DELIVERING SAFER ROADS
BY APPLYING ADVANCED TECHNOLOGIES

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Abstract

'Sign and lines' are the most basic of road safety infrastructure and yet are sometimes a forgotten necessity when road managers think about improving road safety. In recent years new developments have been made to improve these technologies and increase awareness of their road safety benefits.

The changing driving environment with more aging drivers, altered headlamp performance, complex road scenarios and diverse vehicle sizes, all have their implications on visibility and road safety. Studies show that signs and lines that are acceptable during the day can have a remarkably different appearance at night and in rainy weather conditions.

This paper aims to highlight the cost benefits of improved signage and how new technologies can be applied in the field to improve road safety. The advancements in retroreflective technologies have the potential to deliver major improvements in road safety outcomes and exceed current Australian standards. The RTA have been proactive in trialling new reflective technologies designed to increase sign visibility for motorists and introduced a new specification above the current Australian standard to apply these new technologies in practice. These best practice examples demonstrate increased safety.

Furthermore, current pavement markings will be reviewed and the factors affecting line deterioration. Special attention is given to wet visibility and cost benefit calculations to assess what solutions offer the optimum fit for diverse traffic conditions.

Road users mainly rely on road authorities to be more assertive at exploring the increased safety and financial benefits in implementing new technologies.

Key words

Road safety, sign management, pavement markings, retroreflectivity, visibility,

Introduction

Road trauma represents a significant cost on society and governments are developing various measures and safety programmes to reduce the number of fatal accidents and serious injuries. Australia has set a target to reduce the number of annual road fatalities and serious injuries by at least 30% between 2011 and 2020. (ATC 2011) The National Road Safety Strategy 2011-2020 emphasizes that road safety is a shared responsibility, building a national road safety culture is crucial to achieve the desired results. Examples as recognising the need for trials, demonstrating practical applications, analysing cost-benefits, supporting trial projects by allocating separate budget to fulfill the emerging needs, or offering financial incentives for those who outperform current standards and regulations would help to develop the shared responsibility mindset and achieve targets. Many of the road safety initiatives are high cost and long term and will take many years to implement, but many of the low cost, immediate impact measures are often ignored. The advancements in retroreflective technologies can deliver immediate results and targeted applications, for example at black spots or road work zones, are able to prove the benefits in short term.

Changing environment

The driving environment has changed with a larger amount of traffic, more aging drivers, altered headlamp performance and diverse vehicle sizes. It has coupled with increased distractions both on the roadside environment and also within the vehicle such as the use of mobile phones. The Intergenerational Report (2010) states that the proportion of people aged over 65 years is rising and the number of people aged 65-85 years is expected to more than double and the number of people 85 and over more than quadruple until 2050. Aging results in a natural decline in vision (night-time acuity) and motor (physical) functioning.

As the ageing population are also road users, their needs in navigating the roads need to be understood in order to improve safety. Older drivers usually have trouble navigating roads, which were not designed with them in mind. For many of these motorists signs are hard to read, lanes are too narrow and right hand turns are very difficult.

It is understood that as we age our need for light to be able to read doubles around every 13 years after the age of 20. Drivers over the age of 60 require approximately 8 times more light and their reaction times increases, needing around 40% more time to react than younger drivers. (Marland, 1967)

Headlamp performance has also changed. Several motor vehicle models do not provide sufficient illumination towards erected signs. Currently about 80 percent of late model vehicles are factory-equipped with visually/optically aimable (VOA) headlamps that compromise sign performance and reduce the visibility of the signs significantly. (Sivak et al., 2000)

Besides an ageing population and headlamp performance, the diversity of vehicles also affects sign performance. The wide range of vehicle sizes on the roads – from motorbikes to prime movers produces a wide range of observation angles; the angle between the line formed by the source of the light beam striking the surface and the retroreflected beam returned to the driver's eyes. In other words, the size of the angle is determined by the vertical distance between the headlight of the vehicle and the driver's eye level. Therefore, the observation angle is significantly larger for truck drivers than motorists in cars, because of their larger vertical displacement from the headlights. This causes a significant reduction in the amount of returned light received by the truck driver, compared to the light received by the driver of the car. As drivers of these vehicles can sit up to 2 metres above their headlights, the amount of luminance they receive from the sign can be as low as one third that of a driver in a conventional sedan. Less reflected light means less driver ability to detect, recognise and read a sign.

All these three factors mentioned above and their relationship to sign visibility has serious implications on road safety. Thus, clear, conspicuous and legible signage to improve driver safety is essential. This is especially important when driving at night as conditions are generally acknowledged as more difficult to navigate safely.

Advancements in technologies – Signage

1. *Full cube corner technology*

The development of retroreflective sheeting materials dates back to the 1930's and since this time it has seen some major developments in improving the efficiency of the sheeting with advance in technologies at a microscopic level. The original products produced used the glass bead technology that is still in use today. Enclosed lens beaded sheetings were developed in the 1940ies, these represent Class 2 in AS/NZS 1906 standard, or Type I in ASTM. Prismatic technologies have been around since the 1980's doubling the returned light compared to enclosed glass beaded sheetings and providing a performance of 32% of light directed back to the driver. The real breakthrough in technologies, however, arrived in 2005 with the introduction of 3M's Diamond Grade™ DG3 Full Cubed technology that reworked the structure of the existing microprisms in the sheeting. This has been achieved by designing a prism geometry called Micro Full Cube, or simply Full Cube Technology. In effect the full cube reflective sheeting design takes the reflective area of the microprismatic (cube corner) design and discards the ineffective corners. These reflective centres are replicated side by side to create a 100% retroreflective surface. When viewed in this fashion it appears a trivial development but in reality it is far from that. With the full cube prismatic design, the actual efficiency of the material is 58% once physical losses have been accounted for. That means 58% of the light which strikes the sign face is retroreflected to the driver in the cone of retroreflection.

As would be argued by many road users, the brightness of many signs do not need to be increased to improve their legibility. With the Full Cubed sheeting the increased efficiency is engineered to create a broader cone of reflection, thus using the additional light produced to reflect to broader range of observation and entrance angles. By carefully controlling the divergence, the light can be distributed without becoming blinding to any driver. In other words, retroreflectivity at narrow observation angles can be kept relatively equal to that of incumbent high performance sheeting, while retroreflectivity at wider observation angles has been significantly increased.

The big advantages in this Full Cube technology is that it provides greater luminance to large vehicles such as trucks that have a large observation angles. It also provides all vehicles greater light reflectivity from disadvantaged sign positions such as signage on the right hand side of the road, overhead gantry positions and winding roads where vehicles headlights do not focus as much light on the sign.

There is also an advantage in the brightness to cater for older drivers and the current move toward the new VOA headlights in new cars which accurately limits the beam angle of headlights. By providing more light to the driver of all vehicle types and improving the sign legibility for disadvantaged signs, 3M's DG3 sheeting is seen as a breakthrough in improving the ability of drivers to read road signage and providing better road safety outcomes.

2. *The Australian standard and improved specifications*

AS/NZS 1906.1:2007 covers the technical requirements for road traffic signage retroreflective sheetings. Currently Class 1W materials are specified as the highest class with the expectation of greater photometric values at higher entrance and observation angles. This standard was last reviewed in 2006 and takes into account neither the changing road users' requirements for wider angularity nor the advancements in retroreflective technologies. The US ASTM D4956-09 standard has introduced type XI Class into its specifications taking care of the changing road safety needs. As Table 1 illustrates, low level performance is expected at 1˚observation angle and both 4˚and 30˚ entrance angle. Based on the reflectivity levels in the AS/NZS Standard, the associated actual luminance levels – the amount of light required to see the sign – can be insufficient for actual visibility. This is especially so in locations where competing light systems are operating, for example: street lighting or neon lights.

In 2009 the NSW RTA recognised the dicrepancy between the current Australian standard and the road safety expectations and introduced the RTA QA Specification 3400, adding class 1X for increased angles, offering better visibility for disadvantaged signs, - for example, signs placed on the right hand side and on overhead gantries, - for disadvantaged truck drivers and for older drivers through greater brightness. In March 2010 Main Roads Queensland followed, and it is expected that all state road authorities will adopt class 1X.

ASTM Type XI vs Class 1W and 1X				
		ASTM Type XI	AS/NZS 1906.1 Class 1W	RTA QA3400 Class 1X
Observation angle	Entrance angle	White		
0.2°	-4°	580	380	500
0.2°	+30°	220	225	215
0.5°	-4°	420	275	300
0.5°	+30°	150	115	135
1.0°	-4°	120	55	80
1.0°	+30°	45	30	45

Table 1 – Comparison of ASTM and Australian photometric performance requirements for white retroreflective sheetings based on AS 1906 and RTA QA 3400

3. *Cost - benefit considerations for upgrading traffic signs*

At some stage, every component of the road network will require maintenance or replacement, so where the maintenance dollars should be spent? The signs' current condition is not the only factor that should be taken into account. We should also carefully examine whether the proposed replacement sign is the most appropriate solution for the future. In a black spot area where enhanced daytime visibility is also desirable, the usage of fluorescent colours provides the optimum solution. The diference between standard and fluorescent colours is well demonstrated on Figure 1.

Figure 1 – Warning sign and pedestrian signs prepared with standard and fluorescent sheeting.

Signs have long service lives, more than 10 years, and the real sign solution needs to be safety-focused, adopting the Safe System Approach that would serve the needs of the ageing population, increased traffic and diverse vehicle sizes. Being proactive and saving lives pays off, rather than acting reactively and risk legal action and paying claims. The only difference on a sign is the retroreflective sheeting itself which takes up only a small proportion of the total sign cost as illustrated by the sign face components on Figure 2. In terms of regulatory signs, it comprises only 30% of the sign face costs, and the bigger the sign, i.e. guide signs, the lower this percentage is compared to the entire sign costs. The cost of upgrading the sign sheeting to a higher performing product is negligible. Safer solutions can be purchased for minimal dollars, e.g. using the most advanced sign sheeting, Class 1X (RTA – QA3400) on a 'Stop' sign instead of Class 1, would cost less than half a cup of coffee in addition.

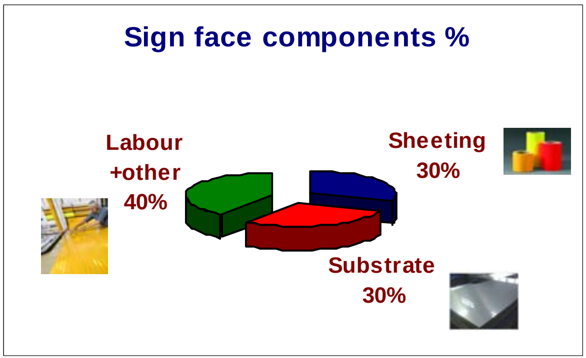


Figure 2 – Sign cost structure

Another easy and quick measure of the cost of a sign is its life cycle cost; the cost of the sign divided by its useful life. Appendix A demonstrates the savings for longer lasting signs and at the same time, higher performing signs. This approach is very simple and does not factor in sign substrates, other material costs, labour, traffic control or administrative costs. If we consider these costs as well, then the savings for longer lasting signs get even better. More durable and higher performing signs cost less in the long term, while they also serve the current and future needs of the road users better.

4. Best practice examples

In 2009 the NSW RTA introduced Class 1X into their specifications determining higher performing sign sheetings for disadvantaged guide signs positions, for example: right side mounted, cantilevered and overhead signs. A list of regulatory signs also require Class 1X, whereas selected warning, regulatory and temporary road signs have to be made with Class 1X fluorescent sheetings. Figure 3 shows one of the biggest RTA Class 1X signs, a 48 m^2 green guide sign prepared with 3M™ Diamond Grade™ DG3 sheeting which was installed on Warringah Freeway in Sydney.

Figure 3 – Class 1X guide sign with 3M™ Diamond Grade™ DG3 sheeting

The RTA has successfully leveraged the latest technologies in signage to improve road safety for different types of road users and diverse vehicle sizes.

Advancements in technologies – Road Marking

1. *Line visibility in rainy conditions*

All of us can agree that one of the fundamental needs for road users is a safe road network. Safety includes several factors ranging from legible and visible signage, traffic signals, through forgiving road planning to safe line markings. Much of the time, line marking is taken for granted. It must be highlighted, however, that effective delineation improves the safety of our roads by helping motorists to process traffic information quickly, thus making the right decision and navigating safely. Similarly to sign performance, line visibility deteriorates over time and the ability to retroreflect light back to the light source at night to the drivers' eyes decreases. The environment, the pavement surface and the traffic volume all influence line quality and durability.

No one can dispute that lines should be visible not only in dry weather, but also in rainy and wet conditions. Brodsky and Hakkert (1988) found the increased danger in driving in wet conditions with accidents rates increases up to three times of that in the dry. A large part of the difficulty in driving in the wet stems from the inability to find the delineation of the road between lanes and the verge. Basically, road line markings become difficult or impossible to see and vehicles can find themselves in the wrong lanes or on the wrong side of the road.

Like older retroreflective road signage, line marking uses glass bead technology to be able to retroreflect the lines back to the driver to give them visibility during the night. The technology is proven and is used in all types of line marking materials such as paints, thermoplastics, tapes and other materials. However, because of the physical properties of the glass beads when water is applied to the surface, the retroreflection is refracted and the visibility of the line is reduced.

2. *Wet reflective optical elements*

A breakthrough technology incorporating special optical elements to provide wet reflective properties in linemarking already exists and is utilised in many solutions ranging from paint through thermoplastic to durable tapes. The technical reason for not being able to see the lines

in the wet is that the refractive index of the glass bead is 1.5 – 1.9 and to be able to reflect with water over a surface a refractive index of 2.4 is required. 2.4 are about the refractive index of a diamond.
In recent years 3M has released a microcrystalline ceramic element that is able to attain the 2.4 refractive index and is now been utilised in many road line marking systems. This structure is pictured in Figures 4 and 5, embedded in paint alongside a glass bead and is called an "optical element". Figure 5 shows a macro view of elements and beads in a linemarking.

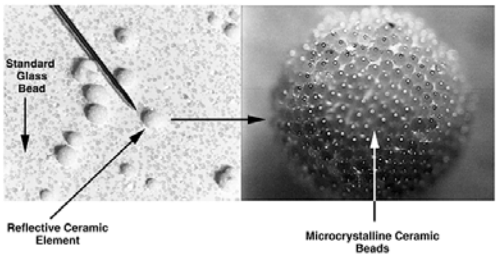


Figure 4 – 3M wet reflective optical elements

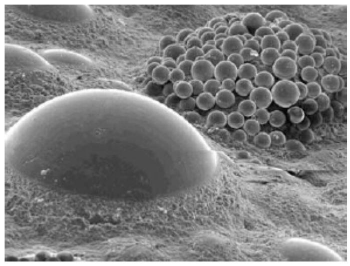


Figure 5– Magnified image of glassbead and 3M elements

3. *Standards and State specifications – the need for performance based specifications*

AS 4049 series standards– Paints and related materials: Pavement Marking Materials, define the performance criteria for linemarking materials. The standards suggest that the absolute minimum level of retroreflectivity on dry roads should be 150mcd/m^2/lx, whereas in wet conditions this value should be not less than 80 mcd/m^2/lx. These values represent the intervention level, i.e. the quality of the lines should never fall below these minimum requirements.
The states also use the standards as guidelines when establishing their own specifications and performance requirements. Table 2 illustrates the diverse expectations in 6 states and 2 territories and shows the specifications in the selected states about the required minimum level performance for lines. Concerning wet visibility only a few specifications pay attention to lines in the wet.

Intervention levels / white markings

	NSW / RTA	QLD / DTMR	WA / MR	VIC / Vicroads	SA / DTEI	NT	ACT
dry	150 mcd	150 mcd	100 mcd	90 mcd	125 mcd	not specified	150 mcd
wet	80 mcd	not specified	not specified	not specified	not specified	not specified	80 mcd
Reference document	RTA QA Specification R145	MRS 11.45	Specification 604	Section 721	Specification 245&246	Road Maintenance 16-PM	SS11 - PM

Table 2 – Intervention levels in Australia in selected states and 2 territories

It is important to discuss if these values are enough to drive safely in all weather conditions, day and night. When we consider dry weather visibility, we can declare that markings in their new condition overperform current standards. Our experience shows that initial reflectivity values range from 250 mcd/lx/m^2 to 1000 mcd/lx/m^2, the latter indicates the usage of high performance, durable materials, e.g. tapes.
There are several studies investigating the optimal visibility level of markings. Cottrell and Hanson (2001) have performed a motorist survey to determine the perception of road users about the various levels of retroreflectivity and the benefits it might offer for drivers. The survey results indicated that pavement markings with retroreflectivity readings less than 300

mcd/m^2/lux were classified as acceptable approximately 53 percent (mean value) of the time, whereas markings with retroreflectivity readings greater than 600 mcd/m^2/lux were classified as acceptable approximately 92 percent (mean value) of the time. The participants comprised different age groups with a special care on senior drivers who usually prefer to avoid nighttime driving due to their decreased abilities of human vision in the dark. The survey concluded that drivers over the age of 65 are generally less satisfied with the brightness of pavement markings than are drivers under the age of 65.
Another study by Gibbons (2006) places a special emphasis on wet visibility. He has found the relationship between retroreflectivity and the detection distance, which was used to postulate a minimum required value for visibility during wet night conditions. A value of 200 mcd/m^2/lx appeared to provide a reasonable detection distance for a minimum performance requirement. The study suggests that the above cited value should be adopted by road authorities when defining their specifications for wet night conditions.

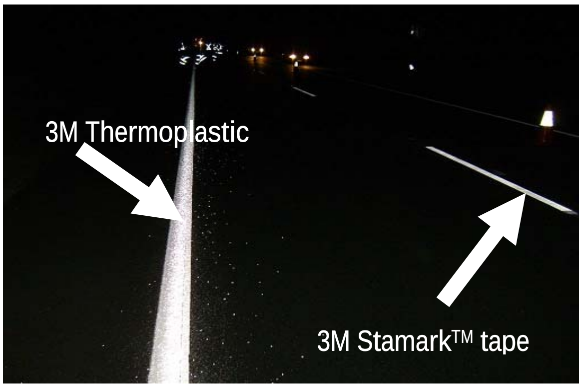
4. *Cost - benefit considerations for linemarking*

For every road safety professional it is a challenge to quantify the benefits of different pavement marking systems. Even after extensive research, many questions still remain unanswered. Numerous guidelines and cost benefit models have been developed all over the world. One approach underlines the importance of performance-based specifications. According to Cottrell and Hanson (2001) this is an alternative method to use when making decisions about pavement markings, especially durable markings. For example, in this approach, the performance criterion could be that minimum retroreflectivity, 150 mcd for example, would be maintained for a given period, such as 3 years. Other criteria such as color and durability (material intact) ratings could also be considered.
Durable marking applications offer substantial savings over the years as shown in Appendix B. This real example represents an average pedestrian crossing - 9 bars, each 450 mm x 3.6 m based on Specification RTA 145 - including the variables of traffic control, speed of application, service life, additional value as wet and rain reflectivity. The speed of application and the time needed for surface preparation are often neglected although they can significantly add up to the total cost of the pavement marking application. As the old saying goes ‘time is money’, this is especially true when we are talking of increased labour costs due to longer time required for line installation, equipment calibration and set up for precise line or bar creation – these all count as “hard” costs that need to be taken into account. Furthermore, additional “soft” costs might also be associated with line applications: traffic delays, congestion, stress for road users, lost productivity etc. which are difficult to quantify but have to be considered. As the example indicates, using permanent, durable pavement marking materials, 3M Stamark^{TM} tapes might seem “expensive” at first sight, but as we break down the fees to be paid, it immediately throws new light upon this issue, and is converted into the most cost effective solution offering additional benefits for road users for wet night visibility.

5. *Best practice examples*

3M wet reflective technologies have been trialled widely in Australia and have proven their effectiveness. A major application of the 3M^{TM} All Weather Paint System has been on the M5 South West Motorway in Sydney. With the agreement of Interlink Roads, the operator of the M5, a section of road between Liverpool and the Crossroads was marked in July 2008 and had been measured after 4 weeks of trafficking. In this case, the left edge line and lane line were marked as All Weather lines and the right edge line was marked to the RTA 141 waterborne paint specification. This particular length of road has traffic of approximately 40,000 ADT including a large number of heavy vehicles so is providing a good demonstration

of the durability of the microcrystalline ceramic elements. The left hand edge line returned an average dry retro of 395 mcd/lux/m^2 and 60 second wet recovery was 280 mcd/lux/m^2. The RTA141 right edge line has dry results of 270 mcd/lux/m^2 and wet recovery of 120 mcd/lux/m^2. A crude flood measurement was also made where the lines were flooded with 1L of water and measured with 3-5 seconds recovery time. The all weather line read, on average, 160 mcd/lux/m^2 while the RTA141 line returned 25 mcd/lux/m^2.
Measurements were repeated in July 2010 and the readings varied according to sections hit by heavy traffic. Considering the age of markings and the heavy traffic (40,000 ADT) 65-70% of the sections still performs above intervention level and ensures excellent dry and wet night visibility. As the paint including the elements and beads was heavily damaged at the corners due to trucks and other heavy vehicles hitting the lines, dry night time performance fell below intervention, whereas wet / rain visibility is still retained and guarantees safe guidance for road users in rainy weather.
A recent application of 3M™ All Weather Systems includes a combined linemarking of All Weather Thermoplastic and durable All Weather Stamark™ tapes. A section of Mona Vale Road (St. Ives, NSW) was selected by RTA in June 2011 and 3M thermoplastic was applied on the left and right edge lines, whereas the centre lines were marked with 3M™ Stamark™ tapes offering longer durability. The initial measurements were taken on the night of the application and values varied between 480-650 mcd/lx/m^2 for thermoplastic and between 500-900 mcd/lx/m^2 for 3M tapes. The photos on Figures 6 and 7 were taken during the application.



Figures 6-7 3M™ All Weather Thermoplastic and Stamark™ tape application on Mona Vale Rd, St Ives, NSW

Recommendations and conclusion

Road signage and line marking are significant parts of the total road asset and should be maintained to a high standard to ensure maximum return on investment and road safety for the community.
The recent advances in retroreflective technologies for road signage and line markings should be leveraged to improve road safety for all Australian road users. For road signage to be as effective as possible, it is important that all road users and the road environment are considered during the material design and specification stages. The current Australian signage standard does not take into account the changing needs of the ageing population and other road users, the disadvantaged sign positions and the diverse vehicle sizes. When it comes to road signage, the fact is 'what you see during the day is not always what you see at night' and performance can differ substantially. Road authorities and traffic engineers have very little control over many factors that impact sign luminance, however they can control the specifications of the retroreflective sheeting that they use and also the effective positioning of

the sign. Some road authorities have already recognised the requirements for better performing materials and have implemented this into their specifications. It is recommended that all road authorities follow the best practices and upgrade their specifications. It is also essential that the next revision of the Australian standard reflects the changes.

With the introduction of new wet reflective line marking technologies there is now an opportunity to improve the road safety problem of line delineation in the wet. Durable marking solutions like wet reflective tapes have proven their cost effectiveness over other, traditional solutions. Additionally, they complement the current standard requirements for the highest performance classes and provide a system compliant even with the most "rigorous" specifications. 3M™ All Weather markings offer a true value added benefit of increased wet night visibility and present road authorities and traffic safety professionals cost effective solutions. Further work and investigation are called for on upgrading the standards and the specifications to include the need for wet and rain night visibility in all states.

The local best practice examples represent how proactive our local governments and road authorities are in trialling new technologies to increase sign and line visibility for motorists. As road users rely on road authorities, they have to be more assertive at exploring the increased safety and financial benefits in implementing these new technologies.

References

2010 Intergenerational report: Australia to 2050: future challenges, Circulated by The Hon. Wayne Swan MP Treasurer of the Commonwealth of Australia, January 2010, 1

Australian Transport Council (2011) – National Road Safety Strategy 2011-2020

Brodsky, H. and Hakkert, A. S. (1988) "Risk of a road accident in rainy weather", *Accident analysis and prevention*, 20(3) 161-176

Cottrell, B. H., Hanson, R. A., (2001) "Determining the effectiveness of pavement marking materials" Virginia Transportation Research Council (VTRC 01-R9) 11, 20, 18

Gibbons, R. B., (2006) "Pavement marking visibility requirements during wet night conditions" Lighting and Infrastructure Technology Virginia Tech Transportation Institute Virginia Polytechnic Institute & State University (VTRC 07-CR7) abstract

Holderness, M. (2011) "Wide observation angle retroreflective sheeting. What to choose?" Discussion paper

King, A. (2009) "Advances in retroreflective technologies for road signage, vehicle visibility and pavement markings, delivering safer roads for all" paper delivered at the 5th Australian Road Engineering and Maintenance Conference March 2010 Melbourne, Victoria, 5

Marland, R.E. (1967) "Let's Shed Some Light on Pedestrian and Cyclist Safety: An Approach to the Problem," US. Department of Health, Education and Welfare, Public Health Service, Washington, D.C., 2

Sivak, M., Flannagan, M.J., Miyokawa, T. (2000) "A first look of visually aimable and harmonized low-beam headlamps" The University of Michigan - Transportation Research Institute, Ann Arbor, Michigan 48109-2150 U.S.A. Report number: UMTRI-2000-1, 14-15

Appendix A

Sign life cycle costs

Sheeting attributes	3MT[M] High Intensity prismatic sheeting	3M[TM] Diamond Grade[TM] DG3 Full cube prismatic sheeting
AS/NZS 1906.1 classification	Class 1	Class 1W
RTA QA 3400 specification	Class 1	Class 1X
Retroreflectivity (0.5/4 ^{o}) measured	380 cd/lx/m2	495 cd/lx/m2
Retroreflectivity (0.5/4 ^{o}) required by AS 1906.1:2007	95 cd/lx/m2	275 cd/lx/m2
Overall performance	good	excellent
Recommended application	general urban and rural environment, lower speed roads, e.g. left mounted signs, regulatory signs	large to extreme angles, disadvantaged sign positions, heavy vehicle traffic roads e.g.:gantry signs, "keep left", right mounted signs
Manufacturer Warranty (years)	10	12
Cost of the sign (e.g. Stop sign 600 x 600)	$32	$34
Expected life	12-15 ys	15-20 ys
Cost / year (cost/warranty period)	**$3.20**	**$2.83**

* example only, actual costs may vary

Appendix B

Cost of an average pedestrian crossing

9 bars, 450 mm x 3.6 m / bar, based on Specification RTA 145

	3M Stamark™ tape		Thermo		Paint	
	$	Time (hours)	$	Time (hours)	$	Time (hours)
Preparation						
Traffic Control	$300	1	$450	1.5	$450	1.5
Set up gear on site	$38	0.15	$230	0.5	$200	0.75
Clean surface with blower	$25	0.1	$0	0	$0	0
Surface prep (grinding or chipping)	$0	0	$100	0.2	$125	0.3
Chalk mark bar positions	$38	0.15	$38	0.15	$38	0.15
Sub Total:	**$401**	**1.4**	**$818**	**2.35**	**$813**	**2.7**
Application						
Material cost	$1,125		$535		$175	
Labour to apply	$75	0.3	$185	0.5	$185	0.5
Clean up	$25	0.1	$75	0.3	$75	0.3
Waiting time before open to traffic	$0	0	$200	0.15	$400	0.3
Sub Total:	**$1,225**	**0.4**	**$995**	**0.95**	**$835**	**1.1**
Total:	**$1,626**	**1.8**	**$1,813**	**3.3**	**$1,648**	**3.8**
Durability:	4 years		3 years		1 year	
Cost / year	**$406.38**		**$604.33**		**$1,648**	
additional value - wet and rain reflective for poor weather line visibility	✓		✗		✗	

* costs may vary depending on suppliers