125-150 mcd/lux/m²: A recent paper (Dravitzki, Laing and Potter, 2004) stated that the objective should be 150 mcd/lux/m²”.

Ross’s explanation is alarming, when we realise that the RTA maintains one of the best models in Australia. One must ask, what are the other State Standards like? Well the Australian Institute of Planning and Management answers the question, after they conducted their own survey during 2004. In the report entitled, ‘Line-Marking Standards - Searching for Best Practice’ (Available on the web www.aitpm.com), it summarises:

“There is strong empirical proof that good line-marking reduces crashes. The exact amount of the reduction depends on the conditions but a wide range of surveys have shown results ranging from 3 to 60%.”

“There is also overwhelming support from technical practitioners that quality line-marking is an effective and cost-efficient road safety measure.”

“Australia’s use of line-marking as a road safety measure is compromised by different standards in each state and by a lack of thorough management strategies to ensure that performance standards are measured and quality standards are met.”

“Particular issues include:

5.1. Performance standards for line-marking vary greatly between States, as do the standards of maintenance, yet the requirements of the driving population they serve are common.

5.2. Many State standards are low compared to international requirements; Standards have, in the past, focused on specifying the quantity and quality of line-marking materials to be placed on the road rather than the resulting visibility performance that should be achieved;

5.3. Setting standards is important but there is insufficient measuring of the performance to ensure standards have been achieved; Even if a line appears “bright” during the day, that is no indication of its performance at night especially if it is wet. The number, size and quality of small reflective beads that are placed in the paint, but are not visible to the naked eye, are the main determinants of the visibility of a line at night;

5.4. Night time performance is not related to the colour of the lines; Maintenance routines have been based on replacing the markings at set intervals. Research shows that a more cost-effective method is to replace the markings based on how much their quality has deteriorated over time;

5.5. With an aging population, the quality of line-marking becomes even more critical as the older we get the more we need brightness, contrast and less glare in our line-marking; “

5.6 The AITPM Report contains a great deal more independent and accurate detail on Australia’s shortfalls with regard to the standard of roadmarking. The report goes on to recommend:

- 5.6.1 .AITPM urges Austroads (the association of Australian and NZ road transport and traffic authorities) to initiate a project to determine uniform national standards for line-marking, set at a level that ensures that the reasonable needs of all drivers, including older drivers.
- 5.6.2 AITPM believes that having standards is only the first step. Every state road authority must ensure that the benefits of a strategic management process including appropriate contract surveillance, performance measurement and cost effective management of line-marking are carried out.

6.0 Road Safety Statistics

Without getting into the cost saving or BCR (we cover this later in the paper), lets look at the life-savings, injury-savings and crash-savings that painted roadmarkings can deliver.

Peter Moses, MRWA, paper entitled 'Edge Lines and Single Vehicle Accidents', 1986, Peter found that by using wider edge-lines (150mm) the visual perception of edge-lines by those effected by alcohol and drowsiness resulted in better vehicular trajectories. In this study, analysing only the single vehicle run-off-the-road type accident, not involving alcohol or mechanical failure, the number reduced from 83 to 55. A reduction of 34%. This may appear to be 'old news' and not relevant to today's times. However, nearly twenty years later, in the same State, another member of MRWA, Mr B Kidd, presented a paper at the Austroads 2001 Road Safety Conference, entitled 'Crash Patterns in Western Australia', statistics are presented that argue the benefits of improved night time delineation. Some extract follow:
"In taking traffic into account it is shown that both the risk and the severity of crashes are higher at night time than daytime particularly in the open road environment".
"The results should not only be useful to road safety agencies in WA but also to agencies elsewhere in Australia". "A total of 38,100 crashes were reported in 2000".
"The risk analysis based on amount of travel found that the night-time crash risk on the open road is about 3 times greater than that of day light hours". "The severity of crashes at night is higher than that during the day both in the urban and open road environment".

"In the open road environment the annual cost of night time crashes was estimated to be \$108M being 46% of total open road crash costs. This suggests that half of open road safety resources should be directed at night time treatments. In urban areas the annual cost of night time crashes was estimated to be \$291M being 35% of total urban crash costs. In this case the results suggest that a third of urban road safety resources should be directed at night time treatments".

So, how wide are the edgelines in Western Australia these days? And how well are they measured and maintained?

Sometimes maybe we loose site of what we have already learned. But in all fairness, how many other States have ever used 150mm wide edgelines, anywhere?

7.0 AUSTRROADS Accident Investigations

Road accident investigations are very important in identifying problems, and therefore potentially minimising future accidents at particular sites.

Highway delineation road markings are recognised internationally as being a functional part of road safety. Although by witness of the statistics gathered throughout the world (as noted below), the scientific evidence / statistics of the condition (retroreflectivity) of highway markings at accident sites throughout Australia are not apparently included in accident investigation statistics.

Due to this lack of historical data, the condition of horizontal painted road markings at accident sites are possibly overlooked or ignored, as to their potential contribution to road accidents.

It must be noted that when assessing the condition of painted road markings, a visual inspection is considered to be scientifically useless. There are hand held instruments that can be used during night or day light hours that measure the night time visibility of the paint road markings. The instruments are known as retroreflectometers. Most Road Authorities use them, as do road marking contractors and road consultants. It's a good way to know if the humble painted road marking is doing its job. Checking if the lines are visibly safe for night time driving.

The Austroads Guide to Traffic Engineering Practice, Part 4, 'Investigations and Treatments of Crash Locations', estimates that there can be a 30% crash reduction of 'run off the road' type single vehicle accidents, by the introduction of edge-lines. Austroads have plans to pursue the incorporation of hand held retroreflectometers (used to measure the night time visibility level of painted roadmarkings) for future use in accident investigations, as part of this year's (2005) national strategic research program.

8.0 Monash Accident Research Centre's Findings

During the early part of 2004 Staff of Monash University Accident Research Centre conducted an experiment, using their driver simulator. The experiment compared an enhanced roadmarking with a standard roadmarking.

The 'enhanced' markings were of waterborne paint with AS2009-2002 Class D 'wet weather glass beads', while the 'standard' markings were of waterborne paint with AS2009-2002 Class B glass beads. The experiment was conducted during simulated wet night driving conditions.

The findings of the experiment were presented in a paper entitled, "The Possible Safety Benefits of Enhanced Road Markings: a Driving Simulator Evaluation" by, Tim Horberry, Janet Anderson, and Michael. A. Regan. Accident Research Centre, Monash University, 2003. www.rsconference.com

An extract of the summary and conclusions says:

"A comparison of the relative effectiveness under simulated wet night driving conditions of an enhanced road marking system with commonly used highway markings was undertaken. Participants completed drives with both types of markings. A secondary mental arithmetic task was also employed in half of the conditions. Both objective and subjective data were collected. The results indicated that participants were better able to maintain lane position and speed with the enhanced markings than with the standard markings. Superior driving performance with the enhanced markings was also found when participants performed the

arithmetic task. A similar pattern was found for the subjective measures: workload was rated as lower for the enhanced markings; likewise, subjects reported the drives as being easier and were more confident in being able to drive safely when the roads displayed the enhanced markings. These findings point to a potential safety benefit from greater use of such enhanced roadway markings”.

“This experiment only considered behaviour in a driving simulator in which a limited number of road scenes were presented. Whether the results found here will generalise to the ‘real world’ needs to be confirmed by future studies. However, the authors argue that the study was well-controlled, the types of markings were systematically manipulated and the many response measures that were taken generally supported each other. Further, it was undertaken in a well-validated advanced driving simulator- many previous studies have shown that measures derived in this simulator closely correlate to those in real world driving (e.g., Godley, Triggs and Fildes, 1997). Also, before the actual study was undertaken the project team spent a great deal of time making the scenes as realistic as possible (for example, by getting independent marking experts to evaluate the scenes created). As such, it is argued that the results are a meaningful like-for-like comparison of enhanced and standard markings.

The study found consistently superior results for the enhanced markings in comparison to the standard markings for both the objective driving performance and the workload / subjective data. As such, the findings suggest that important safety benefits might emerge from greater use of enhanced markings on roads around the world”.

9.0 Benefit Cost

In recent papers, presented at road safety conferences and road industry conferences, there has been a great deal of evidence already provided to establish BCRs for roadmarking, so we won’t go into this detail again. (Roadmarking - High Priority Road Safety, or Just Road Maintenance’. www.rsconference.com). We must mention though, that the UK study found a BCR of 9:1 and the US Federal Highway Authority has established a BCR of 6:1. (‘Road Marking - A Cost Effective First Step Towards Safe Highways’, Tim Palmer. Silk Road Conference, Tashkent – Sept 1999).

A paper from the Texas Transportation Institute, entitled ‘The Use of Wider Longitudinal Pavement Markings’, by Timothy. J. Gates and H. Gene Hawkins, PhD., P.E (www.pottersbeads.com/literature/widerlongitudinalmarkings), says:

“Wider markings typically cost more to implement because of the greater quantity of materials compared to the typical 4-inch (100mm) line. Because of the increased costs, most agencies prefer to have some type of evidence of the benefits of wider markings to justify their use. This report describes five main methods for evaluating the effectiveness of wider pavement markings:

- crash evaluations,
- service life analysis,
- visibility measures,
- intermediate measures, and
- driver opinion surveys / comments

Traditional evaluation methods have centred on crash studies, mainly because of the ability to translate these results into benefit/cost ratios that can demonstrate

economic benefit.....During the study period, there are often other influential factors that confound the analysis such as differences in marking retroreflectivity”

So, it is not only line pattern dimensions that provide roadmarking safety benefits. The markings must be maintained to a sufficient level to be visible also at night. Retroreflectivity for night time driving in both dry and wet conditions contributes significantly to the safe performance of the roadmarkings.

10.0 It's More than Just Putting Beads into Paint

The necessity of beaded lines for night time reflectivity is accepted world wide. One only needs to view an un-reflectorised rural road at night to appreciate why.

During the day a non-beaded painted line may appear to be a richer or more uniform colour.

If a traffic engineer were to make his decision based on a daylight evaluation only, he would probably select the un-beaded line. However, if the same traffic engineer evaluated these lines at night he would undoubtedly select the beaded line.

Pavement markings effectiveness at night is due to the inclusion of surface applied glass beads to the painted markings. At night these markings provide consistent information re direction, form and conditions.

But there is more to glass beads than just making markings visible at night. Pavement markings with glass beads provide greater night time end of line detection distance, or road preview time. This helps the driver see ahead to which direction the road will take him. With well maintained night-time-visible pavement markings he has no need to look to the periphery for other visual clues.

Glass beads add to the durability of pavement markings (Dr J E Kemp 1998). For instance waterborne traffic paint has been found to be little better in durability performance than solvent based paint, until glass beads are surface applied to them. Then the waterborne paint outperforms the solvent based paint by two to three times the durability (Rohm and Haas 1994). You see the waterborne paint is a very efficient 'glue' for glass beads, and the glass beads are very durable, with a high crush resistance. One product compliments the other, creating a very durable pavement marking system.

When paint is applied to the road surface, it changes the microtexture of the road. The skid resistance of the markings are not as good as that of the pavement. However, the addition of glass beads can lift the skid resistance to a more acceptable level. With thicker pavement markings, such as thermoplastic, the macrotexture of the pavement is changed. This can be quite slippery. Surface applied glass beads can once again significantly improve the skid resistance.

Glass beads are an integral part of roadmarking systems, and should be viewed that way - as a 'system'. All the components of the system should work together to provide the performance required from it. Beads are coated to suit various roadmarking binder systems, to provide improved embedment, flow and adhesion. Choose the right coating to suit the right binder. Choose quality binders that are designed to perform. Choose the right systems to suit certain situations (eg: cold

applied plastic and adhesive coated Class D glass beads for 'threshold' treatments at sealed / unsealed side-road sites).

11.0 References

Some sources of information have been referenced throughout the paper with website listings. In addition to this I have repeated quotations / references, below, from previously presented papers.

- **Boyce 1981** - The majority of traffic fatalities occur at night,
- **Boyce 1981** - Traffic fatalities are 3 to 4 time higher at night, than day,
- **Boyce 1981** - Improved night-time visibility for drivers can be a major factor in reducing accidents,
- **Brown 2004** - AITPM Linemarking Standards, Searching for Best Practice
- **Carnaby 2003** - Austroads Road Safety Conf. Roadmarking, Cosmetic or Crucial.
- **Carnaby 2004** - Road Safety Conf. High Priority Road Safety, or Just Road Maintenance.
- **CIE International Commission on Illumination, 1999** - Large glass beads are used to add wet weather retroreflectivity to conventional markings. The beads need to be at least 1mm in size,
- **Dr JE Kemp 1998** - Roads and Traffic Authority, New South Wales. The higher the initial CIL/m_r (retroreflectivity) the longer the life of the line
- **Dravitzski, Laing & Potter 2004** - , Opus Labs NZ. For roads with an AADT of 5,000, the minimum retroreflectivity required is 150mcd/lux/m_r (30m geometry)
- **Godley 1999** - Edgelines improve lateral control, which is linked to reduced accident rates
- **Gibson 2004** - NSW Staysafe Committee (Sydney Morning Herald). It's not just about dividing a road, but it is the delineation of the edge of the road that has saved lives.
- **Horberry, Anderson, Regan, 2003** - Monash Uni Accident Research Centre, Victoria Australia. When comparing enhanced markings with conventional markings in adverse conditions, the enhanced markings provided,
 - Better lateral lane control
 - Better speed control
 - Better maintenance of target level performance

And were found to be,

- Less mentally demanding
- Less physically demanding
- Less temporally demanding
- Less effort was required
 - Less frustration resulted
- Less difficult
- Higher confidence in ability to drive safely
- **Kalchbrenner 1989** - USA. Larger (1mm) sized glass beads provide more effective wet night visibility,
- **Kidd 2001** - MRWA, Road Safety Conf.
- **Miller 1992** - Centrelines and edgelines reduce all accidents by 20%
- **Moses 1986**, Main Roads Western Australia - Centrelines and edgelines reduce single vehicle accidents by 34%

- **McKnight and Tippets 1998** - Higher visibility edgelines decreases lane keeping errors
- **Migletz, Graham, Bauer & Harwood, 1998** - For highway speeds above 80km/hr, a minimum RL value of 150mcd/lux/m₂ was recommended,
- **Migletz, Graham, Bauer & Harwood, 1998** - For nighttime wet-pavement conditions, a minimum RL value of 180mcd/lux/m₂ was recommended,
- **Moses 1986** - MRWA. Edge lines and Single Vehicle Accidents.
- **Palmer 1999** - Silk Road Conf, Tashkent. A Cost Effective First Step Towards Safe Highways.
- **Rohm and Haas 1994** - Waterborne paint outperforms solvent paint by two to three times.
- **Walsh 2004** - RIAA Conf. Raising the Safety Levels of Linemarking on State Roads and National Highways
- **Zwahlen & Schnell 1998** - Uni of Ohio USA. End of line detection distances can be 55% higher for the younger driver than the older driver,
- **Zwahlen & Schnell 1998** - Uni of Ohio USA. Retroreflectivity has more influence over end of line detection distances than head lamp illumination.