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COMMISSION INTERNATIONALE DE L'ÉCLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

TECHNICAL REPORT

GUIDE TO THE LIGHTING OF URBAN AREAS

CIE 136 - 2000

UDC: 628.971.6 ; 625.712
628.971.7

Descriptor: Exterior lighting, lighting of urban roads
Lighting of public squares

THE INTERNATIONAL COMMISSION ON ILLUMINATION

The International Commission on Illumination (CIE) is an organisation devoted to international co-operation and exchange of information among its member countries on all matters relating to the art and science of lighting. Its membership consists of the National Committees in 37 countries and one geographical area and of 10 individual members.

The objectives of the CIE are :

1. To provide an international forum for the discussion of all matters relating to the science, technology and art in the fields of light and lighting and for the interchange of information in these fields between countries.
2. To develop basic standards and procedures of metrology in the fields of light and lighting.
3. To provide guidance in the application of principles and procedures in the development of international and national standards in the fields of light and lighting.
4. To prepare and publish standards, reports and other publications concerned with all matters relating to the science, technology and art in the fields of light and lighting.
5. To maintain liaison and technical interaction with other international organisations concerned with matters related to the science, technology, standardisation and art in the fields of light and lighting.

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A plenary session is held every four years at which the work of the Divisions and Technical Committees is reviewed, reported and plans are made for the future. The CIE is recognised as the authority on all aspects of light and lighting. As such it occupies an important position among international organisations.

LA COMMISSION INTERNATIONALE DE L'ÉCLAIRAGE

La Commission Internationale de l'Éclairage (CIE) est une organisation qui se donne pour but la coopération internationale et l'échange d'informations entre les Pays membres sur toutes les questions relatives à l'art et à la science de l'éclairage. Elle est composée de Comités Nationaux représentant 37 pays plus un territoire géographique, et de 10 membres individuels.

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1. De constituer un centre d'étude international pour toute matière relevant de la science, de la technologie et de l'art de la lumière et de l'éclairage et pour l'échange entre pays d'informations dans ces domaines.
2. D'élaborer des normes et des méthodes de base pour la métrologie dans les domaines de la lumière et de l'éclairage.
3. De donner des directives pour l'application des principes et des méthodes d'élaboration de normes internationales et nationales dans les domaines de la lumière et de l'éclairage.
4. De préparer et publier des normes, rapports et autres textes, concernant toutes matières relatives à la science, la technologie et l'art dans les domaines de la lumière et de l'éclairage.
5. De maintenir une liaison et une collaboration technique avec les autres organisations internationales concernées par des sujets relatifs à la science, la technologie, la normalisation et l'art dans les domaines de la lumière et de l'éclairage.

Les travaux de la CIE sont effectués par 7 Divisions, ayant chacune environ 20 Comités Techniques. Les sujets d'études s'étendent des questions fondamentales, à tous les types d'applications de l'éclairage. Les normes et les rapports techniques élaborés par ces Divisions Internationales de la CIE sont reconnus dans le monde entier.

Tous les quatre ans, une Session plénière passe en revue le travail des Divisions et des Comités Techniques, en fait rapport et établit les projets de travaux pour l'avenir. La CIE est reconnue comme la plus haute autorité en ce qui concerne tous les aspects de la lumière et de l'éclairage. Elle occupe comme telle une position importante parmi les organisations internationales.

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Die Internationale Beleuchtungskommission (CIE) ist eine Organisation, die sich der internationalen Zusammenarbeit und dem Austausch von Informationen zwischen ihren Mitgliedsländern bezüglich der Kunst und Wissenschaft der Lichttechnik widmet. Die Mitgliedschaft besteht aus den Nationalen Komitees in 37 Ländern und einem geographischen Gebiet und aus 10 persönlichen Mitgliedern.

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1. Ein internationaler Mittelpunkt für Diskussionen aller Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik und für den Informationsaustausch auf diesen Gebieten zwischen den einzelnen Ländern zu sein.
2. Grundnormen und Verfahren der Meßtechnik auf dem Gebiet der Lichttechnik zu entwickeln.
3. Richtlinien für die Anwendung von Prinzipien und Vorgängen in der Entwicklung internationaler und nationaler Normen auf dem Gebiet der Lichttechnik zu erstellen.
4. Normen, Berichte und andere Publikationen zu erstellen und zu veröffentlichen, die alle Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik betreffen.
5. Liaison und technische Zusammenarbeit mit anderen internationalen Organisationen zu unterhalten, die mit Fragen der Wissenschaft, Technik, Normung und Kunst auf dem Gebiet der Lichttechnik zu tun haben.

Die Arbeit der CIE wird in 7 Divisionen, jede mit etwa 20 Technischen Komitees, geleistet. Diese Arbeit betrifft Gebiete mit grundlegendem Inhalt bis zu allen Arten der Lichtanwendung. Die Normen und Technischen Berichte, die von diesen international zusammengesetzten Divisionen ausgearbeitet werden, sind von der ganzen Welt anerkannt.

Tagungen werden alle vier Jahre abgehalten, in der die Arbeiten der Divisionen überprüft und berichtet und neue Pläne für die Zukunft ausgearbeitet werden. Die CIE wird als höchste Autorität für alle Aspekte des Lichtes und der Beleuchtung angesehen. Auf diese Weise unterhält sie eine bedeutende Stellung unter den internationalen Organisationen.

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COMMISSION INTERNATIONALE DE L'ECLAIRAGE

CIE Central Bureau

Kegelgasse 27, A-1030 Vienna, AUSTRIA

Tel: +43(01)714 31 87 0, Fax: +43(01)713 08 38 18

e-mail: ciecb@ping.at

WWW: <http://www.cie.co.at/cie/home.html>

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This Technical Report has been prepared by CIE Technical Committee 4-34 of Division 4 "Lighting and Signalling for Transport" and has been approved by the Board of Administration of the Commission Internationale de l'Eclairage for study and application. The document reports on current knowledge and experience within the specific field of light and lighting described, and is intended to be used by the CIE membership and other interested parties. It should be noted, however, that the status of this document is advisory and not mandatory. The latest CIE proceedings or CIE NEWS should be consulted regarding possible subsequent amendments.

Ce rapport technique a été préparé par le Comité Technique CIE 4-34 de la Division 4 "Eclairage et signalisation pour les transports" et a été approuvé par le Bureau d'Administration de la Commission Internationale de l'Eclairage, pour étude et application. Le document traite des connaissances courantes et de l'expérience dans le domaine spécifique indiqué de la lumière et de l'éclairage, et il est établi pour l'usage des membres de la CIE et autres groupements intéressés. Il faut cependant noter que ce document est indicatif et non obligatoire. Pour connaître d'éventuels amendements, consulter les plus récents comptes rendus de la CIE ou le CIE NEWS.

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The following members of TC4-34, Urban Lighting, took part in the preparation of this revision to CIE Publication 92. The Committee comes under CIE Division 4, Lighting and Signalling for Transport. This present publication replaces CIE 92 - 1992 "Guide to the lighting of urban areas".

W.J.M. van Bommel	Netherlands
S. R. Chowdhury	India
D.Crawford	United States of America
J.E. Jewell	United States of America
N.E. Pollard	Great Britain
S. Sakamoto	Japan
D.A. Schreuder	Netherlands
R.H. Simons	Great Britain
K. Sørensen	Denmark
A.C.M. de Visser	Netherlands
R.S. Yates	South Africa (Chairman)

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CIE 136 - 2000

GUIDE TO THE LIGHTING OF URBAN AREAS**SUMMARY**

The purpose of this guide is to supplement the lighting recommendations and standards for roads and areas of public use as detailed in the Publication CIE 115-1995.

The recommendations cover the effect of light on night time crime and suggests lighting requirements for residential roads and community areas, industrial roads, central business districts and malls, pedestrian paths and access facilities and cycle tracks.

In addition to proposing levels of luminance and illuminance the recommendations consider aspects such as modelling of people and structures within the environment, the effects of glare and sparkle, suitability of light sources as far as colour appearance and colour rendering are concerned, the effect of the lighting on the environment and the general aesthetics of the lighting equipment used.

GUIDE D'ECLAIRAGE DES ESPACES PUBLICS**RESUME**

Le but de ce guide est de préciser les règles d'éclairage des rues et espaces publics non pris en considération dans la publication CIE 115-1995.

Ces recommandations étudient l'influence de l'éclairage sur la criminalité nocturne. Elles précisent les besoins en éclairage pour les rues résidentielles, les espaces publics, les rues des zones industrielles, les centres d'activité, les circulations et accès réservés aux piétons et les pistes cyclables.

En complément des niveaux d'éclairement et de luminance, ces recommandations prennent en compte d'autres facteurs tels que le modelé du visage, l'aspect de l'environnement, les effets de l'éblouissement et leur contrôle, le choix des sources de lumière en fonction du rendu des couleurs et de la qualité de l'ambiance colorée, l'influence de l'éclairage sur l'environnement, l'esthétique des luminaires et des installations d'éclairage.

LEITFADEN FÜR DIE BELEUCHTUNG ÖFFENTLICHER PLÄTZE IN WOHNGBIETEN**ZUSAMMENFASSUNG**

Der Zweck dieses Leitfadens ist es, für Straßen und öffentliche Plätze, die in Publikation CIE 115-1995 noch nicht behandelt wurden, Beleuchtungsnormen zu empfehlen.

Die Empfehlungen behandeln den Einfluß der Beleuchtung auf die nächtliche Kriminalität und es werden Richtlinien für die Beleuchtung von Straßen in Wohngebieten und Gemeinden, für Straßen in Industriegebieten, für innerstädtische Geschäftsstraßen und Einkaufszentren, für Fußgänger-, Fahrrad- und Zugangswege vorgeschlagen.

Zusätzlich zu den vorgeschlagenen Leuchtdichte- und Beleuchtungsstärkewerten werden Aspekte wie das "Modelling" von Personen und der umgebenden Gebäude, der Einfluß von Blendung und Glanzlichtern, die Eignung von Lichtquellen unter Berücksichtigung von Lichtfarbe und Farbwiedergabeeigenschaften, die Wirkung der Beleuchtung auf die Umgebung, sowie die ästhetische Wirkung der Beleuchtungsinstallation betrachtet.

INTRODUCTION

The purpose of this publication is to supplement the recommendations for the lighting of public thoroughfares within urban areas which are listed in Publication CIE 115-1995 - "Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic" and CIE 32-1977 which deals with "Lighting in Situations Requiring Special Treatment". This guide includes the justification for the lighting of these public thoroughfares and methods of lighting specific areas such as cycle tracks, pedestrian areas and malls, residential and other non-arterial routes, alleys and lanes. The recommendations will cover analyses of lighting criteria, environmental aspects and installation design.

Traditionally in many countries residential and industrial areas of a town were designed on a grid system where roads generally were straight, intersections with other roads were at right angles to each other and all roads were designed to cater for all types of traffic. Later, through the introduction of outside designed features such as schools and shopping centres, some of these roads developed into arterial routes or link roads between these centres. To facilitate traffic movement along these routes frequently intersecting roads were made into stop or yield roads and occasionally at the junction of one of these routes with another, traffic lights were introduced. The effect was that certain essentially residential roads were turned into busy traffic routes for which no provision had been made in the original township and road design. This frequently led to unacceptably high traffic speeds, noise and accidents.

In recent times the design of new urban areas has changed to eliminate many of the above mentioned problems. Roads no longer run straight, curves are introduced, carriageway widths are decreased to limit certain types of traffic, chicanes and humps are constructed in the road surface to limit speeds. Shopping, community centres, industries and other areas of concentration of people are isolated from the residential zones. The effect is to make the environment safer and, through the introduction of discontinuities in streets and community meeting areas, to make the whole appearance of the area more aesthetically pleasing. The cyclist and the pedestrian have been given areas restricted to their own usage or clearly defined portions of general access routes have been provided.

The intention of this guide is therefore to evaluate the visual requirements of each of the road users and make recommendations for their safe and easy progress along roads and paths in old and new types of urban areas. In addition, as one of the main purposes of urban lighting is the improvement of the night-time appearance and character of the area, recommendations are given on how such effects can be aimed at and how lighting equipment should be aesthetically incorporated into the total visual scene.

In the guide, traditional units of illuminance have been recommended. However, the more recent introduction of the concept of semi-cylindrical illuminance is considered to be appropriate for identification of obstacles and persons in pedestrian orientated areas and recommended values are also given. These methods of design can be used separately or semi-cylindrical illuminance can be used as a supplementary criterion to horizontal illuminance to ensure adequate facial recognition. In the same way, a new approach to discomfort glare assessment has been introduced in certain residential and pedestrian areas where lower mounted luminaires are used.

As some urban areas will require special artistic treatment of the lighting to provide variety and points of interest to attract pedestrians, the values given in this guide should be used with discretion and artistic allowance permitted in these areas. In many places, the recommended values will be considerably exceeded but they should nevertheless be regarded as minimum for security of persons and property. The pleasantness of an installation will often be gauged by the amount of modelling achieved by the lighting on human features and decorative components in the area. Some information on this aspect is given in Section 3.2 c.

It is important with all lighting installations that they be efficiently maintained at all times. In the exterior environment the problem of deciding on specific cleaning intervals is particularly complicated due to the changing weather conditions in a particular area and at varying times of the year. A lot will depend on the IP rating of the luminaire (see Table 3.2)

and the presence of dust, wind, rain, snow, changing temperatures etc. The recommended lighting levels can only be met if these aspects are taken into account in the design stage and implemented efficiently.

1. BENEFITS OF URBAN LIGHTING

1.1 Safety of Person and Property

Public lighting was originally introduced into urban areas as a means of reducing crime, both to people and property. Today, crime and vandalism are still major problems in many public areas and surrounding properties. Many investigations have been carried out into the contribution lighting can make to reduce these undesirable aspects of community living. The majority of these investigations have unfortunately been limited in area and/or detail of the lighting standards and are therefore inconclusive. Furthermore, "crime" can take many forms, for example:

- a) Mugging i.e. personal assault and theft from persons;
- b) Theft of and from vehicles in the streets;
- c) Thefts from vendors and stalls in the streets;
- d) Vandalism of public and private property;
- e) Theft from gardens and other private property adjoining the street;
- f) Misuse of thoroughfares usually lanes and isolated thoroughfares as toilets and for sex acts;
- g) Shop and housebreaking;
- h) Acts of sabotage and terrorism.

It would be a very long and difficult exercise to obtain any reliable data on the effect of lighting on any or all of the above. In many cases these acts are not reported to the police as many members of the public believe that lesser crimes would not receive effective investigation. There is, however, a very definite public conviction that areas of poor, or no lighting do attract criminal acts. This is amply demonstrated by the fact that requests to public authorities for the installation of new or improved lighting from members of the public and the police are far more frequently based on crime prevention in residential and commercial areas than road traffic accident reduction. In view of this the aspect of crime and lighting is very high on the priority list of any public authority and attention must be given to the subject in any consideration of public lighting.

From data and information collected the benefits derived from the installation of lighting can be summarised as follows:

- a) There is a strong indication that darkness is an ally of the criminal and terrorist;
- b) Urban lighting does discourage vandalism and minor crimes and foulage and misuse of public thoroughfares, particularly in lanes;
- c) As the provision of lighting in urban areas does improve the distance of visibility, pedestrians can react earlier to potential threats. It assists law enforcement officers in identification of criminals and vagrants, anticipating criminal tendencies and in enabling the police to keep an eye on the safety of their colleagues;
- d) Urban lighting provides a sense of security to residents and all road users, particularly pedestrians, at night.

The continued provision of funds for urban lighting projects, other than for reduction in road accidents, must therefore be encouraged as it plays an important part in the safety and pleasantness of an area at night.

1.2 Reduction in Road Accidents

There exists documentary evidence that the provision of lighting on roads to recognised standards will reduce the number and severity of accidents at night. This is well covered in Publication CIE 93-1992 "Road Lighting as an Accident Countermeasure".

Much of the data collected refers to accidents on motorways and arterial routes but little information is available on the contribution lighting can make to reducing night time accidents on local and residential roads. Accidents involving pedestrians constitute a high

percentage of all road accidents, especially during dark or twilight hours. Many of these occur at entrances to railway stations and at bus stops. However there is a substantial number of evening and night time accidents which occur in residential areas. These take place near schools and recreation centres as well as in purely residential streets where children play either on sidewalks or in the street itself. Another problem is the old and infirm and others who cross roads at places other than designated road crossings. To this must be added the danger imposed by the presence of animals and pets in the streets which can cause accidents either when the motorist or cyclist (motor or pedal) hits the animal or swerves to avoid it.

It is possible that the generally lower speeds of traffic on residential roads gives a false sense of security to pedestrians. Whatever the cause the relatively high incidence of accidents on these streets cannot be ignored. Adequate and appropriate standards of lighting must be provided if the number of accidents occurring at night are to be reduced.

1.3 Contribution of Lighting to Community Character and Vitality

There are a number of people who will strongly resist the installation of street lighting in a town, and particularly in the area in which they live. The chief claim is that street lights destroy the natural environment by driving away birds and small animals.

Opposed to this is the strong feeling amongst other people that lighting at night in the streets and other public areas can contribute considerably to the character and vitality of a city. This can generate a sense of civic pride and provide a draw card for tourists.

Driving through an unlit town at night creates a sense of isolation from the community. There is no incentive to stop for refreshment or shelter.

Many a central business district of a town has become deserted, especially at night due to lack of amenities, attractions and a sense of security all of which could be enhanced by lighting of streets, squares, malls and buildings to a high standard and quality. This lighting will not come exclusively from the standard street lights, but will emanate from shop and hotel windows, electric signs, tree and building floodlighting and attractive lighting units in pedestrian areas.

The provision of lighting in an urban area will also be of assistance to visitors to the town or strangers in a particular area. It provides proper orientation within the area and allows quick and accurate identification of streets and houses. Good lighting will always assist the services of ambulances, fire fighting crews, police cars and rescue teams in an emergency.

For guidance on the decorative aspects of urban lighting readers are referred to Publication CIE 94-1993 "Guide for Floodlighting".

2. RECOMMENDATIONS

Introduction

In this section recommendations are given for the following application fields:

- Residential areas;
- Industrial areas;
- Commercial areas;
- Miscellaneous areas: pedestrian walkways and paths, pedestrian road crossings, pedestrian staircases and ramps, cycle paths, pedestrian and cycle bridge and underpasses.

The recommendations for each application are divided into three sections viz: "Design Objectives", "Installation Design" and "Environmental Factors". In the Section "Design Objectives" lighting requirements are set out in Tables 3.1 and 3.2 in the Appendix.

The lighting recommendations are given in two forms. Firstly in horizontal illuminance at ground level and secondly as a new alternative design guide using the parameter semi-cylindrical illuminance at 1,5 m above ground level.

(a) *Horizontal Illuminance*

This form of lighting design has been accepted over a long period of time and is the basis of Publication CIE 115-1995 for class P roads and some current national codes of practice. It is

comparatively easy to calculate and measure and does not depend on observer position. For this reason it is included in the guide as a design standard. In general the average values recommended should be used in calculating the lighting levels and checks made to ensure that at no place does it fall below the recommended minimum value.

(b) Semi-Cylindrical Illuminance

In areas dominated or used by pedestrians the most important lighting requirement at night is to be able to recognise other people approaching or in the vicinity at a reasonable distance away. To provide the very necessary sense of security it must be possible to recognise if the other person is likely to be friendly, indifferent or aggressive in sufficient time to make any appropriate response. The minimum distance required to recognise any sign of hostility and take evasive or defensive action is, according to research, 4 m in front of the observer (2.10, 2.40, 2.42). Vertical illuminance of a sufficiently high level at the average height of a human face - approximately 1,5 m above pavement level - will provide the requirements of adequate visibility. For a number of reasons pure vertical illuminance from whatever direction is not the optimum parameter. The comparatively recent introduction of the concept of semi-cylindrical illuminance has therefore been included in this guide. Research has indicated that the minimum semi-cylindrical illuminance necessary to recognise and gauge a person's intention at 4 m is 0,8 lux at 1,5 m above ground level. At 10 m distance, which would give greater time for any necessary avoiding action the recommended level is 2,7 lux. To ensure at each location a sufficiently high possibility of recognition the minimum semi-cylindrical illuminance is given in the recommendations. As the lighting will also be required to contribute to the attractiveness of certain areas, an important part of which will be the recognition of people in a crowded place, recommended average values are given where applicable.

Details of the method of calculation and measurement of semi-cylindrical illuminance are given in Section 3.2 (a).

(c) Discomfort glare

In the same way, a new approach to discomfort glare assessment has been introduced for low mounted luminaires, up to approximately 7 m, where the risk exists of pedestrians having to look straight into the luminaires. This is based on the luminance of the light emitting area of individual luminaires and details of calculation methods are given in Section 3.2 (b). As far as luminaire design is concerned, little practical experience with this new approach to glare has so far been obtained. Relatively high glare values have therefore been suggested in the specification tables. Lower values should be strived for.

By giving the lighting parameters for the pedestrian requirements in different forms innovative thinking is not stifled but encouraged whilst the more conservative designers can still utilise traditional parameters. Designers must decide which parameters best suit their requirements and calculate accordingly. Achievement of one parameter will not necessarily ensure realisation of the other recommended parameters as this will depend on the light distribution characteristics of the luminaires being used.

(d) Modelling

In some situations e.g. civic squares, the appearance of people, the street furniture and architectural features in the area needs to be considered. Guidance on this aspect of design is given in Section 3.2 (c).

2.1 Residential Areas

This section of the recommendations is restricted to collector and local roads as described above for strictly local residents' access. In addition the needs of other road users such as cyclists and pedestrians will be considered and recommendations made regarding the provision of lighting for their needs.

Residential areas can be defined as areas of a village, town or city which are suitable for or are occupied by private dwellings. These dwellings might be any of the following:

- a) individual low-rise structures for single family occupation, generally with front and side gardens;

- b) terrace type buildings where the houses are usually of uniform style built in one block along the street front;
- c) specialised residential areas comprising townhouse complexes, residential precincts, or cluster housing where groups of houses are built either at right angles to the street front or are grouped in one area with a single access to the street front;
- d) areas of high-rise residential hotels and blocks of flats;
- e) dwellings in old towns with shops and offices combined in the same building where streets can be straight or curved, wide or narrow.

Except for c) the roads fronting the residential units can vary in character from a cul-de-sac to a major arterial road. This is a particular feature of older residential suburbs which were constructed on a grid system. In any such suburb it is often very difficult to separate "through" roads from strictly local access roads and these too can change over time as adjacent suburbs develop or alter their character such as from residential to commercial. The demands of these new or changed suburbs will inflict varying demands on the usage of existing roads. For example, a previously low density, local access road can change to a through road as one of the main access roads to a new suburb. The building of a school in a previously unoccupied area can also change the character of the roads surrounding and providing access to it.

It is difficult to accurately define residential areas for lighting recommendations. Where the residences are located on an arterial route of whatever importance, the lighting design must be dictated primarily by the road traffic requirements such as laid down in Table 5.1 of the Publication CIE 115-1995. However, considerable thought should be given to other street users such as pedestrians and particular attention be paid to Section 6.5 of the above document which deals with the lighting of the surrounds to the road.

The modern view regarding residential areas is to remove domestic buildings from any form of arterial route and, with the slight exception of collector roads catering for that area, restrict access to residents, visitors and delivery vehicles. Restrictions can take many different forms - extremely narrow roads, roads with frequent curves, construction of speed humps and chicanes in the roadway, culs-de-sac and loops or crescents (see Fig. 2.1). Even older grid-type suburbs are being re-assessed from the point of view of traffic and many of the roads in these areas are being altered to restrict access in manners similar to new townships.

2.1.1 Collector Roads

Design Objectives

These roads can be defined as principal roads in a residential area which link all local roads to an arterial route. Fundamentally these are Class M2 and M3 roads of Publication CIE 115-1995 but as they will be roads through residential complexes the additional requirements of residents must be included in the lighting design.

These roads could be main feeder roads to community centres, park-and-ride sites, bus or train stations. There is therefore likely to be a fair amount of cycle and pedestrian traffic and their special requirements should be considered. See Section 2.4.

Installation Design

As the lighting must cater both for the vehicle users on the carriageway and pedestrians on footways it is recommended that lights be installed where necessary on both sides of the road in either opposite or staggered formation.

The lighting of these roads will generally form a transition between an arterial traffic route and the local street. It is therefore recommended that the height of the poles above ground level be between that of the poles in the other areas. In practice this will mean mounting heights from 6 to 10 m. Spacing-to-height ratios between luminaires will depend mainly on the type of light distribution of the luminaire and, to a lesser extent, on the road and pavement width. This will need to be calculated. In practice it is unlikely that these will exceed 4 to 5 times the mounting height of the luminaires.

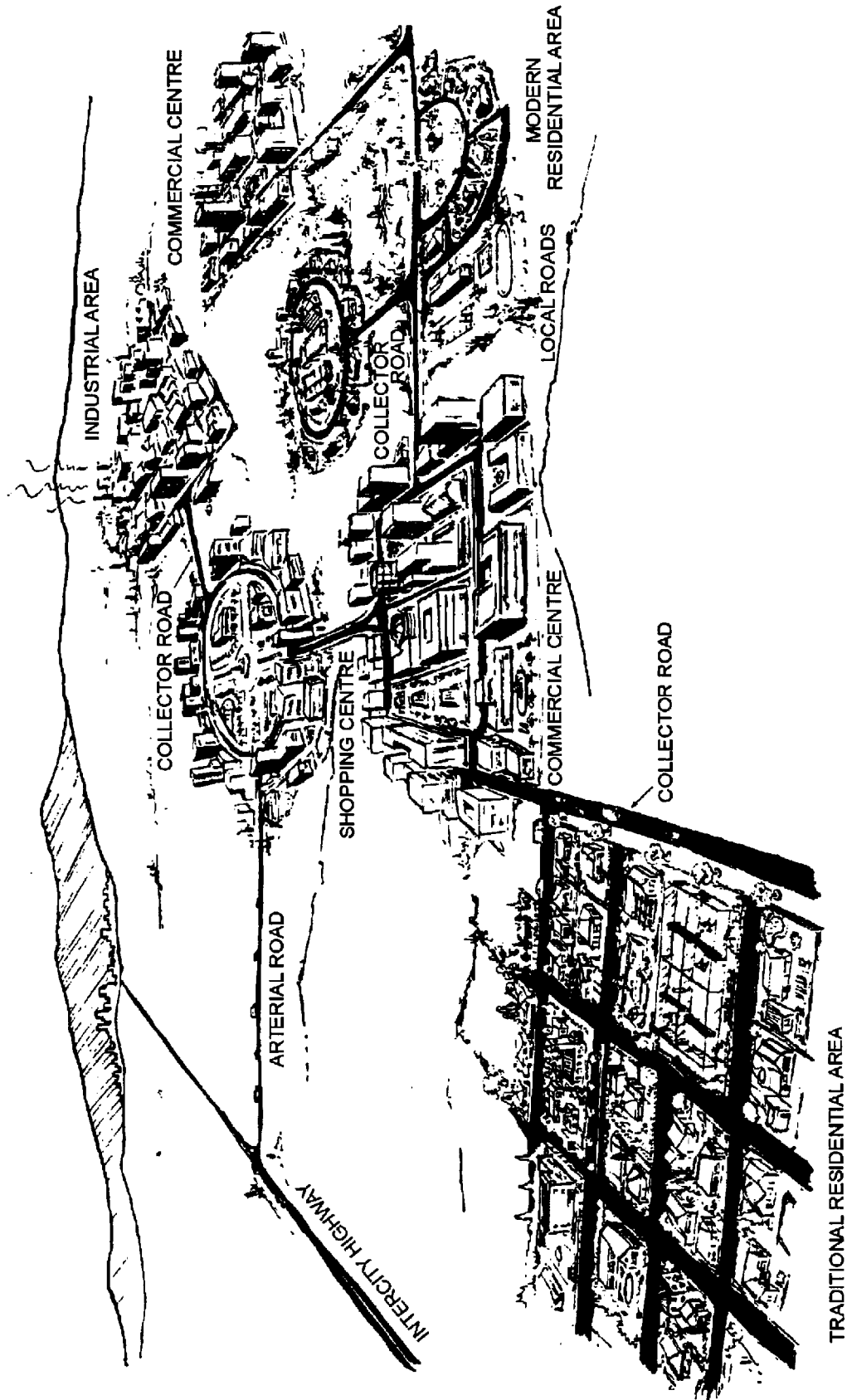


Fig. 2.1 Diagrammatic illustration of typical classification of roads in urban areas