Road Marking -
High Priority Road Safety, or Just Road Maintenance?

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Abstract
Successive Governments in recent times have put in place some very effective road safety programmes to reduce the road carnage. These programmes, such as SPEED, FATIGUE, DRINK DRIVE, SEAT BELTS, and HELMETS, have had an obvious beneficial impact. As effective and successful as these programmes have been, they are aimed at driver behaviour only, and do not address the other half of what contributes to improved road safety, the road environment.

A fundamental of basic road safety is DELINEATION. Delineation, put simply, are guidance systems in the form of painted road markings and other devices that assist the driver in negotiating the travel from A to B, comfortably and safely. So what is happening with delineation? From what we see, it appears to get cut back in budget dollars, or a least there appears to be no growth. No improvement. It doesn't sound as sexy as the other five well-known road safety initiatives, and it is usually considered only another maintenance activity, so it just gets programmed in with other 'things to do'. Well there are many who think it's about time that delineation received the funding that it deserves. There is worldwide recognition of this. Many studies and engineering and scientific reports, both locally and globally, are pointing to the huge importance of improved delineation, and the roll it can play in reducing road trauma. Wider lines, brighter lines, wet-night visible lines, audible lines, line that can be seen over greater distances, or just some better programming strategies that would improve delineation performance would be a good start.

This paper presents 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.

1. Road Marking

Longitudinal pavement markings are the only continuous means of guidance for motorists in their travels. Pavement markings are visible at night because the light from the headlight is reflected back to the driver from the glass bead in the paint. The interaction of these three components, glass beads, paint and light defines how effective the overall system will be at guiding drivers at night. The popular definition of night time visibility of pavement markings is defined as the retroreflectivity of the markings. This is a measurement of the efficiency of the marking to return light in the general direction from which it came. It is simply a ratio of the light visible to the driver compared to the light entering the pavement marking from the vehicle's headlamps.

2. Retroreflectivity (night time visibility) and Measurement

The necessity of beaded lines for night time reflectivity is accepted world wide. One only need to view a 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 are 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. Pavement markings with glass beads provide greater night time end of line detection distance, or road preview time.

Unbeaded paint lines will reflect light except that it does it randomly, scattering the light in all directions. When glass beads are added they reflect light directly back to the source of the light. In the Industry, this is called retroreflection.

The retroreflectivity (night time visibility) of the painted marking can be measured using a hand held portable retroreflectometer. This instrument measures the coefficient of retroreflected luminance and provides a read out in millicandellas / lux / metres squared (mcd/lux/m²). The intervention, or fail level, is usually set at an absolute minimum of 100mcd/lux/m².

Line No1 = 100mcd/lux/m²
(Not very good, is it!?)

3. Road Markings Disappear on Rainy Nights

Glass beads, having a diameter of 0.3 to 0.4mm have been used on painted markings, for this very purpose, in Australia since around 1952, and have proven very effective at providing clear road delineation at night time in dry conditions.

The problem is, however, that once it starts raining (right at the time that you need as much visual information as you can get about the roadway ahead), these lines become virtually invisible. The reason for this is that under wet conditions the tiny beads become covered in a film of water that effectively stops the light from being reflected back to us.

Reassuringly however, this problem can be easily overcome via the use of larger glass beads of around 1mm in diameter.

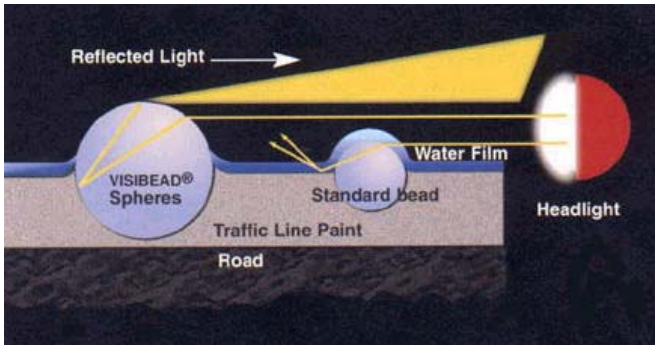

Figure 1 - The traditional 0.3mm sized glass bead functions well, providing good night time visibility of the painted pavement markings until rain begins to fall. The larger 1mm diameter sized glass beads continue to send a visual message at night, in both dry and wet conditions.

4. Value Management Study

In November 1995, the NSW Roads and Traffic Authority, at the direction of the State Minister for Roads, commissioned the Department of Public Works and Services' Production Evaluation Unit, to identify key problem areas, review current practices and examine potential improvement options, so that a strategy could be developed to ensure road delineation would provide all the necessary functions. These functions included the requirement for visibility of road markings during both day and night conditions, particularly in wet weather. As a result of this study, 1mm wet-night-visible sized glass beads were introduced to the road-marking specification in NSW.

5. The Ageing Driver Population

The demographic trend in Australia of an increasing proportion of older drivers means that an increasing number of us have less than "average" visual capabilities, and the ability of painted lines on the road to impart their message becomes increasingly important. As we grow older, a number of things happen to our visual abilities that impact on the ability of delineation devices, both signs and line-marking, to fulfil their function.

Our contrast sensitivity decreases. A 60 year old observer needs about 2.5 times the contrast to achieve the same level of visibility as a 23 year old.

Visual acuity describes our ability to resolve fine detail. Its degradation with age is well known.

Glare sensitivity increases. Light entering the eye is scattered by imperfections in the lens and vitreous fluid of the eye, forming a "veiling luminescence" which reduces the contrast of objects being viewed. As we age, these imperfections in the eye increase and the apparent contrast of objects decreases. Further, the ability of the eye to recover from glare also deteriorates as we grow older.

The implications for line-marking standards are clear. If current standards are assumed to be held constant the road safety effectiveness of line-marking will be diminished for an increasing proportion of our driving population. Conversely, if we wish to maintain the safety effectiveness of line-marking we should be looking to enhance the standards to adopt systems that compensate for the reduced visual capabilities of older drivers.

Research as far back as twenty years ago has demonstrated the benefits for older drivers by providing wider and brighter road markings. In an experiment conducted in the US in Morris County and some other Counties in New Jersey, in the 1980's, the edgelines were marked at 200mm wide. Over a three year study period, where wider edgeleines were used, the fatality and serious injury rates were reduced by 10%.

Left: Two lines viewed on a dry night.
The far left line is a 'conventional' marking, with small sized glass beads to AS 2009-2002 Class B, measuring 350mcd/lux/m². The line next to it has large sized glass beads applied to it, to AS2009-2002 Class D, and measures 450mcd/lux/m².

Right: The same two lines viewed on a wet night.

6. Local Statistics (WA)

In a paper presented at the Austroads 2001 Road Safety Conference by B. Kidd of Main Roads Western Australia, 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 is 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".

"Crash severity on the open road is on average 3 and a half time 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".

7. Benefit Cost

Of course the same old barriers appear when the threat of potential additional costs appear, and so the cost benefit of well maintained road markings needs to be established.

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At the most basic level, studies in California, USA, showed that when a centre line was added to roads which were totally unmarked, the number of accidents was reduced by 64%.

Further studies in USA showed that when edgelines were added to roads which had previously had a centre line only, the number of accidents was reduced by between 16 and 60%.

Test Location	Total Accident Reduction %.
Kansas	17
Kansas	15
Ohio	19
Illinois	21
Michigan	3
Utah	38
Arizona	60
West Milford	44
Idaho	16

If we take a straight average of these 9 edge line studies – this gives an accident reduction of 26%.

We can extrapolate further and say with a reasonable degree of certainty that on an unmarked stretch of highway where there are normally 100 accidents per year, the addition of a centreline reduces the number of accidents to 36 and a further addition of edge lines reduces the number of accidents to 27.

Studies in Great Britain have shown that effect of edge line is dramatically increased at night.

County	Total Accident Reduction %	Night-Time Reduction %
East Essex	18	37
South Yorkshire	30	38
Northamptonshire	13	42

The case for ensuring that road markings can be easily seen at night - that they are retroreflective - is therefore overwhelming and becomes even stronger when we consider that, as unfortunately many of us are beginning to find out, our night vision deteriorates sharply as we become older. In most countries we can expect life expectancy and the proportion of older drivers to increase in the coming years.

Beyond these basic studies, we have large numbers of studies correlating accident reduction with cost effectiveness. Many of these are not particularly meaningful in countries other than those where the studies were done, other than to show trends. This is, of course, because the cost of applying road markings, of building roads and of maintaining the highway infrastructure varies widely from country to country. All the different countries also have widely differing methods of calculating the cost of accidents, of injury, of death, of medical treatments etc. Furthermore, the effects of inflation can make out-of-date shortly after published.

However, the last British study quoted did calculate a financial saving benefit to cost ratio:

Country	Total Reduction %	Benefit to Cost Ratio
East Sussex	18	12:1
South Yorkshire	30	7:1
Northamptonshire	13	9;1

Furthermore, the USA Federal Highways Authority has ranked engineering measures for road safety by calculating a ratio of annual benefit cost. After normal vertical traffic signs, which we must accept as given on any modern road system, markings and delineation clearly provide the most benefit far above any other measure.

8. Global Proof – the Worth of Road Markings

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 are presented in a brief form below:

- Centrelines and edgelines reduce all accidents by 20% (Miller, 1992).

- Centrelines and edgelines reduce single vehicle accidents by 34% (Moses 1986).
- Edgelines improve lateral control, which is linked to reduced accident rates (Godley, 1999).
- Higher visibility edgelines decreases lane keeping errors (McKnight & Tippets, 1998).
- The higher the initial CIL/m² (retroreflectivity) the longer the life of the line (Dr JE Kemp, 1998).
- 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, (Boyce 1981).
- For roads with an AADT of 5,000, the minimum retroreflectivity required is 150mcd/lux/m² (30m geometry) (Dravitzski, Laing & Potter, 2004).
- End of line detection distances can be 55% higher for the younger driver than the older driver, (Zwahlen & Schnell, 1998).
- Retroreflectivity has more influence over end of line detection distances than head lamp illumination, (Zwahlen & Schnell, 1998).
- Larger (1mm) sized glass beads provide more effective wet night visibility, (Kalchbrenner, 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 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, (Migletz, Graham, Bauer & Harwood, 1998).

9. Searching for Best Practice

In a report entitled, 'Line-marking Standards - Searching for Best Practice", released in May this year by the Australian Institute of Traffic Planning and Management (AITPM), the following was concluded:

Line-marking is an essential element of a modern road system, with well established safety benefits. Indeed, expert consensus is that it is one of the most cost-effective road safety measures available.

The age demographics of our driving population will require higher standards of line-marking, ie brighter, more highly retroreflective and better performing in wet weather, just to maintain the current levels of functionality from the older driver's perspective.

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.

There appears to insufficient contract surveillance or performance measurement in some States, contributing to poor in-service performance.

There is a strong case for Austroads to determine uniform national standards for line-marking, set at a level that ensures that the reasonable needs of all

drivers, including older drivers, are met. AITPM urges that an Austroads project be initiated to undertake this work.

A results of a survey conducted by AITPM, demonstrating the inconsistencies of roadmarking standards across Australia, are shown in the table below:

Retroreflectivity in Australia by State

State	Contract Type	Serviced by	Minimum Dry Requirement mcd/lux/m2	Minimum Wet Requirement mcd/lux/m2
WA	Performance	Contractors	100	No requirement
SA	Schedule of Rates	Contractors	No requirement	No requirement
Vic	Performance	Contractors	90	60 (Western Highway only)
(two types)	Schedule of Rates	Contractors	200 at 25-35 days	No requirement
NSW (two types)	Performance	Government	130-150 at 12 months	91-105 at 12 months
	Schedule of Rates	Contractors	No requirement	No requirement
ACT (two types)	Performance - Gov't and Contractors		Initial 250 Up to 2 yrs 140 At end of 3 yrs 100	175 98 70
	Schedule of Rates - Gov't & Contract		Nil	nil
Qld	Schedule of Rates	Government	No requirement	No requirement
NT	Schedule of Rates	Contractors	No requirement	No requirement
Tas	Schedule of Rates	Contractors	200 initial only	No requirement

10. Research and Development of Safer Road Marking Systems

Potters Industries has initiated a series of road marking field trials, in a partnership with the NSW Roads and Traffic Authority's Scientific Services Branch and the ACT's Department of Urban Services. Many combinations of road markings have been applied to roads in the Canberra area, with the intention of developing safer road marking systems, using a variety of road marking materials and application methods. Performance data has been

generated, to date, over the past three years. A Scientific team visits the site each 3 months and measures the line visibility and resistance to skid. This information is reported to industry on a regular basis.

These trials have proven that there are safer road marking systems to suit all road users, in almost all driving conditions, which are immediately available, and cost effective through the extended high performance and durability that is provided.

11. Investigations and Treatments of Crash Locations

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.

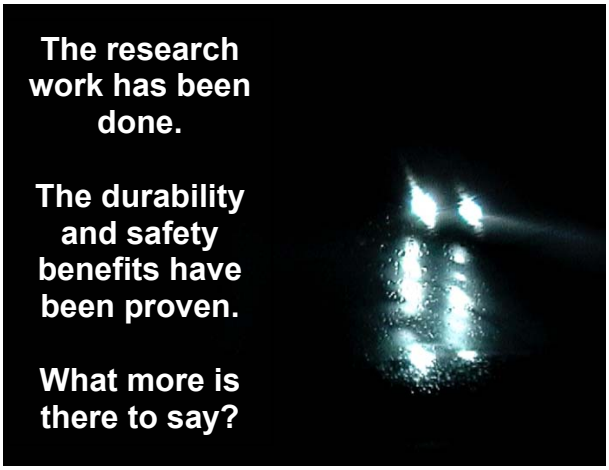
If such instruments are not used in accident investigations, we must assume that no accurate statistics are being gathered, and therefore we do not know if the road markings are in poor conditions and may have contributed to or caused the accident.

If the night time visibility (retroreflectivity) were to be recorded at each accident site, maybe it could be determined statistically whether the road markings contributed to the accident because of their poor performance / visibility. Retroreflectivity measures, used to determine road marking condition could be another safety benefit, delivered at minimal cost (ie: Instead of re-aligning a tight curve in the road, it may be identified that if the delineation were adequate, there may be a huge cost saving made by just painting the lines to a high visible standard. This may not be obvious in a report, where a visual assessment was made).

A senior Manager of Vicroads, said at a recent (May ’04) AITPM Seminar on road markings, that if accident statistics could be produced to prove the benefits of well maintained and highly visible road markings, that he would have no problem in increasing the intervention level, to provide for a higher service level of painted road markings. But these (local) statistics do not exist. Herein lies the problem.

The good news is that Austroads have plans to pursue the incorporation of hand held retroreflectometers for future use in accident investigations, as part of next year’s (2005) national strategic research program.

12. Summary



The American Traffic Safety Services Association says that driving home this evening will be the most dangerous thing that you will do today.

I wish you a safe journey.