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CIE

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

TECHNICAL REPORT

LIGHTING OF ROADS FOR MOTOR AND PEDESTRIAN TRAFFIC

CIE 115:2010
2nd Edition

UDC: 628.971
628.971.6

Descriptor: Exterior lighting
Street lighting (fixed)

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 about 40 countries.

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.

The work of the CIE is carried on by seven Divisions each with about 20 Technical Committees. This work covers subjects ranging from fundamental matters to all types of lighting applications. The standards and technical reports developed by these international Divisions of the CIE are accepted throughout the world.
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'ECLAIRAGE

La Commission Internationale de l'Eclairage (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 environ 40 pays.

Les objectifs de la CIE sont :

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.

DIE INTERNATIONALE BELEUCHTUNGSKOMMISSION

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 rund 40 Ländern.

Die Ziele der CIE sind :

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 auf der ganzen Welt anerkannt.
Alle vier Jahre findet eine Session statt, in der die Arbeiten der Divisionen überprüft, 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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This Technical Report has been prepared by CIE Technical Committee 4-44 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 élaboré par le Comité Technique CIE 4-44 de la Division 4 "Eclairage et signalisation pour les transports" et a été approuvé par le Bureau de la Commission Internationale de l'Eclairage, pour étude et emploi. Le document expose les connaissances et l'expérience actuelles dans le domaine particulier de la lumière et de l'éclairage décrit ici. Il est destiné à être utilisé par les membres de la CIE et par tous les intéressés. Il faut cependant noter que ce document est indicatif et non obligatoire. Il faut consulter les plus récents comptes rendus de la CIE, ou le CIE NEWS, en ce qui concerne des amendements nouveaux éventuels.

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The following members of TC 4-44, "Management and Maintenance of Road Lighting", took part in the preparation of this Technical Report. The committee comes under Division 4 "Lighting and Signalling for Transport".

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LIGHTING OF ROADS FOR MOTOR AND PEDESTRIAN TRAFFIC

SUMMARY

This report is a revision and update of CIE 115-1995 *Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic*. Since it was issued in 1995 power consumption and environmental aspects have become more important and at the same time, the improved performance of luminaires and lamps, and especially the introduction of electronic control gear, has made it possible to introduce adaptive lighting for roads for motorised traffic, conflict areas and areas for pedestrians. A structured model has been developed for the selection of the appropriate lighting classes (M, C, or P), based on the luminance or illuminance concept, taking into account the different parameters relevant for the given visual tasks. Applying for example time dependent variables like traffic volume or weather conditions, the model offers the possibility to use adaptive lighting systems.

L'ECLAIRAGE DES ROUTES POUR LES VEHICULES A MOTEUR ET LES PIETONS

RESUME

Ce rapport a pour objet la mise à jour du rapport technique CIE 115-1995 *Recommendation for the Lighting of Roads for Motor and Pedestrian Traffic*. Depuis sa publication en 1995, les consommations énergétiques et les aspects environnementaux sont devenus des enjeux plus importants. Par ailleurs, l'amélioration des performances des luminaires et des sources d'éclairage, et en particulier l'introduction des systèmes électroniques de contrôle des installations, a permis d'introduire la pratique de variation de l'éclairage des routes, des zones de conflit et des espaces piétons. Un modèle structuré permettant la sélection des classes d'éclairage (M, C ou P) a été développé ; il est basé soit sur le concept de luminances, soit sur celui de niveaux d'éclairement, et prend en compte les différents paramètres pertinents pour caractériser la tâche visuelle. En considérant des variables temporelles telles que le trafic ou les conditions climatiques, le modèle répond aux utilisations des systèmes de variation d'éclairage.

BELEUCHTUNG VON STRASSEN FÜR FUSSGÄNGER UND MOTORISIERTEN VERKEHR

ZUSAMMENFASSUNG

Dieser Bericht ist mit dem Ziel erarbeitet worden, die Publikation CIE 115-1995 *Recommendation for the Lighting of Roads for Motor and Pedestrian Traffic* auf den neuesten Stand zu bringen. Seit ihrer Herausgabe im Jahr 1995 sind Aspekte des Energieverbrauchs und des Umweltschutzes verstärkt in den Vordergrund getreten. Gleichzeitig ist es durch den Einsatz leistungsfähigerer Lampen und Leuchten und besonders durch die Verfügbarkeit elektronischer Betriebsgeräte möglich geworden, adaptive Beleuchtungen für Straßen, Konfliktzonen und Fußgängerbereiche einzuführen. Es wird ein neu entwickeltes, vereinfachtes Verfahren zur Auswahl geeigneter Beleuchtungsklassen (M, C oder P) vorgestellt, aufbauend auf dem Beleuchtungsstärke- oder Leuchtdichte-Konzept, unter Berücksichtigung der verschiedenen, für die gegebenen Sehaufgaben relevanten Parameter. Bei Anwendung zum Beispiel Zeit abhängiger Variablen wie Verkehrsaufkommen oder Wetterbedingungen eröffnet das Modell die Möglichkeit, adaptive Beleuchtungssysteme einzusetzen.

1 INTRODUCTION

1.1 General

The recommendations in this Technical Report are structured with the intention of making them easily adaptable to the needs of individual countries. This document is a framework, which could serve for developing national codes of practice and standards.

Since Publication CIE 115-1995, *Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic*, was issued, the performance of luminaires and lamps has improved and the realization of efficient adaptive lighting systems is technically possible at reasonable cost. This technical report considers these matters in detail and gives information about the use of control systems able to satisfy the requirements of adaptive lighting. The visibility level concept and Small Target Visibility (STV) algorithm are not considered here because they are under evaluation in CIE TC 4-36 “Visibility Design for Roadway Lighting”.

The report is based on experience gained worldwide in the application of the luminance concept to the lighting of traffic routes. The document takes into account the needs of all road users.

In conformity with the most recent CIE practice, this report is based on maintained lighting levels (CIE 154:2003) and lighting quality. This implies that performance must not fall below the prescribed limits, which are minimum values, for the life of the installation.

1.2 Need for Road Lighting

The decision on whether a road should be lit is defined in the national road lighting policy. This varies by country or municipality. Specific guidelines are usually available at national level for each country.

Matters that need to be considered when planning and installing road lighting are summarized below:

a) When the service level of traffic conditions and standard of the road are normal the need for road lighting will usually be evaluated on the basis of traffic volume and traffic speed.

b) It is possible to estimate the savings in road usage costs that can be attained through the benefits of road lighting. The most important savings are through the reduction in accident rates and severity. In accordance with Publication CIE 93-1992, *Road Lighting as an Accident Countermeasure*, road lighting will decrease night-time accidents on average 30 %. Calculations must always be based on the national values of reduction of night-time accident rates, see Annex A, examples 7 and 8.

c) The basis for calculating the benefits of those road lighting installations that are justified by traffic volume is the average personal injury and fatality rate for each road class. On motorways and other highways, the savings obtained in travel time are also considered.

d) The profitability of road lighting in terms of traffic economy is analyzed by comparing the average annual savings in total costs of road traffic with the annualized total costs of the lighting system and the annual cost of collisions with installed lighting columns. The traffic volume required to make road lighting profitable is obtained by performing the analysis for the period from installation to half of the anticipated service life of the road lighting system. An example of a calculation method is provided in Annex A.

e) Where traffic volumes are lower than those needed to justify lighting on accident reduction grounds alone, road lighting may be justified if there is an inhomogeneous traffic environment, poor road alignment, short spacing of junctions, greater than normal number of crossroads and bus stops, a lack of dedicated pedestrian footways, etc.

f) On some types of roads, particularly in urban areas and on residential roads, injury and fatal accidents may not be relevant, and the benefits of lighting cannot be evaluated only in terms of the potential reduction in injury accident rates. On such roads, lighting is provided for social reasons; to improve the general amenity, to give safe passage for pedestrians and to provide a sense of personal security (see clause 9)

The methods presented in clauses 7, 8 and 9 have to be considered as the starting points of a comprehensive approach. In that sense, the models cannot cover all the different road cases; they introduce general parameters and the impact on lighting requirements. Only the real situation and its unique characteristics (geometry of the road, marking, visual environment, difficulty of the navigation task, lack of visibility, risks of glares due to existing elements, local weather, specific users such as high rate of elderly or visually impaired people, etc.) can lead to a final determination of luminous requirements.

Renewal or refurbishment of obsolete and uneconomic installations is important. It is possible to obtain higher luminance values with lower energy consumption using new designs and new technology. The upgrading of lighting and control systems will often give good cost-benefit ratios and short amortization periods.

The visual needs of road users under reduced traffic volumes during certain periods of night or under varying weather conditions, and the positive benefits of reduced energy consumption and potential environmental improvements, are some of the considerations which justify the installation of adaptive road lighting. There are a variety of suitable instruments, devices and methods which can be used for the intelligent control of a road lighting installation. The control systems range from very simple to the most sophisticated applications.

2 TERMS AND DEFINITIONS

The terms discussed in this clause are defined in the *International Lighting Vocabulary* (CIE DS 017.2/E:2009) or in CIE 140-2000.

2.1 Average Luminance of the Road Surface [L_{av}]

The values of L_{av} are the minimum values to be maintained throughout the life of the installation for the specified lighting class(es). They are dependent on the light distribution of the luminaires, the luminous flux of the lamps, the geometry of the installation, and on the reflection properties of the road surface. Higher levels are acceptable when they can be environmentally or economically justified.

The calculation of the average luminance of the road surface should be carried out in accordance with CIE 140-2000.

Calculated values should consider the luminaire and lamp maintenance factors. Luminaire maintenance factors vary according to the intervals between cleaning, the amount of atmospheric pollution, the quality of the sealing of the lamp housing of the luminaire, and the age of the materials. Their values may be established by field measurements. Lamp flux maintenance factors vary according to lamp type and power. Values are usually available from lamp manufacturers.

2.2 Overall Uniformity of Road Luminance [U_o]

U_o is the ratio of the minimum luminance at a point to the average road surface luminance and should be calculated according to CIE 140-2000. This criterion is important as regards the control of minimum visibility on the road.

2.3 Longitudinal Uniformity of Road Surface Luminance [U_l]

U_l is the ratio of the minimum to the maximum luminance along a line or lines parallel to the run of the road and should be calculated in accordance with CIE 140-2000. It is mainly a criterion relating to comfort and its purpose is to prevent the repeated pattern of high and low