

Australian/New Zealand Standard®

Road lighting

Part 1.3: Vehicular traffic (Category V) lighting—Guide to design, installation, operation and maintenance

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee LG/2, Road Lighting. It was approved on behalf of the Council of Standards Australia on 27 September 1996 and on behalf of the Council of Standards New Zealand on 19 August 1996. It was published on 5 April 1997.

The following interests are represented on Committee LG/2:

Australian Electrical and Electronic Manufacturers Association
AUSTROADS
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Australian/New Zealand Standard[®]

Road lighting

Part 1.3: Vehicular traffic (Category V) lighting—Guide to design, installation, operation and maintenance

First published as AS/NZS 1158.1.3:1997.

PUBLISHED JOINTLY BY:

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Homebush NSW 2140 Australia

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Level 10, Standards House,
155 The Terrace,
Wellington 6001 New Zealand

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee LG/2, Road Lighting.

This Standard forms Part 1.3 of a new series, the AS/NZS 1158 series, which will collectively cover lighting for the generality of roads and outdoor public areas, for the movement of vehicles and pedestrians. The AS/NZS 1158 series will progressively replace Standards existing in the AS 1158 series, and NZS 6701.

For the application of Standards in the AS/NZS 1158 series, a number of lighting categories are defined in AS/NZS 1158.0, which may be broadly described as follows:

- (a) *Category V lighting* Lighting which is applicable to roads on which the visual requirements of motorists are dominant, e.g. traffic routes.
- (b) *Category B lighting* Lighting which is applicable to roads on which the visual requirements of pedestrians are dominant, e.g. local roads.
- (c) *Category C lighting* Lighting which is applicable to outdoor public areas, other than roads, where the visual requirements of pedestrians are dominant, e.g. outdoor shopping precincts.

This Standard applies to Category V lighting and has as its objective the provision of guidance to all concerned with the design, installation, operation and maintenance of such lighting, to facilitate compliance with the requirements of AS/NZS 1158.1.1.

As at the date of publication of this Standard, the following Standards have been issued in the AS/NZS 1158 series:

AS/NZS

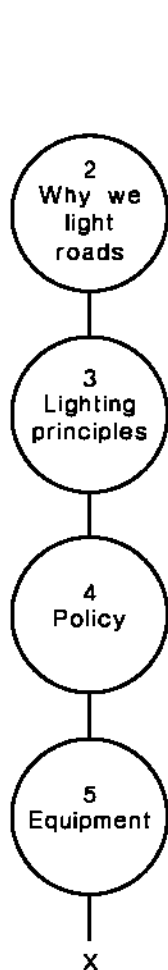
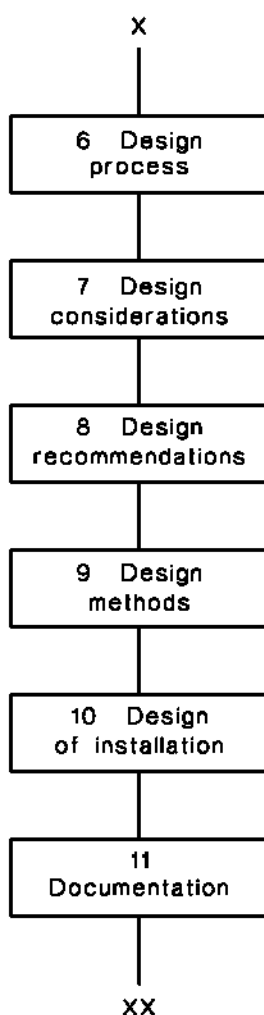
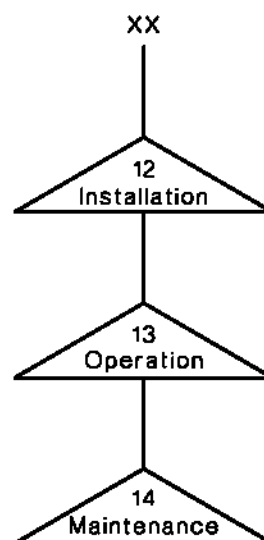
- 1158 Road lighting
- 1158.0 Part 0: Introduction
- 1158.1.1 Part 1.1: Vehicular traffic (Category V) lighting—Performance and installation design requirements
- 1158.1.3 Part 1.3: Vehicular traffic (Category V) lighting—Guide to design, installation, operation and maintenance (this Standard)

Requirements for the lighting of minor roads (i.e. Category B lighting) and for the lighting of outdoor public areas for pedestrian movement (i.e. Category C lighting) have yet to be issued within the AS/NZS 1158 series. Until that time, the relevant requirements of AS 1158.1—1986 or NZS 6701:1983 will continue to apply.

The subject matter covered in this Standard is divided into three main elements, as follows:

- (i) *Fundamentals* The information which must be known before engaging in a road lighting design.
- (ii) *Design* The considerations and processes involved in the development of a design for a road lighting scheme.
- (iii) *Application* Advice relating to the installation, operation and maintenance of a road lighting scheme.

These three broad subject areas are further divided into sections within this Standard as shown in the flow chart below.

Fundamentals**Design****Application**

Road lighting is acknowledged to be an effective accident counter-measure. The costs involved in providing road lighting can be demonstrated to provide significant financial and community benefits in terms of reductions in road accidents at night. Studies in Australia and New Zealand, and in other countries, have led to the conclusion that traffic route lighting is likely to reduce night time casualty accidents by about 30%, taken over the road network. See CIE Publication No. 93* and Reference 18 in Appendix A.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

* CIE Publication No. 93, Road lighting as an accident countermeasure (see extract in Appendix C).

CONTENTS

Page

SECTION 1 SCOPE AND GENERAL

1.1	SCOPE	9
1.2	LIGHTING CATEGORIES AND THEIR APPLICATION	9
1.3	REFERENCED DOCUMENTS	9
1.4	DEFINITIONS	9

SECTION 2 WHY WE LIGHT ROADS

2.1	ROAD LIGHTING OBJECTIVES	10
2.2	ROAD SAFETY	10
2.3	ROAD LIGHTING AS AN ACCIDENT COUNTERMEASURE	10
2.4	SECURITY AND AMENITY	10

SECTION 3 LIGHTING PRINCIPLES

3.1	VISUAL PROCESSES AND THE LIGHTING NEEDS OF ROAD USERS .	11
3.2	LIGHTING INSTALLATIONS AND LIGHT TECHNICAL PARAMETERS .	11
3.3	FACTORS AFFECTING PAVEMENT LUMINANCE	13
3.4	PAVEMENT REFLECTANCE	16

SECTION 4 POLICY CONSIDERATIONS

4.1	INTRODUCTION	19
4.2	STATUTORY REQUIREMENTS	19
4.3	DEVELOPMENT OF WARRANTS	19
4.4	GENERALIZED WARRANTS FOR TRAFFIC ROUTE LIGHTING	20
4.5	WARRANTS FOR LIGHTING ISOLATED INTERSECTIONS	20
4.6	WARRANTS FOR FREEWAY LIGHTING	21
4.7	WARRANTS FOR SUPPLEMENTARY LIGHTING AT PEDESTRIAN CROSSINGS	23
4.8	FUNDING ARRANGEMENTS	23
4.9	LIGHTING TARIFFS	23
4.10	THE USE AND PLACEMENT OF RIGID AND FRANGIBLE ROAD LIGHTING POLES	24
4.11	STANDARDS	24

SECTION 5 EQUIPMENT

5.1	GENERAL	25
5.2	LAMPS	25
5.3	ROAD LIGHTING LUMINAIRES	25
5.4	BRACKET ARMS AND POLES	27

SECTION 6 DESIGN PROCESS

6.1	GENERAL	28
6.2	SIMPLIFIED ROAD LIGHTING PROCESS	28
6.3	FULL ROAD LIGHTING DESIGN PROCESS	28

SECTION 7 DESIGN CONSIDERATIONS

7.1	GENERAL	30
7.2	ROAD SAFETY CONSIDERATIONS	30
7.3	TREE-LINED TRAFFIC ROUTES	31
7.4	WEATHER CONDITIONS	31
7.5	REFLECTING PROPERTIES OF ROAD SURFACES	32
7.6	ROAD LAYOUT	33
7.7	ROADWAY FEATURES	33
7.8	SURROUNDING BACKGROUNDS TO ROAD	33
7.9	VISIBILITY OF ROAD SIGNS	34
7.10	ENVIRONMENTAL CONSIDERATIONS	34
7.11	AESTHETICS	34

SECTION 8 DESIGN RECOMMENDATIONS

8.1	INSTALLATION GEOMETRY	35
8.2	LIGHTING ARRANGEMENTS (ARRs)	37
8.3	MEDIAN BARRIERS	37
8.4	MEDIAN	37
8.5	CURVES AND BENDS	37
8.6	ROUNDBABOUTS	37
8.7	CRESTS AND HUMPS	39
8.8	TREE-LINED TRAFFIC ROUTES	40
8.9	SHORT BRIDGES, UNDERPASSES AND SHORT TUNNELS	41
8.10	ORIENTATION OF LUMINAIRES	41
8.11	TERMINATION OF ROAD LIGHTING	41

SECTION 9 DESIGN METHODS

9.1	GENERAL	42
9.2	COMPUTER DESIGN	42
9.3	USE OF COMPUTER-GENERATED DESIGN AIDS	42
9.4	USE OF CURVE SPACING CHART	44

SECTION 10 DESIGN OF INSTALLATION

10.1	PROCEDURES USED IN LIGHTING DESIGN	45
10.2	MINIMUM DESIGN AREAS FOR APPLICATION OF ILLUMINANCE REQUIREMENTS TO SPECIFIC ROAD SITUATIONS	45
10.3	LIGHTING LAYOUTS	45
10.4	ELECTRICAL DESIGN	47
10.5	CIVIL/STRUCTURAL WORKS	48
10.6	LIGHTING DESIGN AUDIT	48

SECTION 11 DOCUMENTATION

11.1	EVIDENCE OF COMPLIANCE	49
11.2	PLANS AND SCHEDULES	49
11.3	ESTIMATES AND MATERIAL LISTS	49

SECTION 12 INSTALLATION

12.1	STANDARDS, REGULATIONS AND OTHER REQUIREMENTS	50
12.2	INSTALLATION AUDIT	50

SECTION 13 OPERATION

13.1	HOURS OF OPERATION	54
13.2	SWITCHING CONTROL	54

SECTION 14 MAINTENANCE

14.1	GENERAL PURPOSE	55
14.2	FACTORS AFFECTING PERFORMANCE	55
14.3	LAMP OUTAGES	55
14.4	LAMP AND LUMINAIRE DEPRECIATION	59
14.5	THE MAINTENANCE PROGRAM	61

APPENDICES

A	REFERENCED AND RELATED DOCUMENTS	64
B	GUIDELINES FOR THE USE AND PLACEMENT OF RIGID AND FRANGIBLE ROAD LIGHTING POLES	66
C	THE PROBLEM OF NIGHT ROAD ACCIDENTS AND ROAD LIGHTING AS AN ACCIDENT COUNTERMEASURE	82
D	TYPICAL FULL ROAD LIGHTING DESIGN PROCESS	85
E	ABBREVIATED LIGHTING DESIGN BRIEF	90
F	RECOMMENDED LIGHTING LAYOUTS FOR SPECIFIC ROAD SITUATIONS	91
G	MINIMUM DESIGN AREAS FOR APPLICATION OF ILLUMINANCE REQUIREMENTS TO SPECIFIC ROAD SITUATIONS	111
H	TYPICAL PERFORMANCE CURVES SHOWING LAMP MORTALITY AND LUMEN DEPRECIATION	121

TABLES

3.1	CLASSIFICATION OF ROAD SURFACES FOR LUMINANCE CALCULATIONS	17
5.1	COMPARISON OF DISCHARGE LAMPS USED FOR CATEGORY V LIGHTING	26
8.1	SUGGESTED MOUNTING HEIGHTS FOR LUMINAIRES WITH HIGH PRESSURE SODIUM VAPOUR LAMPS	36
14.1	GUIDE TO FAULTS WITH HIGH PRESSURE SODIUM LAMPS	56
14.2	GUIDE TO FAULTS WITH HIGH PRESSURE MERCURY LAMPS	57
14.3	TYPICAL LUMINAIRE MAINTENANCE FACTORS	60
B1	GUIDE TO POLE SELECTION	70
C1	SUMMARY OF THE BENEFITS OF LIGHTING (PERCENT REDUCTION OF NIGHT-TIME ACCIDENTS)	83

Page

FIGURES

3.1	CHARACTERISTIC 'T' SHAPE LIGHT DISTRIBUTION FROM A SINGLE LUMINAIRE	14
3.2	TYPICAL LIGHTING INSTALLATION WITH INTERLOCKING OF 'T' SHAPED LIGHT DISTRIBUTIONS	15
3.3	PARAMETERS AFFECTING PAVEMENT LUMINANCE	15
3.4	PAVEMENT REFLECTION	16
3.5	EFFECT OF SURFACE TEXTURE	17
3.6	EFFECT OF PAVEMENT WETNESS	18
8.1	ROAD LIGHTING DESIGN PARAMETERS	36
8.2	CONFLICT AREAS IN ROUNDABOUTS	39
14.1	GUIDE TO REMEDIAL ACTION FOR FAULTY HIGH PRESSURE SODIUM AND MERCURY LUMAIRES	58
B1	POLE SETBACK WITH RESPECT TO EDGE OF TRAFFIC LANE	67
B2	COLLAPSE MODES FOR FRANGIBLE POLES	69
B3	POLE SEBACK ZONES FOR ROADS WITH SPEED LIMITS NOT EXCEEDING 70 KM/H	72
B4	POLE SEBACK ZONES FOR ROADS WITH SPEED LIMITS EXCEEDING 70 KM/H	73
B5	POLE SEBACK FOR CUT/FILL SLOPE EMBANKMENTS	74
B6	ZONE 1 POLE SETBACK AT INTERSECTIONS WITH TYPICAL VERGES	74
B7	ZONE 1 POLE SETBACK AT ROUNDABOUTS WITH TYPICAL VERGES	75
B8	POLE SETBACK ZONES FOR ISLANDS, MEDIANS, SPLITTERS AND SEPARATORS	76
B9	POLE SETBACK ZONES FOR ROUNDABOUT CENTRAL ISLANDS	77
B10	LOCATION OF POLE BEHIND GUARD FENCE	78
B11	NON-TRAVERSABLE PERMANENT OBSTRUCTION IN FRONT OF POLE	79
B12	NON-TRAVERSABLE PERMANENT OBSTRUCTION BEHIND POLE	79
D1	TYPICAL FULL ROAD LIGHTING DESIGN PROCESS	86
D2	PRELIMINARY ROAD LIGHTING DESIGN	88
D3	FINAL ROAD LIGHTING DESIGN	89
F1	RECOMMENDED SINGLE-SIDED LAYOUT AT NON-CHANNELIZED FOUR-WAY INTERSECTIONS	92
F2	RECOMMENDED STAGGERED LAYOUT AT NON-CHANNELIZED FOUR-WAY INTERSECTIONS	93
F3	RECOMMENDED OPPOSITE LAYOUT AT NON-CHANNELIZED FOUR-WAY INTERSECTIONS	94
F4	RECOMMENDED OPPOSITE LAYOUT AT CHANNELIZED FOUR-WAY INTERSECTIONS	95
F5	RECOMMENDED STAGGERED LAYOUT AT CHANNELIZED FOUR-WAY INTERSECTIONS	96
F6	RECOMMENDED CENTRAL LAYOUT AT CHANNELIZED FOUR-WAY INTERSECTIONS	97
F7	RECOMMENDED SINGLE-SIDED LAYOUT AT NON-CHANNELIZED JUNCTIONS	98

F8	RECOMMENDED STAGGERED LAYOUT AT NON-CHANNELIZED JUNCTIONS	99
F9	RECOMMENDED OPPOSITE LAYOUT AT NON-CHANNELIZED JUNCTIONS	100
F10	RECOMMENDED OPPOSITE LAYOUT AT CHANNELIZED JUNCTIONS	101
F11	RECOMMENDED STAGGERED LAYOUT AT CHANNELIZED JUNCTIONS	102
F12	RECOMMENDED CENTRAL LAYOUT AT CHANNELIZED JUNCTIONS	103
F13	RECOMMENDED LAYOUT AT CONVERGING AND DIVERGING TRAFFIC STREAMS	104
F14	MISLEADING ARRAY OF LUMINAIRES AT CONVERGING TRAFFIC STREAMS	105
F15	RECOMMENDED LAYOUT AT SMALL ROUNDABOUTS	106
F16	RECOMMENDED LAYOUT AT LARGE ROUNDABOUTS	107
F17	CHANGE IN LUMINAIRE ARRANGEMENT AT ABRUPT CHANGE IN ROAD WIDTH	108
F18	CHANGE IN LUMINAIRE ARRANGEMENT AT GRADUAL CHANGE IN ROAD WIDTH	109
F19	RECOMMENDED LAYOUT AT SHARP BENDS	110
G1	MINIMUM DESIGN AREA FOR SIMPLE INTERSECTIONS	112
G2	MINIMUM DESIGN AREA FOR SIMPLE JUNCTIONS	112
G3	MINIMUM DESIGN AREA FOR CHANNELIZED INTERSECTIONS	113
G4	MINIMUM DESIGN AREA FOR CHANNELIZED ROUNDABOUT	114
G5	MINIMUM DESIGN AREA FOR CHANNELIZED JUNCTION	115
G6	MINIMUM DESIGN AREA FOR CHANNELIZED CONVERGING/DIVERGING TRAFFIC STREAMS	116
G7	MINIMUM DESIGN AREA FOR CHANGE IN CARRIAGEWAY WIDTH	117
G8	MINIMUM DESIGN AREA FOR CHANGE FROM SINGLE TO DIVIDED CARRIAGEWAY	117
G9	MINIMUM DESIGN AREA FOR TRANSITION BETWEEN LIGHTING FOR STRAIGHT SECTIONS OR CURVES AND SPECIFIED LOCATIONS	118
G10	MINIMUM DESIGN AREA FOR ISOLATED PEDESTRIAN REFUGES	119
G11	MINIMUM DESIGN AREA FOR PEDESTRIAN REFUGE IN MEDIANS	119
G12	MINIMUM DESIGN AREA FOR CURVES WITH RADIUS LESS THAN 100 M	120
G13	MINIMUM DESIGN AREA FOR SHARP BENDS	120
H1	TYPICAL LAMP MORTALITY/LUMEN DEPRECIATION DATA FOR LOW PRESSURE SODIUM VAPOUR LAMP	121
H2	TYPICAL LAMP MORTALITY/LUMEN DEPRECIATION DATA FOR HIGH PRESSURE SODIUM VAPOUR LAMP	122
H3	TYPICAL LAMP MORTALITY/LUMEN DEPRECIATION DATA FOR HIGH PRESSURE MERCURY VAPOUR LAMP	122

STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard**Road lighting****Part 1.3: Vehicular traffic (Category V) lighting—Guide to design, installation, operation and maintenance**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard sets out guidelines for the design, installation, operation and maintenance of lighting for roads which require Category V lighting complying with AS/NZS 1158.1.1. Performance criteria and installation design requirements for such lighting are specified in AS/NZS 1158.1.1 and should be read in conjunction with the recommendations of this Standard.

The purpose of this Standard is to provide background information and advice to assist in the application of the requirements of AS/NZS 1158.1.1. It also provides guidance on other matters for which it is not possible to specify requirements in a mandatory form.

The Standard does not purport to cover every possible means of ensuring compliance with AS/NZS 1158.1.1.

1.2 LIGHTING CATEGORIES AND THEIR APPLICATION For the purpose of this Standard, the lighting categories set out in AS/NZS 1158.0 shall apply. AS/NZS 1158.0 also describes typical applications for each of the lighting categories given.

The appropriate lighting category for a particular road should be a matter for determination in consultation with the road or traffic authority concerned.

1.3 REFERENCED DOCUMENTS A list of the Standards and other documents referred to in this Standard is given in Appendix A. The Appendix also lists a number of additional documents which are considered useful sources of information on the subject of this Standard.

1.4 DEFINITIONS For the purpose of this Standard, the definitions given in AS 1158.0 apply.

NOTE: See Paragraph B3 of Appendix B for definitions of terms related to the use and placement of road lighting poles.

SECTION 2 WHY WE LIGHT ROADS

2.1 ROAD LIGHTING OBJECTIVES The objective of road lighting is to provide an illuminated environment, which is conducive to the safe and comfortable movement of vehicular and pedestrian traffic at night, and the discouragement of illegal acts. To accomplish this, the lighting should reveal necessary visual information. This consists of the road itself, the course of the road ahead, kerbs, footpaths, property lines, road furniture and surface imperfections, together with the road users including pedestrians, cyclists and vehicles and their movements, and other animate and inanimate obstacles.

2.2 ROAD SAFETY The primary purpose of road lighting is to protect people from injury and death on the roads at night. All efforts and technological developments harnessed to attain this goal will also help curb the economic toll that traffic accidents take on national resources. The lowering of accident costs alone will generally justify investment in optimized road lighting.

2.3 ROAD LIGHTING AS AN ACCIDENT COUNTERMEASURE Road accidents at night are disproportionately higher in number and severity compared to daytime accidents. Individual factors such as increased alcohol usage, fatigue, and over-representation of young drivers in night traffic contribute to the problem. However, the major factor is darkness.

With the low light levels that prevail at night, visual capabilities such as acuity, distance judgement, speed of seeing, colour discrimination and glare tolerance are impaired. There will also be adverse interactions between impaired vision and other factors, such as inclement weather.

As a result of these conditions, visibility will be severely reduced at night. Thus, it can be expected that the provision of light through road lighting will be an accident countermeasure. However, the installation of the lighting cannot be expected to result in a reduction in accidents if there is a major traffic management or road design problem at any particular site.

The International Commission on Illumination (CIE) has conducted a review of research worldwide into the effectiveness of road lighting as an accident countermeasure. The findings are given in CIE Publication No. 93.

NOTE: A summary of CIE Publication No. 93 is given in Appendix C.

2.4 SECURITY AND AMENITY Further objectives of road lighting are to facilitate security and amenity. The provision of appropriate lighting can discourage crimes against both people and property, including parked vehicles. It may also enhance the environment for appropriate use by pedestrians and give rise to feelings/perceptions of safety and security.

SECTION 3 LIGHTING PRINCIPLES

3.1 VISUAL PROCESSES AND THE LIGHTING NEEDS OF ROAD USERS Vehicle drivers require a readily discernible flow of visual information in order to safely, efficiently and comfortably carry out the task of driving. Some of this information is provided by traffic control signals, road signs or markings and by vehicle lighting, e.g. presence and brake lights and turn signals. However, much of the required information comes from the general road scene itself, e.g. from the run of the road ahead and its layout, the presence of vehicles and other road users, and their perceived speeds and manoeuvres.

Assimilation of this information is facilitated by the contrast of the objects of interest with their surrounds, by detail within the objects, and by colour and movement.

The capacity of the human visual system to assimilate information largely depends on the ambient light level. In daylight (unless dazzled by the sun) vision is optimal; contrast sensitivity, acuity, colour perception, motion perception and the speed of vision are all as good as is humanly possible.

In spite of the facility of the eye to adapt to changing light levels, optimum vision cannot be sustained at low light levels. The light level provided by a traffic route lighting installation should be sufficient to limit any deterioration of vision at night, so that the driver's vision is as near as practicable to the optimum. This is particularly important on traffic routes where an error in judgement could result in an accident of severe consequences. If the lighting is sufficient for drivers of vehicles, it will be more than adequate for other more slow-moving road users, such as pedestrians and cyclists.

The values of luminance and illuminance specified in Section 2 of AS/NZS 1158.1.1 are pitched so that the human visual system is on the borderline between being light-adapted (photopic vision) and of starting to become dark-adapted (mesopic vision). The values specified are much greater than those pertaining to the completely dark-adapted eyes (scotopic vision). If completely dark-adapted, e.g. to a moonless night, the eye would only have the facility to detect very large moving shapes, without any colour or detail being discernible; not an acceptable state of affairs for driving. However, the lighting levels specified for traffic route lighting, whilst maintaining vision at close to optimal, are modest and will only be a fraction of those applying under daylight. Light levels experienced in daylight will generally be a thousand times higher, and even on dull days, a hundred times higher. Again, by comparison, office lighting will be more than 10 times the level implicit in traffic route lighting.

That such a modest lighting level is both sufficient and necessary, is borne out by the success of road lighting as a traffic accident counter measure (see Clause 2.3 and Appendix C).

3.2 LIGHTING INSTALLATIONS AND LIGHT TECHNICAL PARAMETERS

3.2.1 Basis of road lighting Having established the general level of lighting, attention needs to be paid to how the light is to be utilized in the installation and how it is to be specified by the relevant light technical parameters.

The carriageway of the traffic route is particularly important, in that this is the area of most activity and of the fastest activity. Moreover, the carriageway will have a surface of reasonably predictable and stable reflection characteristics. This allows the lighting of the carriageway to be designed on the basis of the luminance of the road surface, which is appropriate, since it is the luminance (or 'brightness') of that surface which is seen and not the illuminance (or quantity of light) falling on it.

Making the road surface bright by exploiting its reflection characteristics has the effect of —

- (a) raising the adaption light level of the driver and, by so doing, maintaining general visual performance at near optimum;
- (b) emphasizing the condition and run of the road ahead;
- (c) providing an extended luminous background, which provides a frame of reference in judging (subconsciously) relative speed and movement; and
- (d) facilitating visibility of the presence and shape of objects on the carriageway by silhouette, i.e. dark object against bright surrounds.

In order to make the road surface bright, a luminaire emits light in a beam directed towards the oncoming driver. With this beam direction there is no light on the object surfaces facing the driver. Hence, the possibility of viewing objects by silhouette as described in Item (d) above; the effect is most apparent when objects are some distance away (several spans of lighting ahead) and are thus, angularly, relatively small.

The luminaire will also have a trailing beam emitting light in the direction of travel. This light will directly illuminate objects to show up colour and detail; the effect is most apparent when the objects are close and are thus, angularly, relatively large.

Of course, for drivers travelling in the opposite direction, the two beams of light are in effect reversed; the one luminaire thus serves both directions of travel.

3.2.2 Light technical parameters Section 2 of AS/NZS 1158.1.1 specifies minimum values for the average carriageway luminance ($\bar{L}$) which is the simple arithmetic mean of luminances within a span of lighting*. Both minimum initial and minimum maintained values for $\bar{L}$ are specified, to ensure an adequate level of carriageway luminance on the initial installation of the lighting and to limit the subsequent deterioration in service to a tolerable level. Several lighting categories are given to cover the range of traffic routes with respect to the amount and type of activity on them (see Section 1 of AS/NZS 1158.1.1).

In specifying minimum values for $\bar{L}$, a limitation is placed on the uniformity of luminance to ensure the following:

- (a) That there are no dark areas within a span of lighting, which may conceal objects. The light technical parameter is U_0 and is a ratio, i.e. $U_0 = L_{\min} \div \bar{L}$. The specified value is the same for each lighting category since it effectively limits the minimum luminance ($L_{\min}$) anywhere within a span of lighting.
- (b) That there are no light and dark bars across the road, repeated through the length of the installation. This may arise, for example, if luminaires with excellent glare control are spaced excessively far apart. The light technical parameter is U_L and is a ratio, i.e. $U_L = L_{\min} \div L_{\max}$. The specified value applies along a designated longitudinal line within a span of lighting and, being a ratio, is the same for each lighting category.

The roadway will consist of a variety of elements other than the straight carriageway. For example, there are the intersections and the immediate surrounds to the carriageway edges, i.e. the verges. These areas do not lend themselves to a luminance-based lighting design.

For intersections, the carriageway may not be visible ahead when undertaking turning manoeuvres. It is therefore important to illuminate channelizations, road surface markings and vehicles within the general area of the intersection. For road verges, the surface will be indeterminate, i.e. shoulder, footpath, nature strip; nevertheless such surfaces are important as a starting point for pedestrians to cross the carriageway. In these cases, the lighting design is based on the illuminance on the relevant surface.

* The exact definitions of the light technical parameters are given in AS 1158.2.

For intersections, a minimum illuminance ($E_{\min}$) at any point within the designated area is specified. Initial and maintained values of $E_{\min}$ are given, together with different values for each lighting category reflecting the level and type of activity on the road. Thus $E_{\min}$ sets the general level of lighting required. The uniformity of illuminance is controlled to ensure that there are no excessively bright points within the designated design area. The light technical parameter is U_v and is a ratio, i.e. $U_v = E_{\max} \div E_{\min}$. As the uniformity is a ratio, only one value is given for all the lighting categories.

The illumination of the verges is ensured by specifying that the illuminance on the designated verge area be not less than a specified fraction of the value for $E_{\min}$ that applies for the contiguous carriageway area. The light technical parameter is U_v and, being a ratio, only one value is specified for each lighting category.

Glare from the luminaires has the potential to inhibit vision. Glare is conventionally categorized into that which gives rise to an impairment in seeing (disability glare) and that which gives rise to visual discomfort (discomfort glare). In road lighting, attention is specifically given to the former on the basis that, if disability glare is suitably controlled, the discomfort glare will be controlled as well. The relevant light technical parameter is TI ; one maximum value is given for all lighting categories.

It should be noted that glare control and the production of carriageway surface luminance are not independent of one another. The specified value of TI is a compromise between adequate glare control and economic spacing of the luminaires. Excellent glare control will necessitate the use of luminaires with a much lower value of TI ($\approx 10\%$). However, the resulting reduced angle of the beam of light from the luminaire downward vertical will require a concomitant closer spacing of the luminaires. The use of such luminaires will normally be restricted to situations where good glare control is necessary, e.g. on bridges where luminaires may be seen against dark backgrounds, around airports, and in other locations where a high degree of glare control is required. (See also Clause 5.3.)

The glare from vehicle headlights is controlled by specified limits in the relevant (motor vehicle) Australian Design Rules.

The environmental effects of installing road lighting also need to be considered. These are described in Clause 7.10. The upward waste light ratio ($UWLR$) is the only light technical parameter specified in Section 2 of AS/NZS 1158.1.1 and controls the amount of light which road lighting luminaires may release above the horizontal.

3.3 FACTORS AFFECTING PAVEMENT LUMINANCE A road lighting luminaire mounted above the pavement produces a characteristic 'T' shaped bright patch on the road surface. It comprises a wide head stretching across the road, commencing a very short distance behind the luminaire, with a tail extending in the direction of the observer towards the image point (see Figure 3.1).

The actual shape will depend partly on the light distribution from the luminaire and partly on the type of road surface. A well-lit road is judged to be one which looks evenly bright, and to achieve this, the 'T' patches of brightness from each luminaire should interlock rather like the pattern of a jigsaw (see Figure 3.2).

The luminance of a point on the pavement is principally influenced by the amount of light incident at the point in question, the angles of incidence and of observation, and the reflecting characteristics of the pavement surface. The parameters involved are illustrated in Figure 3.3.

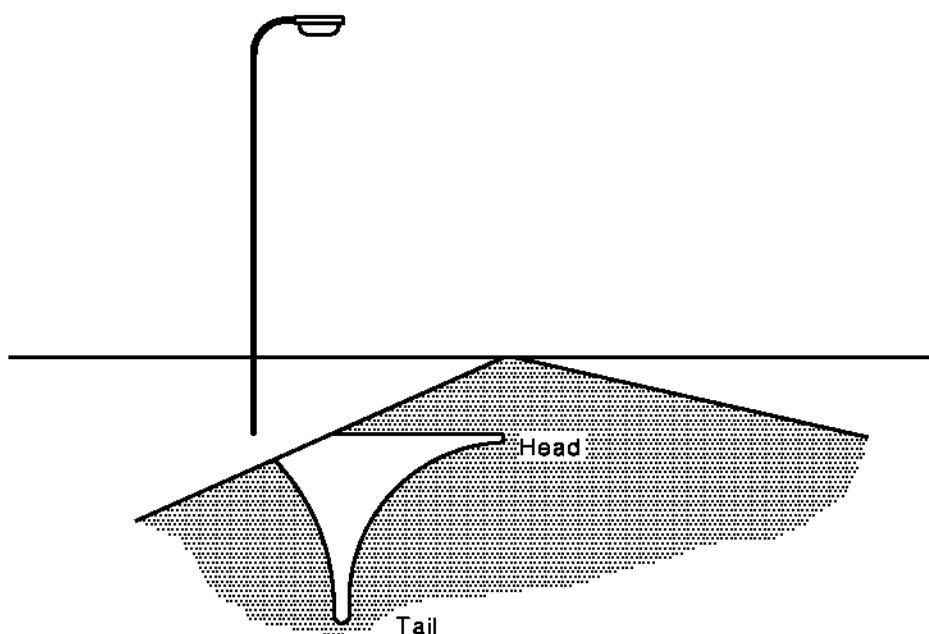
The illuminance (E), or the amount of light incident on the horizontal surface, in lux, at a given point (P) may be calculated from the following equation:

$$E = \frac{I \cos^3 \gamma}{H^2} \quad \dots 3.3(1)$$

Part of this light is reflected in the direction of the observer's eye and it is this component which creates the sense of brightness or luminance of the surface. The luminance (L), in candelas per square metre, in the direction of observation, is given by the following equation:

$$L = \frac{I q \cos^3 \gamma}{H^2} \quad \dots 3.3(2)$$

Where q is the luminance coefficient for the surface at the point, which varies with the angles alpha (α), beta (β) and gamma (γ) as defined in Figure 3.3 and with the surface characteristics as discussed in Clause 3.4 (see Ref. 17 in Appendix A).



NOTE: The tail of the light patch always extends towards the observer.

FIGURE 3.1 CHARACTERISTIC 'T' SHAPED LIGHT DISTRIBUTION FROM A SINGLE LUMINAIRE

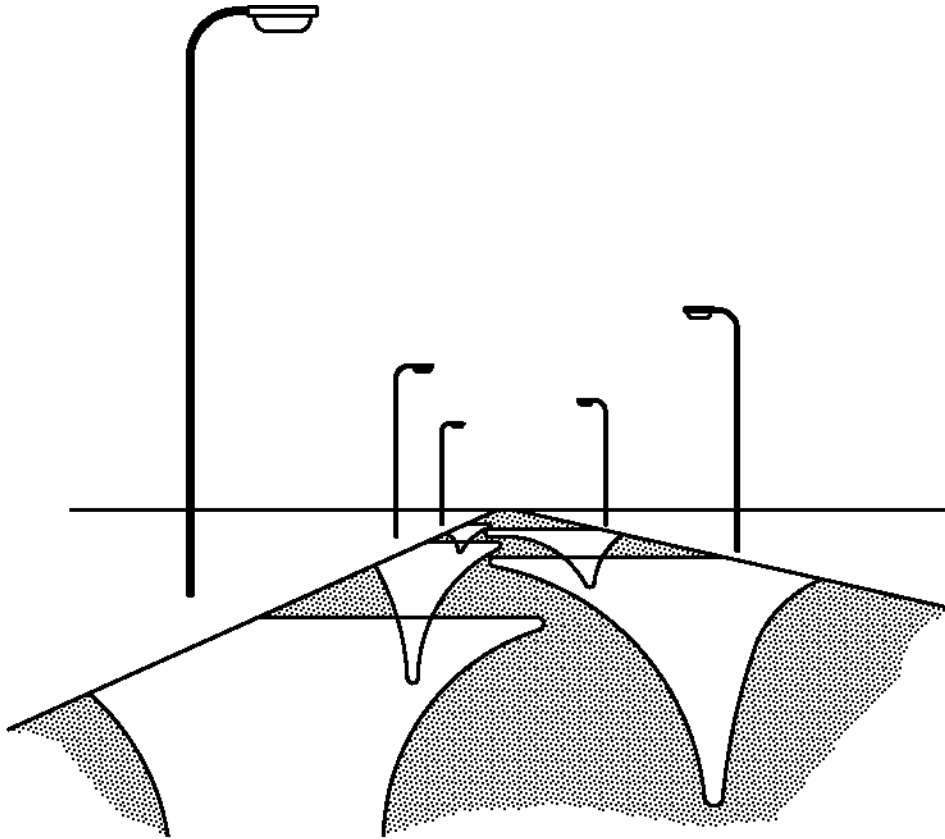
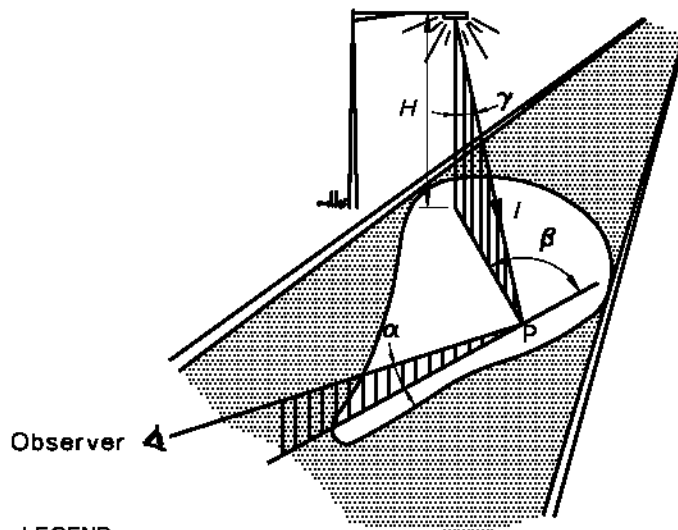


FIGURE 3.2 TYPICAL LIGHTING INSTALLATION WITH INTERLOCKING OF 'T' SHAPED LIGHT DISTRIBUTIONS



LEGEND:

- I = luminous intensity of the light source directed toward P, in cd/m^2
- α = angle of observation [usually taken as 1°]
- γ = vertical angle of intensity
- β = angle between the planes of the direction of illumination and the direction of observation at the point P
- H = mounting height of the light source, in metres

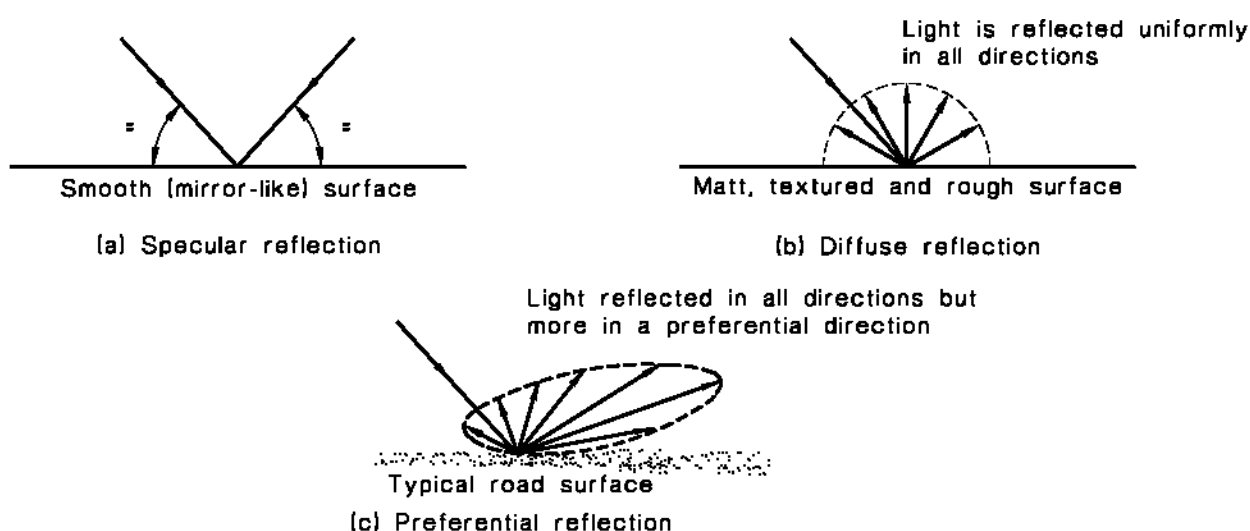
FIGURE 3.3 PARAMETERS AFFECTING PAVEMENT LUMINANCE

3.4 PAVEMENT REFLECTANCE

3.4.1 General When light is beamed onto a surface, it is reflected as a specular reflection if the surface is mirror-like or, as diffuse reflection if the surface is completely matt, textured and rough. In practice, road surfaces exhibit both of these modes of reflection resulting in preferential reflection towards the eye of the vehicle driver. This is illustrated in simplified terms in Figure 3.4.

The reflecting properties of the road surface play an important part in the performance achieved by a road lighting installation. The reflecting characteristics of a road pavement surface, which influences the luminance coefficient (q), depends on the following:

- The macro and micro texture (i.e. whether it is rough or smooth, harsh or polished).
- The colour and lightness of the road material.
- The degree of dampness of the surface.



NOTE: A road pavement exhibits a combination of specular and diffuse reflection, resulting in preferential reflection towards the eye of the vehicle driver

FIGURE 3.4 PAVEMENT REFLECTION

3.4.2 Surface texture Surface texture is very important to road lighting performance, and also influences skid resistance and other traffic characteristics, such as noise. In respect to lighting, coarse-textured surfaces produce more diffuse reflection of light, which results in more rounded (i.e. shorter) light patches from individual luminaires. This requires a closer spacing of luminaires to achieve a given average luminance and uniformity (see Figure 3.5). Polishing of the surface has the effect of reducing surface micro texture. This slightly increases the specular reflecting properties, thus increasing the light reflected in the preferential direction, resulting in longer light patches and possible improved uniformity of lighting on dry pavements.

3.4.3 Colour and lightness While the actual colour of the surface plays only a minimal role, the lightness (especially where artificial brighteners are used) can significantly increase the luminance coefficient and thus the average luminance.

The variation of colour, lightness and surface texture are represented in several standard road surfaces defined in CIE Publication No. 30.2. The classification adopted in that publication is summarized in Table 3.1.

See Clause 7.5 for details of the standard road surfaces that are assumed in AS/NZS 1158.1.1 for calculations of the light technical parameters.

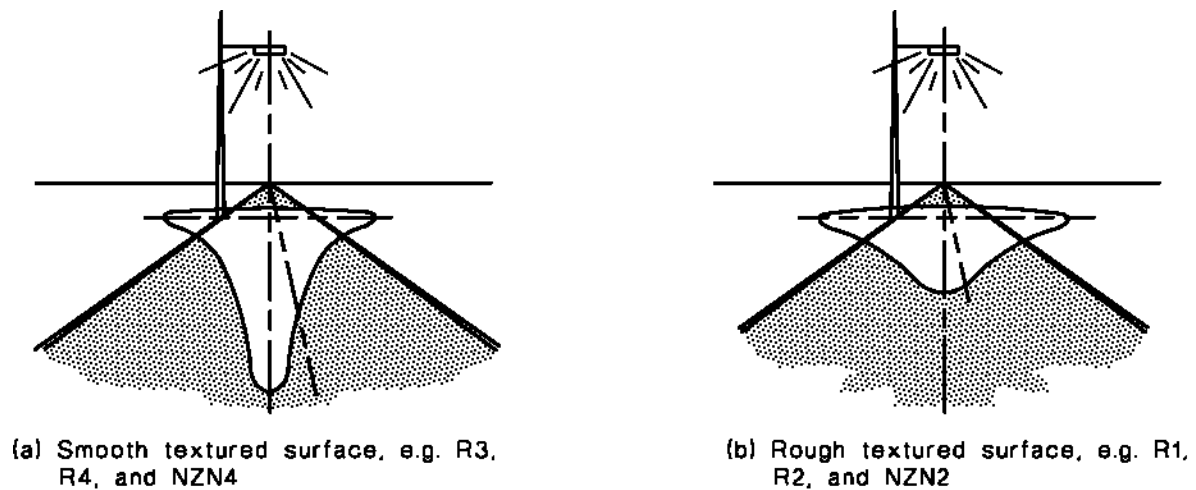


FIGURE 3.5 EFFECT OF SURFACE TEXTURE

TABLE 3.1 CLASSIFICATION OF ROAD SURFACES FOR LUMINANCE CALCULATIONS

Class	Description
R1*	(a) Asphaltic road surfaces with at least 15% of artificial brightener or with at least 30% of very bright anorthosites (arclyte, labradorite or similar)
	(b) Surface dressings with chippings where over 80% of the road surface is covered and where chippings exist for a great many artificial brighteners or for 100% of very bright anorthosites
	(c) Concrete road surfaces
R2* and NZR2†	(a) Surface dressings with harsh texture and with normal aggregates
	(b) Asphaltic surface with 10% to 15% of artificial brighteners in the mixture
	(c) Coarse and harsh asphaltic concrete rich in gravel (>60%) and with gravel sizes up to or greater than 10 mm
	(d) Mastic asphalt (Gussasphalt) after dressing in new condition
R3*	(a) Asphaltic concrete (cold, mastic asphalt) with gravel sizes up to 10 mm but with harsh texture (sandpaper)
	(b) Surface dressings with coarse texture but polished
R4* and NZN4†	(a) Mastic asphalt (Gussasphalt) after some months of use
	(b) Road surfaces with rather smooth or polished texture

* Characteristics defined in CIE Publication No. 30.2.

† Characteristics defined in NZS 6701. Same as corresponding CIE surfaces but with a multiplication factor applied to the luminance coefficient (q).

3.4.4 Wet pavements The degree of wetness or dryness of the pavement surface has a marked effect on the performance of road lighting. As a normal pavement changes progressively from a dry state to become damp, then wet and ultimately inundated, the reflecting characteristics change from diffuse reflection, becoming increasingly specular to the point where the surface of the water film reflects like a mirror. During this change, the size and shape of the light patches formed by the luminaires initially become larger (when the surface is just slightly damp) thereby improving both the level of luminance and uniformity. As further wetness develops, the light patches become narrower, elongated and brighter (as specular reflection increases), until ultimately the light from each luminaire is reflected as intense bands of light with the width and luminance approximately that of the actual luminaire (see Figure 3.6).

Increasing the coarseness or texture depth of a road pavement surface enhances the ability of the surface to maintain uniformity of lighting under damp to wet conditions. It may be noted that coarse textured pavements also improve skid resistance in wet conditions and reduce the amount of spray thrown up by tyres from a wet road. A classification of wet surfaces, including standard tabulations of reflection data for each surface, is given in CIE Publication No. 47.

The performance of a lighting installation under wet conditions depends largely on the characteristics of the road pavement over which the lighting designer has no control. No light technical parameters are therefore specified for wet road conditions but advice is given on measures that can be taken to enhance visibility (see Clause 7.4.2).

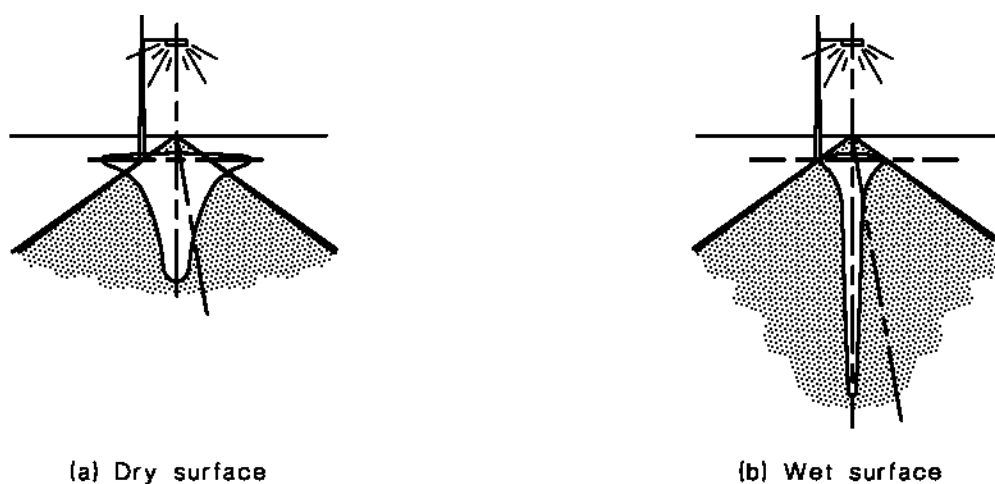


FIGURE 3.6 EFFECT OF PAVEMENT WETNESS

SECTION 4 POLICY CONSIDERATIONS

4.1 INTRODUCTION The advice given in this Section is intended as a guide to the development of policies relating to the provision of road lighting. This includes the formulation of warrants or criteria justifying road lighting.

The information given should be read in conjunction with the specific categories of lighting set out in Table 1.1.

4.2 STATUTORY REQUIREMENTS In the formulation of policies with respect to the provision of road lighting, consideration should be given to any statutory requirements with which the road lighting installation is required to comply. The following are examples of such requirements:

- (a) *Civil aviation authorities*—glare and spill light control in the vicinity of airports.
- (b) *Transport authorities*—limitation of glare and lamp colour appearance adjacent to railway/tramway lines and signal systems.
- (c) *Road traffic authorities*—limitation of glare and lamp colour appearance adjacent to roadways and traffic signals.

4.3 DEVELOPMENT OF WARRANTS

4.3.1 General Road lighting provides a number of benefits to the community, but the cost of installation and maintenance of the lighting is significant, particularly in the current climate of increased demands for energy conservation. It is therefore reasonable to require road lighting installations to provide positive economic benefits to the community. However, a number of the benefits of road lighting are not easily qualified in dollar value terms. As a result, a somewhat pragmatic approach is often taken with respect to warrants for the provision of road lighting.

The need for road lighting may be determined by considering the warrants set out in Clause 4.3.2. It should be recognized, however, that while warrants may or may not be met in a particular case, all other relevant factors should be taken into consideration and judgement exercised at all times. Furthermore, there may be merit in checking design traffic volumes for the installations, as roads with high traffic growth may need to be upgraded to a higher lighting category.

4.3.2 Factors to be considered in developing warrants Warrants for the provision of Category V lighting complying with requirements of AS/NZS 1158.1.1 may be determined by taking into account factors such as the following:

- (a) The nature of the road in terms of its hierarchical importance and its geometric standards.
- (b) The nature and extent of abutting development and access control.
- (c) The volume of traffic during the hours of darkness.
- (d) The operating speed of traffic or the prevailing speed limit.
- (e) The volume of pedestrian and bicycle traffic and its interaction with motor traffic.
- (f) The frequency and nature of intersections.
- (g) The historical or expected night accident rate.
- (h) The level of lighting proposed and its costs.

- (i) The location and nature of overhead power distribution, which may influence the choice of lighting arrangement (e.g. use of existing power poles to support luminaires); the nature of the power lines may impose limitations on the mounting height and on the positioning of lighting poles, particularly frangible type poles.
- (j) The location and form of any local area traffic management devices (e.g. speed humps and slow points); these will require special attention to ensure satisfactory visibility.
- (k) The security of pedestrians and property.

4.3.3 Economic considerations If required, an economic basis for a warrant may be derived by ensuring that the cost of the installation, operation and maintenance of the road lighting is less than the expected savings in accidents, which may be attributed to the provision of the road lighting. Various economic models exist that may be used to carry out a cost/benefit analysis.

4.4 GENERALIZED WARRANTS FOR TRAFFIC ROUTE LIGHTING Generalized warrants should be developed as a basis for determining whether a particular traffic route should be lit. Such warrants should provide justification for the provision of lighting on all elements of the road under consideration, including intersections.

Criteria for the provision of road lighting on non-freeway routes generally include a minimum traffic volume requirement. Average annual daily traffic (AADT) criterion volumes vary considerably between road authorities, but typical values would be within the range of 5000 to 15 000 AADT.

Other criteria such as—

- (a) a high night accident rate;
 - (b) a night/day accident ratio of greater than 1.3:1; and
 - (c) two or more lanes of moving traffic in one direction,
- coupled with some form of economic analysis (see Clause 4.3.3) are adopted by most authorities.

4.5 WARRANTS FOR LIGHTING ISOLATED INTERSECTIONS

4.5.1 General provision At intersections and junctions, the driving task is much more demanding than at other points along the route. The complexity of the driving task at intersections is graphically illustrated by the tendency for accidents to concentrate there. In rural or other areas where continuous traffic route lighting cannot be justified, consideration should be given to lighting the isolated intersections.

In lighting isolated intersections, particularly in dark rural areas, care needs to be taken to control glare and to avoid providing excessive light, which could cause dark adaptation problems on the road immediately beyond the intersection.

There are two basic types of isolated intersections, as follows:

- (a) *Flag-lit intersections* Flag lighting is appropriate at minor intersections that are geographically remote and do not have channelization. The lighting objective should be to provide a clear indication from a reasonable distance of the location of the junction or intersection. This can be achieved by placing one or two luminaires, other than of the aeroscreen type, in a strategic position near the junction. Illuminance calculations for this situation would not be necessary.
- (b) *Isolated major intersections* Intersections with channelization, traffic signals or major traffic flows should be considered for lighting irrespective of whether the connecting roads are currently lit. The lighting objective is to indicate both the presence of the intersection and to illuminate the conflict areas and the approaches.

Most authorities adopt a warrant criteria for lighting isolated intersections. These may include one or more of the following:

- (i) Traffic volume (e.g. AADT over 1000 vpd).
- (ii) High night to day accident ratio (e.g. over 1.3:1).
- (iii) Economic benefit/cost criteria.

4.5.2 Special conditions Special local conditions should also be considered. These may include one or more of the following:

- (a) Visibility restrictions where traffic facilities are not visible at night for a specified distance (e.g. 120 m in a 50 km/h or 60 km/h zone or 200 m in a 100 km/h zone).
- (b) Complex road location or geometry.
- (c) Presence of traffic control devices such as traffic signals or channelization.
- (d) Presence of background lighting (including offsets of opposing headlights).
- (e) Fog prone areas. Flag lighting can be particularly effective in reducing overshoot problems experienced in fog-prone areas.
- (f) Tourist areas or routes where drivers are not familiar with the road.
- (g) Special safety needs of pedestrians.
- (h) Railway or cane train crossings. Flag lighting should be considered.
- (i) Unusual traffic patterns such as heavy right turn movements or a predominant movement of heavy vehicles.

4.6 WARRANTS FOR FREEWAY LIGHTING

4.6.1 Application This Clause refers to freeways, for convenience, but applies to all divided highways for through traffic that have no access for traffic between interchanges and that have grade separation at all intersections. It specifically includes expressways and motorways.

4.6.2 General justification for lighting While many of the factors that contribute to night accident problems on normal urban roads and streets are absent on freeways (e.g. pedestrians, driveways, parking, intersections), it is generally accepted that benefits may be obtained from lighting freeways in particular situations and where high traffic volumes occur.

The provision of lighting on freeways and expressway-type facilities can reduce night accidents by improving traffic operation in congested conditions, where vehicle positioning relative to traffic lanes and adjacent vehicles is important. It can also be of significant benefit during emergencies, particularly where there may be pedestrians or emergency services activity on the carriageway.

The provision of isolated lighting at interchanges may be justified at lower volumes than continuous freeway lighting. This may be a staged development of future continuous freeway lighting aimed at improving the level of safety and traffic service in the following situations (listed in order of precedence):

- (a) Ramp intersections, including the service road between these intersections where closely spaced ramps are involved.
- (b) At exit ramp gore areas.
- (c) At entry ramp gore areas.
- (d) Along ramps, particularly where substandard alignment is involved.
- (e) At converge, diverge and weaving areas on the freeway.

4.6.3 Freeways in urban areas The following guidelines are suggested in respect to the provision of lighting on urban freeways:

- (a) Continuous full freeway lighting is warranted where one or more of the following conditions exist:
 - (i) The current AADT is 40 000 vpd or greater.
 - (ii) On all unlit sections less than 2 km long between sections of complete lighting.
 - (iii) If road design standards are significantly less than normal (particularly alignment, sight distance, cross-section and clearance).
 - (iv) If a significant night-time accident record is likely to be corrected by lighting.
 - (v) If adjacent roads are provided with Category V lighting, which might adversely affect the visibility of drivers using the freeway.
- (b) Full lighting of interchanges (i.e. lighting of ramps, intersections, crossroads and main carriageways through the interchange only) is warranted where one or more of the following conditions exist:
 - (i) If the total AADT (existing or estimated) on the ramps is greater than 10 000 vpd.
 - (ii) If connecting roads are provided with Category V lighting, which might adversely affect the visibility of drivers using the interchange.
 - (iii) If warrants for continuous lighting are satisfied.
- (c) Partial lighting of interchanges (i.e. lighting of the entry and exit gore areas plus ramps, intersections and crossroads where justified) is warranted where one or more of the following conditions exist:
 - (i) If the current AADT on the freeway is greater than 25 000 vpd.
 - (ii) If the total AADT on the ramps (i.e. the sum of the volumes entering and leaving the freeway at the interchange) is greater than 5000 vpd.
 - (iii) If the road design standards are significantly below those of the approaches.
 - (iv) If a significant night-time accident record exists, which is likely to be corrected by lighting.
 - (v) If connecting roads are provided with Category V lighting, which might adversely affect the visibility of drivers using the interchange.
- (d) The lighting of the ramp crossroad intersections and the crossroad between them is warranted when one or more of the following conditions exist:
 - (i) If continuous freeway or complicated interchange lighting is provided.
 - (ii) If the crossroad approaches are lit.
 - (iii) If the crossroad is divided between the ramp intersections, or if there are raised islands at the ramp intersections.
 - (iv) If the volume on the crossroad through the intersection is 3600 vpd or greater.
- (e) The lighting of crossroads, without connections to freeways, is warranted if the crossroad approaches are lit, or if there is a possibility of glare or distraction from the freeway lighting.

4.6.4 Freeways in rural areas In general, rural freeways need not be lit either continuously or at interchanges. The following exceptions may apply:

- (a) Where there are unusual conditions such as a location with a high night-time accident record likely to be corrected by lighting.

- (b) A high volume interchange exists with reduced road geometric standards.
- (c) At a location where the background of illumination in the vicinity of the freeway is likely to adversely affect the visibility of motorists if lighting is not provided.

4.7 WARRANTS FOR SUPPLEMENTARY LIGHTING AT PEDESTRIAN CROSSINGS

4.7.1 General provision Supplementary lighting at pedestrian crossings is generally appropriate in areas where the traffic volume (AADT) exceeds 1000 vpd.

Lighting to at least Category V4 or V5 should exist or should be provided on the carriageway for a minimum of three spans either side of the crossing (see AS 1158.4).

4.7.2 Special cases For traffic volumes less than those referred to in Clause 4.7.1, other conditions that may suggest supplementary lighting at pedestrian crossings include the following:

- (a) Road location geometry.
- (b) Background lighting (including offsets of opposing headlights).
- (c) Weather conditions (such as fog) or separate needs of pedestrians that indicate the existence of a special risk.

Three spans of at least Category V4 or V5 lighting should exist or should be provided as set out in Clause 4.7.1.

4.8 FUNDING ARRANGEMENTS Funding arrangements may exist between road authorities, electricity authorities, local authorities and developers, to share the cost of the design, installation, operation and maintenance of road lighting schemes complying with the requirements of AS/NZS 1158.1.1. These cost-sharing arrangements may include consideration of the following:

- (a) New or existing lighting installation.
- (b) Addition of new luminaires to an existing installation.
- (c) Intersection or route lighting.
- (d) Proposed or existing lighting meeting the requirements of relevant lighting warrants.
- (e) Proposed or existing lighting meeting requirements for the applicable lighting category in AS/NZS 1158.1.1 or other nominated standard of lighting.
- (f) Ownership/responsibility for equipment.

In general, if works such as road widening, additional accesses, new intersections or service relocations become necessary for whatever reason and such works involve lighting alterations, the body generating the change should normally fund the full capital cost of the changes and the altered design should be agreed to by all parties concerned.

4.9 LIGHTING TARIFFS Road lighting tariffs may be used by an electricity authority as a means of recouping the costs for the provision of power or road lighting infrastructure. The calculation of these tariffs will depend on various factors, such as the following:

- (a) The capital cost of the supply and installation of the luminaire, including wiring.
- (b) Interest and depreciation charges based on the period over which the delivered energy costs are to be amortized.
- (c) Maintenance costs associated with both the luminaire and lamp.
- (d) Energy delivery costs based on annual hours of operation.
- (e) Management costs covering aspects of design and billing.

4.10 THE USE AND PLACEMENT OF RIGID AND FRANGIBLE ROAD LIGHTING POLES Advice on the selection and placement of road lighting poles in the road reserve is given in Appendix B. Reference should be made to the policies of the relevant road or traffic authority when determining the appropriate types and locations of road lighting poles.

4.11 STANDARDS Before engaging in the design of a road lighting installation refer to all relevant standard plans, equipment specifications, codes of practice and policies of the client.

SECTION 5 EQUIPMENT

5.1 GENERAL Road lighting equipment involves three main items, as follows:

- (a) *Lamps*—the replaceable unit which is the source of the light.
- (b) *Luminaires*—the apparatus housing the lamp and controlling the light distribution.
- (c) *Bracket arms and poles*—the structural members that mount the luminaire(s) via a bracket arm to the vertical support structure.

Other equipment includes luminaire control gear, terminal panels, pole cages, pits, ducting, electrical cables and junction boxes. While these are important elements of lighting equipment, they will not be discussed in this Standard. Detailed information can be obtained from the relevant authority/agency.

5.2 LAMPS The following high intensity discharge (HID) lamps are in common use for the provision of Category V lighting:

- (a) High pressure sodium vapour lamps with clear or diffusing outer envelopes.
- (b) High pressure mercury vapour lamps with diffusing outer envelopes.

Other HID lamps that are used to a lesser extent are as follows:

- (i) Metal halide lamps with clear or diffusing outer envelopes.
- (ii) Low pressure sodium vapour lamps.

A comparison of the main characteristics of the above lamps is given in Table 5.1.

5.3 ROAD LIGHTING LUMINAIRES Luminaires may have either integral or remote control equipment. Requirements for road lighting luminaires apply as follows:

- (a) *In Australia* AS 3771 specifies requirements for the design, construction, performance and testing of luminaires with integral control gear. Essential safety requirements are covered by reference to AS 3100.
- (b) *In New Zealand* NZS 6705.2.3 specifies safety requirements for all types of road lighting luminaires.

Luminaires are available with either dished bowl or flat (aeroscreen) visors.

The dished bowl visor types are designed to allow a higher light output at angles nearer to horizontal than the flat (aeroscreen) visor types. The former provide substantially increased spacing compared with the flat (aeroscreen) visor types and consequently are the most commonly utilized luminaires. However, these luminaires exhibit higher glare than the flat (aeroscreen) visor types.

The flat (aeroscreen) visor types, whilst normally providing a higher quality installation, may only be justified where a greater degree of glare control is deemed necessary. The following are typical examples of these installations:

- (i) To satisfy the requirements of the civil aviation authority, in areas surrounding airports.
- (ii) To reduce spill light onto properties abutting roads that require Category V lighting, e.g. residential properties adjacent to freeways.
- (iii) To reduce glare at locations where the background is intrinsically dark, e.g. bridges, flyovers, overpasses, isolated intersections.

TABLE 5.1
COMPARISON OF DISCHARGE LAMPS USED
FOR CATEGORY V LIGHTING

1	2	3	4	5	6	7
Lamp type	Approx. average luminous efficacy (see Notes) (lm/W)	Typical average useful life (see Notes) (h)	Commonly used ratings W	Source appearance	Colour rendering	Comments
High pressure sodium vapour	100	14 000	100 150 250 400	Golden yellow	Fair/good	Most cost-effective light source due to high efficiency, long life and high lumen maintenance. Most widely used lamp for Category V lighting
High pressure mercury vapour (coated)	55	12 000	250 400 700	White	Good	Superseded by high pressure sodium. Now used mostly in extensions of existing installations
Low pressure sodium vapour	140	10 000	90 135 180	Monochromatic yellow	Poor	Not widely used in new installations mainly due to overall cost. Some road safety problems in vicinity of traffic signals. Use favoured near astronomical observatories
Metal halide	80	8 000	250 400	White	Excellent	Not favoured on overall economic grounds. Some variations in colour appearance may be observed between individual lamps. Used mainly in specialty installations

NOTES:

- 1 The data given in Columns 2 and 3 are only indicative. See Appendix H for typical lamp mortality and lumen depreciation data, which should be considered in conjunction with the data of Columns 2 and 3. Significant variations in this data may apply for different lamp ratings and for lamps of the same rating produced by different manufacturers.
- 2 For design purposes, data applicable to the selected lamp type and rating should be obtained from the lamp supplier.

5.4 BRACKET ARMS AND POLES

5.4.1 Dimensions Preferred dimensions of lighting poles and bracket arms used for the mounting of road lighting luminaires are given in AS 1798.

5.4.2 Pole types Consideration should be given to the type of pole used and its installation requirements (see Clause 7.2) as follows:

- (a) *Material* The pole may be manufactured from a variety of materials including metal (generally galvanized steel), fibreglass, concrete or timber.
- (b) *Installation* The method of installation can be—
 - (i) direct-buried; or
 - (ii) baseplate-mounted.
- (c) *Power supply* The power supply to rigid poles can be aerial or underground. The power supply to frangible poles is required to be underground, via a special plug and socket connector located in the pole base.
- (d) *Maintenance* Account should be taken of necessary provision for access to lighting equipment for maintenance.

Sound traffic engineering and safety principles should be employed in the selection of the correct type of pole for the task at hand.

NOTE: See Appendix B for guidelines on the use and placement of rigid and frangible road lighting poles.

5.4.3 Combination traffic signal mast arm and joint-use road lighting poles Combination mast arm and joint-use poles in accordance with AS 2979 should be used when lighting intersections and junctions at which traffic signals are proposed or installed. This will enable the road lighting luminaires to be accommodated on the proposed/existing road traffic signals hardware resulting in a safer and more economical installation. In addition it may be easier to meet the lighting design requirements at larger intersections and junctions.

Conversely, when designing new traffic signal installations, it is important that current and future requirements for road lighting be considered so that, where possible, road traffic signals and lighting can share the same pole.

SECTION 6 DESIGN PROCESS

6.1 GENERAL Road lighting design requires more than just putting luminaires on poles; it involves a design process addressing sound traffic engineering principles and safety, as detailed in Clauses 6.2 and 6.3.

The design process commences with the provision of a detailed design brief from the client containing all the relevant design information. By necessity there will often be consultation between the client and the road lighting designer concerning design parameters and site conditions; for example, in the determination of the carriageway lighting design width. However, the final decisions are the responsibility of the client.

6.2 SIMPLIFIED ROAD LIGHTING PROCESS The simplified process for providing and operating a road lighting installation is as follows:

- (a) Background information—see Sections 2 and 3.
- (b) Authority—see Section 4.
- (c) Preliminary design information—see Sections 5 and 7.
- (d) Road lighting design—see Sections 8, 9 and 10.
- (e) Documentation—see Section 11.
- (f) Installation—see Section 12.
- (g) Operation—see Section 13.
- (h) Maintenance—see Section 14.

6.3 FULL ROAD LIGHTING DESIGN PROCESS

6.3.1 Steps involved in process A full road lighting design will involve all or most of the steps illustrated in Appendix D.

6.3.2 Design brief checklist The design brief should contain all the relevant information required for a specific project and may contain some or all of the following:

- (a) Brief description of work(s).
- (b) Lighting categories, including those of intersecting roads.
- (c) Overall site plan(s) showing a line view of the project, including features such as intersections, junctions, roundabouts, on/off ramps, bridges, overpasses at grade separation and road names.
- (d) Accurate base plan(s) to a nominated scale, preferably showing only the following:
 - (i) Road features, e.g. lanes, shoulders, medians.
 - (ii) Details of any traffic signals.
 - (iii) All radii of curvature of route lighting segments and on/off ramps.
 - (iv) Control lines with identifying names.
 - (v) Chainages.
 - (vi) Roadside features, e.g. cut, fill, trees, drainage.
 - (vii) Electricity authority details, e.g. poles, overhead power supplies and existing lighting.
 - (viii) Relevant underground ducting or services.
 - (ix) Clear start/cut-off points where plans overlap.

- (e) Extent of the road lighting required, including nominated chainages.
- (f) Cross-section plan(s).
- (g) Electricity authority lighting tariff(s).
- (h) Any special equipment requirements, e.g. aeroscreen luminaires.
- (i) Relevant road authority policies on equipment and pole placement.
- (j) Any regulatory limitations, e.g. civil aviation, marine and railway.
- (k) Identification of observatories.
- (l) Clear indication of areas where lighting structures are not permissible.
- (m) Identification of areas of civic, historical, or special significance.
- (n) AADT of major and minor roads.
- (o) Project engineer's name and contact number.
- (p) Name of local authority.
- (q) Name of electricity supply authority.
- (r) Project identification number.
- (s) Required by date.
- (t) Estimate costing type, e.g. detailed or lump sum.

NOTE: See Appendix E for a sample abbreviated lighting design brief.

6.3.3 Site inspection check list A site inspection should be performed to identify all the relevant site details applicable to the road lighting design, as follows:

- (a) Base plans reflect all relevant site feature, e.g. drainage, cut, fill and trees.
- (b) Road layout.
- (c) Road cross-sections.
- (d) Location of driveways/accesses, and property lines.
- (e) Civil works, e.g. location and condition of pits and ducting.
- (f) Record location and type of existing road lighting poles and distribution poles and their pole numbers.
- (g) Location of proposed new road lighting pole(s).
- (h) Location of proposed new outreach arm(s).
- (i) Location of proposed new ducting and overhead catenary lines.
- (j) Clearance to obstacles, e.g. power lines and trees.

Before undertaking a site inspection, all the relevant service authorities should be contacted to confirm that service details, as supplied with the design brief, are accurate and current. It is important that the road lighting allocation in the road reserve is identified and whether or not there is an alternative allocation that can be used, if necessary, so that poles can be positioned as far from the edge of the traffic lane(s) as possible, e.g. on the property line.

SECTION 7 DESIGN CONSIDERATIONS

7.1 GENERAL To be effective, Category V road lighting should provide a level of visibility that enables the motorist to see quickly, distinctly and with a degree of certainty all significant detail, notably the alignment of the road (its direction and its surrounds). Uniformity in relation to light levels and pole placement is essential so as not to cause indecision and confusion.

When designing Category V lighting, the lighting designer should call upon traffic engineering input to optimize lighting designs taking into account road lighting parameters, lighting poles, luminaires, road safety, site geometry, economics, maintenance and aesthetics.

7.2 ROAD SAFETY CONSIDERATIONS

7.2.1 General Road lighting is provided, in addition to other traffic control devices, so as to improve road safety during night-time hours. The designer should ensure that the provision of road lighting does not detract from the existing level of road safety. Consideration should be given to the relevant road authority policies on lighting levels and the location and use of road lighting poles.

Where economically viable, consideration should be given to the use of existing structures, or new structures with combined functions, to support lighting equipment so as to reduce the number of roadside hazards. Typical examples are as follows:

- (a) Joint-use pole for the support of luminaires and traffic signals.
- (b) Combination traffic signal mast arm with lighting outreach arm assembly.
- (c) Joint-use pole for road lighting and electricity distribution, telecommunications or tramway services.
- (d) Other structures such as building walls or verandahs.

7.2.2 Pole positions Road safety will be enhanced by locating lighting poles in positions that are unlikely to cause a hazard to errant vehicles. If it is not possible to satisfy this objective, then consideration should be given to the use of frangible pole types. In determining the location and type of pole, consideration should be given to the following:

- (a) Speed zones.
- (b) Traffic volumes.
- (c) Traversable and non-traversable verges.
- (d) Narrow, unprotected traffic islands and medians.
- (e) Obstructions on the side of the road, e.g. services, trees and road furniture.
- (f) Presence of guard fence.
- (g) Locations where the fall of the pole may foul overhead electrical conductors.
- (h) Low-lying areas where drainage is a problem.
- (i) Accessibility to luminaires for maintenance purposes, e.g. provision for service vehicle access, clearances from overhead conductors.
- (j) Parking or other low speed activity that may result in accidental damage to the poles.
- (k) Level of pedestrian activity.

7.2.3 Pole setback Research by Fox et al. (see Ref. 6 in Appendix A) has established that one of the major factors affecting the likelihood and severity of any injuries sustained by occupants of errant vehicles is the relationship between the road lighting pole and the edge of the carriageway (pole setback).

Selection of an appropriate pole setback commensurate with the traffic hazard will result in the safest possible lighting installation. In urban areas, the lighting poles should be positioned against the property line and, for all other locations, lighting poles should be as far as practicable from the edge of the carriageway. Increased pole setback can be accommodated by a corresponding increase in outreach to maintain lighting design requirements.

7.2.4 Pole type Lighting poles should be of a type appropriate to the risk of collision by errant vehicles, taking into account any site limitations. Where there is an unacceptable risk of collision by errant vehicles, consideration should be given to the use of frangible lighting poles. See Appendix B or other relevant policies.

7.2.5 Curves Curves may be lit from poles positioned on the inside, the outside or in some combination of this, depending on (amongst other factors) the road width.

Locating poles on the outside of curves provides additional visual guidance through the curve, and fewer poles will be required to achieve the required lighting level. Locating poles on the inside of curves places the poles in a less vulnerable position and reduces the chances of them being struck by errant vehicles.

The decision of where to locate poles will be dependent on the pole type (see Appendix B) and the parameters of the lighting design.

7.2.6 Roundabouts The satisfactory operation of a roundabout relies heavily on the ability of drivers to enter into and separate from a circulating traffic stream in a safe and efficient manner.

When lighting roundabouts, the poles should be located on the central island of the roundabout where they will least likely be in conflict with errant vehicles or entering traffic streams. The use of high-mast lighting should be considered as an option for roundabouts (see Clause 8.6).

7.2.7 Delineation Where possible, luminaires and poles should provide a clear and continuous line, delineating the course of the road ahead. At complicated locations care should be taken to position the luminaires so that motorists are not presented with a misleading view.

NOTE: See Figure F14, Appendix F, for an example of a misleading array of luminaires.

7.2.8 Joint-use traffic signal mast arms and joint-use lighting poles The use of joint-use traffic signal mast arms and joint-use lighting poles at signalized intersections and junctions will minimize the number of potential hazards placed adjacent to the roadway and may also provide the driver with a clearer view of the road situation, highlighting the location of traffic signals and the course of the road ahead (see Clause 5.4.3). Where the luminaire outreach is mounted at an angle to the carriageway, care should be taken to avoid presenting misleading visual information to the motorist (see Clause 7.2.7).

7.3 TREE-LINED TRAFFIC ROUTES Where trees are planted at the roadside or in the road shoulders and partially overhang the carriageway, the light output from conventionally placed luminaires may be obstructed. Where the trees are large, of spreading habit and very substantially or completely overhang the carriageway, conventional placement of luminaires is generally impracticable. Guidance for the lighting designer is given in Clause 8.8.

7.4 WEATHER CONDITIONS

7.4.1 Effects on visibility

7.4.1.1 Wet conditions As a paved surface passes from the dry state through stages of being damp, wet and finally flooded, its reflecting characteristics change. When merely damp, the effectiveness of the lighting installation may be affected very little, if at all. Thereafter, reflection changes from diffuse to specular, and visibility deteriorates. Bright patches contract into bright streaks leaving areas of comparative darkness between. The distorted specular image has a brightness comparable with that of the light source and a width dependent on its size.

When wet, painted line markings, including those with retroreflecting beads, tend to lose their contrast with the road surface. Lane marking studs continue to be visible while retroreflecting signs and markers lose none of their effectiveness.

Road verges, particularly if dark in colour and rough in texture, appear darker, as do objects on them; and contrast is thus diminished.

Visibility is further impaired in wet conditions because of the presence of water droplets and road dirt in the atmosphere and on vehicle windscreens, which deflect, absorb and reflect light.

7.4.1.2 Foggy conditions The conditions described in Clause 7.4.1.1 will, in general, also apply when fog is present. Additionally, visibility is further affected as a consequence of light from a vehicle's headlights being reflected back from the densely packed water droplets in the direction of the driver's eyes. The scattering of light from the water droplets produces a luminous glow which inhibits visibility of distant objects.

7.4.2 Means of improving visibility The use of reflective material such as white paint or retroreflective markers is of great value at all times and may be essential for safety in wet or foggy weather (see Clause 7.8).

The revealing of the road ahead, especially on bends and curves, is greatly assisted in bad weather by logical placement of luminaires as seen in perspective; misleading placement may cause accidents (see Figure F14, Appendix F).

The most critical light technical parameter to be considered in designing for wet carriageway conditions is the overall luminance uniformity (U_O). This uniformity can be enhanced by one or more of the following:

- (a) Reducing the spacings of the luminaires.
- (b) Increasing the luminaire mounting height.
- (c) Selecting a luminaire with a greater toe-in.

In some instances, the adoption of a greater overhang can also result in an improvement of U_O .

In fog-prone areas, the use of high pressure sodium vapour luminaires is recommended due to their ability to more efficiently pierce the fog, with reduced atmospheric scattering compared to other current light sources.

Lighting above the minimum requirements of AS/NZS 1158.1.1 is especially advantageous in wet or foggy weather by reason of the improved visibility and route guidance afforded by the higher illumination of objects.

7.5 REFLECTING PROPERTIES OF ROAD SURFACES Because a primary objective of roadway lighting is to produce bright road surfaces, the reflecting characteristics of that surface are vital factors affecting both the luminaire design and planning of the luminaire layout. The light technical parameters specified in AS/NZS 1158.1.1 are based on the reflecting characteristics of the following standard road surfaces:

- (a) *In Australia* The light parameters are based on the reflecting characteristics of the CIE R3 road surface (see Table 3.1), which pertain to a dry asphaltic concrete surface in a moderately worn condition. It has been shown, based on an analysis of the limited data available on the reflecting properties of Australian road surfaces, that the choice of the CIE R3 road surface is appropriate.

The CIE R3 road surface will also be applicable for surface-treated pavements whose reflecting characteristics vary much more widely according to the state of wear, but whose average characteristics are, in general, not dissimilar to those of the dry asphaltic concrete surface.

Concrete surfaces have preferential reflecting characteristics little different from those of bituminous pavements, but can exhibit high luminance values because of their better diffuse reflectance. Variation in texture and colour may improve visual conditions, but should not influence the lighting design.

- (b) *In New Zealand* Two standard road surfaces apply for the purposes of calculating the light technical parameters, viz. NZR2 and NZN4. Compliance is to be achieved in calculations involving both of these surfaces. The NZR2 surface is typical of a fairly new chip seal (diffuse) surface, and NZN4 of a polished asphaltic (glossy) surface, as these represent the two extremes in reflection properties of New Zealand roads.

7.6 ROAD LAYOUT In designing a road lighting installation instances will occur where, for aesthetic or practical reasons, departures from the recommended geometry will be necessary. Also, locations may be encountered where difficult problems of visibility exist by day as well as by night, due primarily, or even in some cases entirely, to the road layout features.

In such cases special treatment will be required. As road lighting is an integral part of road design, the cooperation of road authorities and electricity supply authorities may be needed in arriving at a satisfactory solution. On occasions, potentially troublesome areas are not evident from roadway plans. The lighting designer should therefore undertake an inspection of the site at an early stage to establish the topography of the area and to locate existing features such as drains, trees, bridges, overhead conductors or other obstructions that may not be shown on the base drawings.

7.7 ROADWAY FEATURES Visibility of roadway features (e.g. kerbs, islands) depends largely on brightness contrasts produced by diffuse reflections from the relevant surfaces (i.e. upon their 'lightness' and 'darkness'). It follows that the effectiveness of a lighting system will be greatly enhanced if contrasting colours or textures can be introduced into the roadway features.

These considerations are particularly important at channelizations and where medians with mountable kerbs are used.

7.8 SURROUNDING BACKGROUNDS TO ROAD A specific requirement for the lighting of traffic routes is the provision of illumination on the immediate verges or footpaths to the carriageway (light technical parameter E_s). It follows therefore that a significant proportion of the luminous flux from the luminaires will be directed to that area and beyond. It is advantageous if this light falls on light coloured surfaces, particularly vertical surfaces facing the roadway. This arises because the surroundings to the carriageway, as well as the carriageway surface itself, will appear relatively bright to road users. This will add to the effectiveness of the road lighting in further raising the general light adaptation level of the road users, so improving visibility and reducing glare.

It is not realistic to expect the surrounds to roads, such as building facades, walls and fences, to be always light in colour. However, when the opportunity arises, as in planning new, or refurbishing, land development and roads, it may be feasible to incorporate this principle in the design requirements. One example would be to deliberately use light-coloured surfaces on any noise barriers adjacent to the roadway.

A corollary is that the lighting installation itself should be as effective as possible where the surrounds to the road are intrinsically dark. This will arise where there is extensive abutting foliage or building facades are dark coloured or are distant from the roadway. In these cases consideration should be given to the provision of a somewhat higher level of road luminance and more restrictive glare control than is warranted by the lighting category otherwise applicable to the particular road type and operating characteristics.

7.9 VISIBILITY OF ROAD SIGNS A road lighting installation should not be adjusted to light road signs but every effort should be made to avoid the installation obscuring or otherwise distracting from their visibility, including such influences as background glare.

Attention should also be given to the possibility of specular reflections from road lighting luminaires interfering with the legibility of signs. Usually there is some latitude for signs to be adjusted or moved within limits to fit in with the road lighting layout. Where this is not possible because of structural or other considerations, such as a critical location for a large sign, the position of the luminaire may need to be reviewed.

To ensure adequate visibility at night, the use of independently illuminated signs should be considered; however, glare to the motorist should be controlled within defined limits. Where the road lighting employs sources of predominantly monochromatic light (e.g. low pressure sodium vapour lamps), it is generally necessary to illuminate the signs independently to restore a reasonable colour appearance.

7.10 ENVIRONMENTAL CONSIDERATIONS The effects which the road lighting will have upon the environment should be considered at the design stage. These considerations should include the following:

- (a) The use of energy-efficient lamps and equipment, which will have minimum demands and impacts on the electricity supply system in particular and the electromagnetic environment in general.
- (b) The provision of adequate but not excessive illuminances and luminances for the specific lighting category involved.
- (c) The efficient use of other road safety devices such as perimeter line marking (audible and visual) and retroreflective materials, wherever possible, to minimize the need for higher lighting levels or additional lighting.
- (d) The use of luminaires and installation geometry, which will confine most of the emitted light to the carriageway and immediate surrounds. Such action will minimize sky glow and reduce any adverse effects upon residential areas adjoining the road.

With reference to Item (d), a requirement is specified in AS/NZS 1158.1.1 for control of the light emitted by road lighting luminaires in directions above the horizontal. The applicable light technical parameter is the upward waste light ratio (*UWLR*).

NOTE: Recommendations for control of the obtrusive effects of outdoor lighting, other than public lighting, are included in AS 4282(Int).

7.11 AESTHETICS At all times consideration should be given to the aesthetic appearance of the lighting equipment used. While aesthetic evaluations rely largely on subjective assessment and often on personal preference, it is desirable to consider this aspect, particularly in sensitive areas, e.g. in the vicinity of cultural and civic centres.

The ability of the lighting layout to be in scale and to harmonize with its surroundings requires careful appraisal by appropriately skilled people.

SECTION 8 DESIGN RECOMMENDATIONS

8.1 INSTALLATION GEOMETRY

8.1.1 Required data The geometric parameters of the installation should be determined in accordance with Clauses 8.1.2 to 8.1.4. These parameters are defined in AS/NZS 1158.0 and are illustrated in Figure 8.1 of this Standard.

8.1.2 Carriageway lighting design width (W_K) The installation should be designed to adequately light the whole of the used portion of the road, whether or not it is sealed across the full width. In some cases there may be difficulty in deciding just what width of road should be used for design purposes. It is then necessary to exercise judgement in determining how much of the road is normally used by vehicles, either moving or stationary (taking into account breakdown lanes and parking lanes), and therefore needs to be lit, and to take the boundaries of this portion of the road as the carriageway edges.

The point at which pedestrians become vulnerable is a factor which may need to be taken into account. For example, a road might consist of a narrow, sealed pavement with very wide shoulders in which is planted a row of trees leaving spaces between the trees, which can be used for manoeuvring and parking vehicles. In this case the installation will need to be designed to light the whole width between the tree trunks, and the line of tree trunks would then be taken as the carriageway edge.

8.1.3 Mounting height (H) The required luminaire mounting height will depend on the road cross-section and should be commensurate with the carriageway lighting design width. The following guidelines are given to establish a mounting height to serve as a starting point for design:

- (a) *Single sided and central*— H should not be less than W_K .
- (b) *Staggered*— H should not be less than $W_K/1.25$ for aeroscreen luminaires and $W_K/1.75$ for other types of luminaires.
- (c) *Opposite*— H should not be less than $W_K/2.25$.

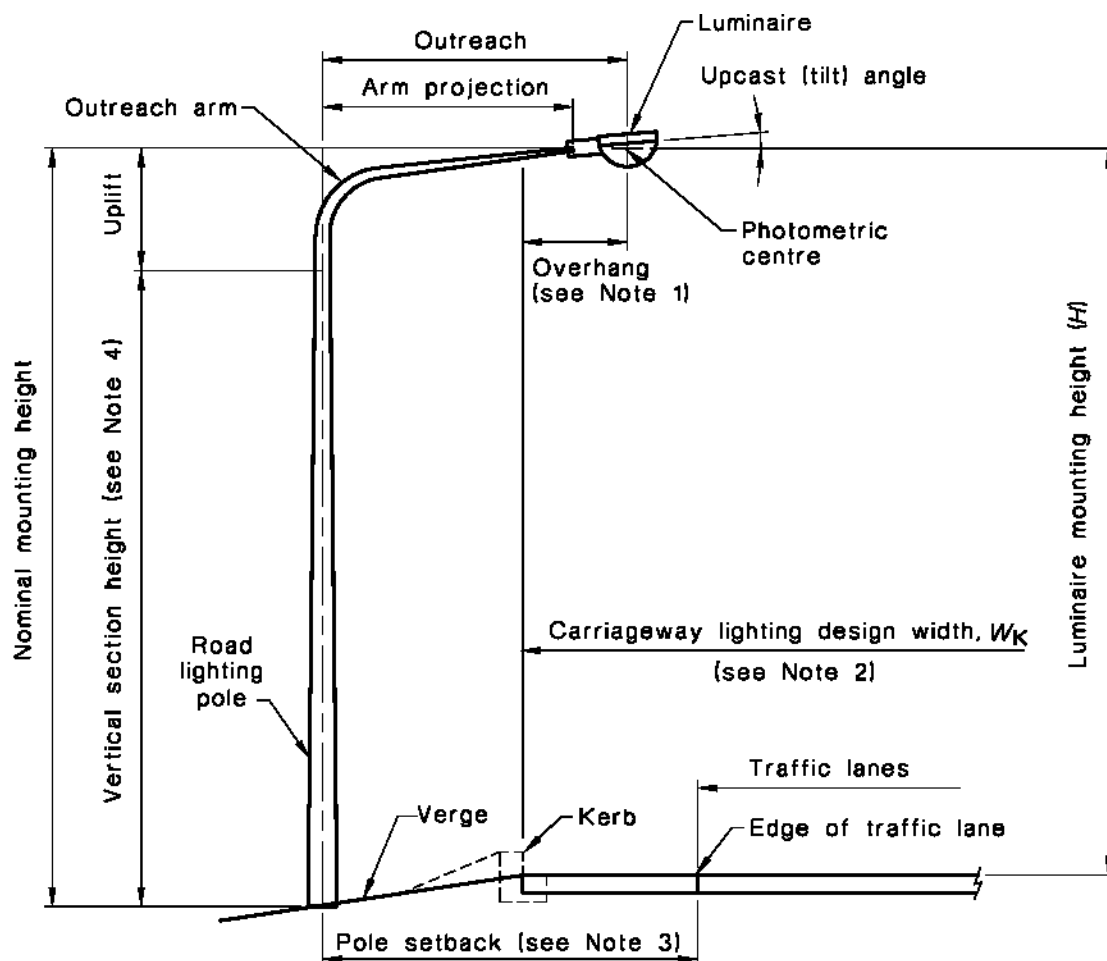
The mounting height should generally be not less than 8.5 m unless special conditions exist, e.g. in the vicinity of airport runways or for bridge parapet lighting.

Where dedicated lighting poles are used, it is recommended that the luminaire mounting height (H) correspond to one of the preferred nominal mounting heights, e.g. 9 m, 10.5 m, 12 m, 13.5 m or 15 m (see AS 1798). Where existing electricity distribution poles are used, mounting heights other than the preferred values referred to above may need to be adopted.

In any one installation the mounting height should, as far as possible, be kept constant to preserve continuity of the line of luminaires.

Subject to attainment of the required values of luminance or illuminance, as applicable, the use of greater luminaire mounting heights will lead to improved uniformity of these parameters, fewer lighting poles and lower operating costs. However, account should be taken of economics (e.g. from the use of existing structures), aesthetics and maintenance (e.g. ability to access the luminaires). It should be noted that the adoption of greater mounting heights will necessitate the use of luminaires with a higher light output and may unnecessarily increase the light spilled into properties abutting the roadway.

Table 8.1 provides suggested mounting heights for luminaires that utilize high pressure sodium vapour discharge lamps. These mounting heights have been found, from practical experience, to provide an efficient utilization of the available luminous flux output.



NOTES:

- 1 Overhangs of between 0 and $H/4$ will generally achieve the best lighting designs.
- 2 W_K is the width of that part of the carriageway which is used for calculation or assessment of road lighting (see Clause 8.1.2).
- 3 Pole setback is the horizontal distance between the edge of the carriageway and the centre-line of the lighting pole, measured normal to the direction of traffic. Shoulders and breakdown lanes should be taken as part of the carriageway.
- 4 Vertical section height is only applicable where a detachable outreach arm is used.

FIGURE 8.1 ROAD LIGHTING DESIGN PARAMETERS

TABLE 8.1
SUGGESTED MOUNTING HEIGHTS FOR LUMINAIRES
WITH HIGH PRESSURE SODIUM VAPOUR LAMPS

Lamp rating	Nominal mounting height m	Suggested minimum mounting height m
W		
100	9.0	8.5
150	10.5	9.0
250	10.5	10.5
400	12.0	12.0

NOTE: Suggested mounting heights for other lamp types and ratings are under consideration.