



ISBN 978 3 901 906 61 9

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

TECHNICAL REPORT

ROAD TRANSPORT LIGHTING FOR DEVELOPING COUNTRIES

CIE 180:2007

UDC: 628.971
628.971.6

Descriptor: Exterior lighting
Street lighting

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3. Richtlinien für die Anwendung von Prinzipien und Vorgängen in der Entwicklung internationaler und nationaler Normen auf dem Gebiet der Lichttechnik zu erstellen.
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Published by the

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This Technical Report has been prepared by CIE Technical Committee 4-37 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 4-37 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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ROAD TRANSPORT LIGHTING FOR DEVELOPING COUNTRIES

SUMMARY

The great majority of the deaths from road accidents happen in the less-motorised developing regions of the world, particularly Asia - and the absolute numbers are growing. As in the highly motorised countries of the world, a significant proportion of accidents occur at night. This report deals with the part that better lighting and visibility can play in reducing the toll of death and injury; it is addressed to those involved in road safety work, not to lighting specialists. Its basic intentions are to guide, inform and encourage.

The report starts by explaining the basic "language of light" and defining the terms and quantities it uses. The night-time value of simple road markings and signs is then explained, stressing the importance of retroreflective materials. This leads to the role of vehicle lighting, with particular emphasis on the need for individual drivers to take responsibility for cleaning and aiming. A chapter on fixed roadway lighting deals with the basic design of simple installations and explains the many different factors that need to be considered. Because of its importance, maintenance is considered in a separate chapter. Finally, there is some general lighting-related material for use in road safety campaigns.

A consistent message of the report is that it is worth doing something rather than nothing, as long as it is done intelligently and with an understanding of the basic principles involved.

ECLAIRAGE ROUTIER POUR LES PAYS EN VOIE DE DEVELOPPEMENT

RESUME

La grande majorité des décès dus aux accidents de la route ont lieu dans les régions du monde en développement les moins motorisées, surtout en Asie – et leur nombre ne cesse d'augmenter. Comme dans les pays du monde fortement motorisés, une grande proportion des accidents ont lieu la nuit. Ce rapport montre qu'un bon éclairage et une bonne visibilité peuvent jouer sur la réduction du nombre de morts et de blessés; il s'adresse aux personnes concernées par la sécurité routière, et non aux spécialistes de l'éclairage. Ses buts principaux sont de les guider, les informer et les encourager.

Le rapport commence par des explications sur le « langage de la lumière » et les définitions des termes et des quantités utilisés. Il explique l'avantage pendant la nuit des simples marquages et signaux routiers, en insistant sur l'importance des matériaux rétro réfléchissants. Cela conduit au rôle de l'éclairage propre des véhicules, en insistant sur la nécessité pour les conducteurs d'assurer leur nettoyage et leur réglage. Un chapitre sur l'éclairage routier traite des études d'installations de base et détaille les multiples facteurs à prendre en compte. Du fait de son importance, la maintenance est traitée dans un chapitre spécifique. Enfin, en annexe sont donnés des conseils relatifs à l'éclairage général pour mener des campagnes sur la sécurité routière.

Le message essentiel de ce rapport est qu'il vaut mieux faire quelque chose plutôt que rien du tout, à partir du moment où on le fait de façon intelligente et avec une bonne compréhension des principes de base concernés.

STRASSENBELEUCHTUNG IN ENTWICKLUNGSLÄNDERN

ZUSAMMENFASSUNG

Die meisten Verkehrsunfälle mit tödlichem Ausgang passieren in den weniger motorisierten Teilen der Erde, in Entwicklungsländern, und hier besonders in Asien – und die absolute Zahl ist im Steigen. Wie in den hochmotorisierten Ländern findet ein wesentlicher Teil der Unfälle bei Nacht statt. Dieser Bericht beschäftigt sich mit besserer Beleuchtung und Sichtbarkeit und ihrer Rolle in der Verminderung der Zahl der Verkehrstoten. Er richtet sich an Experten für

Verkehrssicherheit und nicht an Strassenbeleuchtungsspezialisten und möchte vor allem anleiten, informieren und ermutigen.

Der Bericht beginnt mit der Bedeutung des Lichtes oder auch der „Sprache des Lichts“ und mit den Definitionen der verwendeten Ausdrücke und Einheiten. Die Wirksamkeit von einfachen Strassenmarkierungen und -zeichen während der Nacht, wird ebenso erklärt, wie die Wichtigkeit von rückstrahlenden Materialien. Danach wird übergeleitet zur Rolle der Fahrzeugbeleuchtung mit besonderer Betonung der individuellen Verantwortung des Fahrers, diese zu reinigen und einzustellen. Ein Kapitel über feste Strassenbeleuchtung nimmt sich der Planung einfacher Anlagen an und erklärt die vielen unterschiedliche Faktoren, die berücksichtigt werden sollten. Wegen ihrer Bedeutung wird die Instandhaltung in einem separaten Kapitel behandelt. Zum Schluss sind einige allgemeine Materialien angeführt, die für Kampagnen zur Erhöhung der Strassensicherheit verwendet werden können.

Die durchgängige Botschaft des Berichtes ist, dass wenig tun deutlich besser als nichts tun ist, solange grundlegende Zusammenhänge beachtet werden.

PREFACE

This document has been written to help reduce the growing number of deaths and injuries in developing countries caused by road accidents. More specifically, it is concerned with ways of improving night-time visibility, and hence night-time road safety.

Road safety programmes demand the efforts of a wide range of people, with different skills and specialisations. The topics in the following chapters will be of interest to a similarly wide range of disciplines. For example, the chapters on roadway signs and markings, and fixed roadway (public) lighting, will be of most relevance to the highway engineer. The chapter on vehicle lighting will be more appropriate for officials concerned with vehicle standards and road-worthiness. The appendix listing points of good practice for the general public will help those responsible for compiling "Highway Codes" or running safety campaigns.

The contents have been written for the technically-literate engineer or decision-maker who can influence activity in any of the areas covered. It should also prove useful to policy-makers in donor countries and organisations who are concerned with road safety technical assistance. It has not been written for the lighting professional, who will (or should) already be familiar with its contents.

In compiling this report much time was spent trying to define the term "developing country". Out of context this proved a futile exercise. Suffice it to say that the content is geared towards the lower end of the developing country spectrum, in terms of gross national product, and is aimed more at rural areas and small towns than at the major cities, where there will usually be more financial and technical capability. If the reader recognises something of his/her situation in the remarks in the following introduction, then it is hoped that what follows will be of relevance and some value.

A recurring theme in the manual is that it is possible to make some improvements even when resources are tightly stretched, and when the ideal from the point of view of international standards seems unattainable. The stance taken is that "something is better than nothing" - as long as it is done properly and with understanding of the fundamental principles at work. To assist with this, a chapter on the basics of lighting is included. This should improve understanding, not least of the technical jargon involved, and give the non-specialist confidence to experiment and improvise.

The information presented here has drawn on many sources, and on the collective wisdom of CIE Technical Committee 4-37. Thanks are due to the members of that committee who contributed their time and expertise, and assisted in shaping the contents of the final document.

J Stuart Yerrell
Chairman TC 4-37

1. INTRODUCTION

1.1 Road safety worldwide

A global survey of road safety made at the turn of the century has estimated that between 750 and 880 thousand people die each year in road accidents, and that between 23 and 34 million are injured. Only 14% of these deaths take place in the highly motorised countries of the world in Europe, North America and Japan. The great majority, some 86%, occur outside these regions, with Asia accounting for nearly half the total.

Region	Fatalities (%)	Vehicles (%)	Population (%)
Highly motorised	14	60	15
Asia/Pacific	44	16	54
Central/E. Europe	12	6	7
Latin America/Caribbean	13	14	8
Sub-Saharan Africa	11	4	11
M East/N Africa	6	2	4

This broad picture is consistent with a more detailed country-by-country analysis, where the records permit. High rates of fatalities per vehicle are linked with low vehicle ownership in the poorer countries, and low rates with the high vehicle ownership levels of the richer industrialised countries. The number of deaths relative to population is much more stable, being of the order of one death per year for every ten thousand people. The middle-ranking countries face the worst on this measure, having rates typically double those of the poorest and the richest countries.

In general, accident numbers are still climbing in the developing countries, although not as dramatically as in the last few decades, and numbers are falling in the industrialised countries. Overall, the total is still rising, with predictions of 1,0 to 1,1 million fatalities per year by the year 2010, and between 1,0 and 1,3 million by 2020. As now, the greatest burden will fall on the developing countries.

1.2 Road safety at night

Where statistics are available from developing countries, it appears that their night-time accidents account for about 30% of the total, a figure similar to the more motorised countries and large enough to merit special attention.

Country	Day (%)	Night-lit (%)	Night-unlit (%)
Shanghai 2000 - All accidents *	67,2	24,0	3,5
Shanghai 2000 - Fatalities	61,4	22,6	16,0
Bangladesh 1998 - All accidents	70,7	22,2	7,1
Bangladesh 1998 - Fatalities	69,9	21,6	8,5
Zimbabwe 1998 - All accidents	66,6	19,5	13,9
Zimbabwe 1998 - Fatalities	50,3	21,5	28,2
Botswana '94-95 - All accidents	62,4	12,3	25,3
Botswana '94-95 - Fatalities	57,5	10,6	32,0
Botswana '94-95 - All accidents, village and rural only	55,1	8,1	36,9
Fiji 2000 - All accidents	72,1	6,6	21,3

* 5,4% of accidents in Shanghai are unattributed and minor. For Bangladesh, dawn and dusk accidents have been added to the "lit" category. For Botswana, "moonlight" has been added to the "unlit" category.

These figures also show that night-time accidents are, on average, more severe - the percentage of fatalities increases at night. This is particularly marked in Zimbabwe and Botswana, which also have most of their night-time accidents on unlit roads. Even in the urban environment of Shanghai, the proportion of deaths and injuries are higher at night: pro rata there are five times as many fatal accidents on the unlit roads there at night than on the same roads in daylight. The authorities in Thailand report night-time accident rates on the Bangkok freeways to be four times as great as during the day. This gives a measure of the need, and the potential value, of improving night-time driving conditions in such countries.

Of course, there is far more to night-time accidents than just poor visibility. Generally speaking, drivers are more tired, younger and less experienced, and are more likely to have been drinking. But darkness conspires with all these factors to increase the risk of misjudgement. The conscientious driver needs all the help that the transport highway engineers and vehicle engineers can provide. Even in broad daylight, consistently good driving is a demanding task, and the onset of darkness increases those demands. The familiar landmarks and features of the road change or disappear. The distance ahead that can be seen with confidence is dramatically reduced, particularly when there is glare from oncoming traffic. Pedestrians and road users without lights can quickly be lost in the shadows.

Any improvements to the visibility of the road, its features, the vehicles on it - including pedestrians, cyclists, animals and carts - is likely to improve the overall accident record.

1.3 Application and modification of recommendations

The basic processes of seeing and perceiving are universal. Human eyes respond to different lighting levels the same the world over. But the technologies and standards of night-time driving have been developed largely in the highly motorised and relatively wealthy industrialised countries. The recommendations of the International Commission on Illumination (CIE) are geared to the conditions in the industrialised countries, with their heavy levels of high speed traffic, dominated by the private motor car.

This report accepts that the principles are universal, but putting them into practice has to recognise some important differences. The conditions found in the less-industrialised countries vary enormously, but some or all of the following have been taken into account in the advice which follows:

1. Self-evidently neither the public authorities nor the vast majority of private citizens in developing countries have the means to spend much on lighting - which is probably seen as something of a luxury - an optional extra in the basic means of transport. This is made worse by the fact that much of the technology, although relatively simple, is imported and uses foreign exchange.
2. Similarly, skilled technicians and the resources to undertake all-important maintenance are at a premium.
3. The level of development in many developing countries is unevenly distributed, with the rural areas and villages having few of the amenities of the cities. In particular, mains electricity is a rare luxury - for domestic or public use.
4. Major parts of the road network, including the intercity links, are relatively lightly trafficked, especially in Africa. The rural networks have a high proportion of gravel (or even hardened earth) roads. Although many of these are properly engineered (in terms of structural strength, and vertical and horizontal curvature) the need for them to be maintained by grading rules out the use of surface markings.
5. To reduce capital costs in mountainous regions lower geometrical design standards are often used, resulting in sharp bends and steep gradients, and frequently poor sight-lines.
6. Many roadside features, such as large drains and culverts (capable of handling monsoon volumes of water) and bridge parapets have been installed close to the running surfaces of roads. This makes them especially unforgiving to driver error. The submerged or "Irish" bridge can be particularly hard to discern at night.
7. Poor maintenance of both urban and rural roads means that bad surfaces and potholes, together with poorly signed roadworks, are a common hazard.

8. Many developing countries lie in the tropics, where all evening social activity takes place during the hours of darkness. The warm temperatures encourage people to "live out-doors", and the roadways in townships and villages alike become social meeting places. The distinction between shops and business premises and the public highway is frequently blurred.
9. A wide diversity of vehicles uses the roads, many slow-moving compared to the motor car. Animal drawn carts, animals themselves, handcarts, bicycles, motorcycles etc. all compete for roadspace. Large numbers of pedestrians use the roadways - outside the central urban areas there are few sidewalks.
10. Because of high daytime temperatures many intercity bus services, and much long distance freight, operate through the night.
11. In developed countries there is a relatively clear distinction in the road hierarchy between through traffic routes (dominated and designed for vehicle flow) and pedestrian/residential areas. These distinctions are more blurred in developing countries, and there is a greater range of road types. The emphasis in this report is not on the centres of the major cities, where the traditional public lighting standards of the developed world can apply, but on the less-motorised regions of those countries: i.e. the sub-urban areas and rural areas, including village streets.

Because the "language" of lighting is somewhat specialised, the report starts with a short explanation of the terms and quantities used, and the basic mechanisms of vehicle and roadway lighting. It then deals, in order, with markings and signs (especially reflectorisation), vehicle lighting and fixed roadway lighting.

A consistent theme throughout the report is that it is better to make modest improvements rather than none at all. In other words, it is better to do something than nothing. Inaction should not be excused simply because the improvements that can be afforded fall short of the standards and ideals set by the highly motorised and more affluent countries.



2. LIGHTING BASICS

2.1 Fundamentals

All objects are seen by contrast, either dark against a light background (e.g. words on a page) or light against dark (a candle flame in the dark). Our ability to see them depends on this contrast, and we need more of it at lower lighting levels and when we need to see small detail. Unless the objects are self-luminous their contrast with the background comes from the amount of light directed at them which is returned to the eye of the road user, be they driver or pedestrian.

Vehicle headlights are most effective at making vertical features, on or off the road, appear brighter than the background. Fixed roadway lighting, on the other hand, works largely by making the road surface brighter than objects upon it, which are often seen as silhouettes with little internal detail. In both systems, light coming directly from the light source into the eye (glare) has to be kept to a minimum as it reduces the sensation of contrast. As will be seen later, this is a particularly intractable problem for vehicle headlighting.

2.2 Building blocks of lighting and definitions

2.2.1 Lamps

The lamp is the basic source of radiation. In transport lighting we are dealing almost exclusively with electric lamps, which convert electrical energy into electromagnetic radiation to which eyes are sensitive (light, in common language). There are three basic ways of doing this:

1. Passing current through a wire or filament to a high temperature, in a sealed bulb, the incandescent lamp. It is the oldest lamp type, comes in a wide variety of power ratings, is relatively rugged and cheap, and needs no special circuitry. It has, however, a low efficacy (see next section). Until recently it was the only lamp used in vehicle lighting.
2. Passing current through a gas or mixture of gases in a sealed tube, generically called discharge lamps. The light emitted depends on the gases and their pressure. With greater efficacy and with longer lives than incandescent lamps, they are used extensively in fixed roadway lighting. They are, however, more expensive and require special circuitry for starting and control. A miniaturised form of discharge lamp (HID-high intensity discharge) is starting to appear in vehicle headlights.
3. Passing a current through a semiconductor - the light emitting diode or LED. This has many of the desirable properties of the small incandescent lamp, but has higher efficacy, longer life, and is more rugged. LEDs are set to become the norm for all vehicle lighting with the exception of the headlights themselves, where (for the present) they cannot provide the necessary high powers from a small area/volume. However, this situation is also changing rapidly.

For all the lamps, it is their engineering properties which are of most interest, their efficiency in turning electricity into light, how that light can be directed where it is wanted, and their unit cost and average lifetime.

2.2.2 Power of light - the lumen

The radiation, or "luminous flux", which comes from a lamp is measured in lumens (lm). This quantity allows for the fact that the sensation of "light" experienced by the human eye/brain system depends on the wavelength of the radiation entering the eye. The same amount of energy at the opposite ends of the spectrum - red and blue - produces less sensation than in the middle (yellow/green). At the peak of sensitivity one watt of radiated electromagnetic power is equivalent to 683 lumens.

2.2.3 Efficacy

This is defined as the number of lumens produced by a lamp for each watt of electrical power it consumes. The unit is lumens per watt. From the comments in the previous paragraph it can