PUBLIC AND VEHICLE LIGHTING IN RESIDENTIAL AREAS

Paper presented to the Chartered Institution of Building Services
CIBS Annual Conference 1979, Harrogate, 19-23 May 1979

R-79-4
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Voorburg, 1979
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1. INTRODUCTION

Roads in the conventional residential areas serve the purpose to reach and leave the houses in them. Thus, they are essentially traffic routes which may carry all road traffic modes, viz.: pedestrians, pedal and motor bicycles, motorcars and trucks, and public service vehicles (busses or trams).
Furthermore, it should be realised that in many cases the residential area either contains or at least borders on areas with social functions, areas that often create or attract much traffic (hospitals, shopping centres, sport facilities, offices and even factories).
Thus, roads in residential areas always have a traffic function, and often an important one. The requirements for this traffic function must be met both at day and at night. As a consequence, residential areas have nearly always a "public" lighting installation which may have further functions for public safety. Additionally, all vehicles carry lights that illuminate their way apart from signalling lights.
This paper deals with aspects of public and vehicle lighting and their interactions.

Usually, engineers, architects and town planners apply most of their skill and enterprise to projects of importance and grandeur, overlooking to some extent the residential areas in spite of the fact that these form the major part of the town and of its roads. Recently, however, more attention is paid to the residential area, more in particular to the social aspects of it. This will be illustrated by means of the "woonerf" (residential yard) concept.

2. A CLASSIFICATION OF ROADS IN RESIDENTIAL AREAS

In a trip, one may discern three phases: the origin, the trip itself, and the destination. Now, for obvious reasons, a destination usually is the origin for a next trip.
It is customary to distinguish two functions of roads: a travel function and an origin/destination function. From a point of view of construction and of operation these two functions have quite different requirements - including those for the public lighting.

Urban roads vary in many aspects, so that a classification of road types is desirable. As most urban roads present a mixture of the two functions mentioned above, it seems logical to base such a classification on this mixture, which in its turn can be quantified as the percentage of through-traffic.
Apart from the classes that relate to purely travel function and purely origin/destination function, we will introduce three more classes, representing different percentages of through-traffic.
Thus, five classes of urban roads can be distinguished:

A purely travel function: urban freeways
B mainly travel function: main streets
C both travel and origin/destination function: side streets
D mainly origin/destination function: residential streets
E exclusively origin/destination function: "woonerf".

The class D can, of course, include types of origin and destination functions other than residing, e.g. industrial areas.

The roads of the classes B, C and D can vary very much as regards the volume of traffic. For our purpose, three classes of traffic volume seem to be sufficient

1. busy
2. lively
3. quiet

For classes A and E such a subdivision does not seem very useful.

And finally, it is essential to know whether the roads are open for all traffic, or restricted to certain categories of vehicles (e.g. motor traffic only).

In this way, all urban roads can be subdivided in 11 classes:

	A urban freeway	
B 1 busy mainstreet	B 2 lively mainstreet	B 3 quiet mainstreet
C 1 busy sidestreet	C 2 lively sidestreet	C 3 quiet sidestreet
D 1 busy residential street	D 2 lively residential street	D 3 quiet residential street
	E woonerf	

"Busy" in main streets may mean something quite different from "busy" in residential streets. At present, only very preliminary data are available as regards the actual number of vehicles corresponding with the different classes.

It is suggested to apply the following intensity values, based on the "busiest hour", the morning or evening rush hour of week days (vehicles per hour)

B 1 > 1500	B 2 > 500	B 3 > 150
C 1 > 500	C 2 > 150	C 3 > 50
D 1 > 150	D 2 > 50	D 3 > 0

It must be stressed that these figures are a rough first suggestion only. Not only are main streets with lower than 150 veh/h possible; more important is that the classes are split up exclusively on the basis of motor vehicles. The number of other road users, notably of pedal bicyclists and moped riders may differ quite markedly from the motor vehicle trends.

As regards the design criteria for these different classes of road, we will concentrate on the public lighting. In order to establish the lighting requirements, however, the main characteristics of construction and operation must be taken into account. In this respect, a general division according carriageway-width and operation speed seems to be adequate - at least for classes B, C and D. Class A - urban freeways - are usually restricted for motor traffic only, and have more or less motorway standards: dual carriageway roads, parallel roads or routes for slow traffic, limited access. An operation speed (defined here as the highest speed that can be used safely and with reasonable comfort under prevailing traffic conditions - not to be confused with the design speed, the speed limit or the actual driving speed) of 70 km/h or more is feasible. Class E again is quite different; this will be discussed separately.

Usually class B 1 and occasionally B 2 and C 1 will be dual-carriageway roads, or roads with parallel roads and/or separate cycle tracks. They will usually have a width corresponding with 4 to 6 traffic lanes (two directions together). The classes C 3, D 2 and D 3 usually are quite narrow, the road width corresponding to about 2 traffic lanes, one of which often is occupied by parked cars. In the other classes (D 1, C 2 and B 3) one may find all sorts design.

The values of traffic and of the width of the carriageway have to be reconsidered for one-way roads.

The operation speed can be indicated only very roughly. One may suppose that the operation speed is primarily related to the function of the road. In good design the road width should be selected in such a way that the operation speed can be maintained for different levels of travel intensity. Therefore, it seems justified to give one value only for the operation speed for each group of roads. The following values are suggested:

B : 50 km/h
C : 40 km/h
D : 30 km/h.

3. REQUIREMENTS FOR PUBLIC LIGHTING FOR ROADS IN RESIDENTIAL AREAS

As indicated already, usually all urban roads have public lighting. It is therefore primarily a matter of indicating the quality (or quantity) of lighting, rather than a question of installing public lighting or not. In this respect, the situation differs from that outside built-up areas. Most standards and recommendations concentrate on "important" roads; the lighting of lower categories of roads in residential areas is hardly discussed.

Driving a car can be described in terms of a hierarchy of levels of decision making processes. One of these levels contains the elementary manoeuvres such as: "stopping" "changing speed", etc. All driving manoeuvres can be described in terms of the four elementary manoeuvres (1).

The functional requirements of lighting of residential areas follow from two considerations: firstly in all-purpose roads the elementary manoeuvre "stopping" must be possible. This implies that the object for which one may have to stop must be visible from an adequate distance. And secondly, on all-purpose roads such objects may be of all kinds. More in particular, one has to reckon with dark-clad pedestrians.
The required visibility distance must at least be equal to the stopping distance.
The stopping distance depends upon the driving speed, the "reaction" time and the deceleration; these in their turn depend on the class of road. For the classes of road B, C and D the operation speeds of 50, 40 and 30 km/h have been suggested; as a first approximation they will be used as the actual driving speed (v). The reaction time (t) must be larger in more dense traffic, and the maximum deceleration (a) is smaller. The stopping distance s follows from the well-known formula

$$s = vt + \frac{v^2}{2a}.$$

The values of t and a for "busy" will be taken as 3 s and 2 m/s^2 respectively, for "lively" as 2 s and 3 m/s^2, and for "quiet" as 1 s and 4 m/s^2 respectively. The values are to some extent arbitrary but they correspond to what is usually accepted (2).
In this way, the following stopping distances (and thus visibility distances) will be arrived at:

B 1 $\sim$ 90 m	B 2 $\sim$ 60 m	B 3 $\sim$ 38 m
C 1 $\sim$ 64 m	C 2 $\sim$ 43 m	C 3 $\sim$ 27 m
D 1 $\sim$ 42 m	D 2 $\sim$ 28 m	D 3 $\sim$ 17 m

In view of the fact that the selected values of v, t and a are somewhat arbitrary, it seems justified to round off the values of the required stopping distance as follows:

B 1 > 90 m	B 2 > 60 m	D 3 > 40 m
C 1 > 60 m	C 2 > 40 m	C 3 > 30 m
D 1 > 40 m	D 2 > 30 m	D 3 > 20 m

In this way, the nine classes of roads in residential areas with mixed function can, regarding the visibility requirements, be subdivided in five groups. Within each group the traffic, the road width and the required stopping distance are equal and thus so are the lighting requirements, although in other respect (function, operation speed) they may be quite different. The five groups are:

Group	Classes	Traffic volume	Road width	Stopping distance
a	B 1	> 1500 veh/h	4 - 6 lanes	> 90 m
b	C 1 ; B 2	> 500 veh/h	4 - 6 lanes	> 60 m
c	D 1 ; C 2 ; B 3	> 150 veh/h	variable	> 40 m
d	D 2 ; C 3	> 50 veh/h	2 lanes	> 30 m
e	D 3	> 0 veh/h	2 lanes	> 20 m

The next step is to derive lighting requirements. These requirements can be set up when the traffic situation and the required visibility are known. As we focussed on the elementary manoeuvre "stopping" it is primarily the average road surface luminance and the degree of uniformity of the luminance pattern that are important (3). Visual guidance and glare, usually considered as at least as important in rural roads, play a minor rôle in roads in residential areas.

The quantification of the lighting requirement in terms of the road surface luminance for the five groups of roads is not an easy task. During the last three decades, a considerable amount of research has been devoted to this question (1) (3) (4) (5). The results, however, cannot be applied directly to residential areas as the research was primarily focussed on major urban thoroughfares with heavy, mixed traffic and many disturbing factors (parked vehicles, pedestrians crossing the road, show windows etc.). Besides, driving comfort was the major criterion for quality. Thus, the often-quoted value of 2 cd/m^2 for the average road-surface luminance, justifiable as it may be, does not apply for the roads discussed in this paper.

It is generally accepted, and supported by practical experience, that the luminance level may be lowered if the visual requirements are lower. This is not self evident, as the visual components are the same for all road traffic situations. Lowering the requirements can be argued, however, on the grounds that in less complicated traffic situations the driving task is less demanding, and that comfort requirements can be lessened. Quantification, however, is difficult; the luminance values recommended in different codes are to a certain extent arbitrary. And finally, it has been found in practice that in residential streets the quality of the public lighting cannot be described very adequately by means of the average road-surface luminance pattern.

The average illuminance is often used in this case. Although it is not related very closely to the visual aspect of the road lighting, at least it is easy to calculate and to measure. The minimum requirements for residential streets have been investigated by Tan (6) (7). The general results were that a lighting which resulted in an illuminance of some 2 to 3 lux is accepted by lighting experts, residents and police authorities as adequate. A much higher level is often considered as excessive for quiet residential streets although a level of 5 lux is often accepted for streets that have to a certain extent a traffic function (8) (9) (10). Regarding a lower level of some 1 to 2 lux, the opinions of the residents on the one hand and of lighting experts and police on the other hand did not agree completely - be it that this level is not considered as being objectionably low.

This approach, involving the residents and the police, is an interesting one, because is has been found that the usual types of subjective appraisals made by lighting experts often have too large a spread to be useful for the assessment of the lighting level in roads in residential areas.

Further research obviously is required; it seems, however, reasonable to suggest - on the basis of the above considerations - as a first approximation the following lighting levels:

Group	Classes	Lighting level
a	B 1	L_{av} 1.5 to 2 cd/m^2
b	C 1 ; B 2	L_{av} 1 to 1.5 cd/m^2
c	D 1 ; C 2 ; B 3	L_{av} 0.5 to 1 cd/m^2
d	D 2 ; C 3	E_{av} 3 to 5 lux
e	D 3	E_{av} 2 to 3 lux

Recommendations for urban motorways are given a.o. in the CIE publication (3). The "woonerf" will be discussed lateron.

At the moment, it is not possible to give more information regarding uniformity and glare.

It is generally accepted that a classification of roads should be based on the idea that within one group all roads must be simular, consistent, recognisable, and all driver behaviour should also be similar, consistent, and above all, predictable (11). This should be kept in mind for future elaborations of the classification.

4. THE "WOONERF"

In the 'fifties and the early 'sixties, towns gradually were flooded by cars, causing, apart from the obvious economic losses due to the congestions, a marked increase in road accidents, noise, air pollution etc. The result was in most cities a drastic reduction in the quality of life, in amenity.

Many individuals did believe that the solution for all this grief was the complete and total banning of all motor traffic, at least in residential areas. The results of this endeavour were quite unsatisfactory in residential areas; they were, however, highly successful in shopping areas and other pedestrian precincts.

A more modern approach is based on the realization that the private motorcar is an essential part of modern daily life, and that it should be integrated in, and not banned from living. The most consequent and complete elaboration to data of this idea is the "woonerf" concept (residential yard concept) which has been developed in recent years in The Netherlands. The basic idea is that the houses and the open space between the houses together should allow the residents to live there. The woonerf therefore is primarily aimed at improving the quality of live, the amenity. As said already, the primary tool for this is the integration of the motorcar: the car must loose its predominant position. Although not primarily a traffic safety measure, it goes without saying that any increase in accidents cannot be accepted.

The increase in amenity is realised by four independend sets of measures.
1. Legal measures.
Both for the authority and for the road users (not only the drivers!) a complete new set of regulations has been introduced. The most striking regulations are:
- authorities must comply to a number of standards before a street may become a woonerf.
- vehicles may not proceed faster than at a walking pace.
- parking is permitted on specially marked parking areas only.

- the paved area is available for all users, all drivers and pedestrians - and children!; there is no distinction between the carriageway and the pavement.

2. Road construction and traffic management measures.
- the actual driving path is narrow (some 2 to 3 m).
- at a spacing of maximum 50 m physical and visual obstructions must be erected, which force drivers to obey the speed limit.

3. Planning measures.
- the woonerf concept should not be restricted to individual streets.
- establishments that attract much traffic should be left outside the woonerf (hospitals, shopping centres, etc.).
- the woonerf should clearly look like a woonerf; it must be clearly indicated as such.

4. Social measures.
- citizen participation is considered to be an integral and essential part of the decission processes regarding the woonerf.

Although most elements of the woonerf concept are well-known and applied in many countries with positive results, it is the combination, the total concept which makes the woonerf an outstanding new development (12) (13) (14) (15) (16).

Regarding the lighting, the woonerf differs markedly from other roads, particularly from residential streets. Firstly, the amenity is the major aspect of the woonerf concept: this has repercussions on the lighting. Secondly, the physical and visual obstacles that are required in the woonerf, necessitate a careful planning of the lighting. And thirdly, the fact that pedestrians and playing children may use the whole paved area will result in more possible "conflicts" between pedestrians and motorists.
On the other hand, the very low driving speed (walking pace is to mean in practice 10 km/h or less) may reduce the difficulties in some ways.

A detailed analysis (17) (18) resulted in the following suggestions for recommendations for the lighting of the woonerf:

A. The average illuminance on the main paved area should be about 5 lux. This value is suggested on the basis of the considerations which have been used in the earlier recommendation for roads in residential areas (Group d, above).

B. The minimum illuminance on the main paved area should be at least 1 lux. This suggestion is based on the fact that pedestrians must be able to see where they walk. The actual value of 1 lux is recommended for emergency path lighting (19) (20), although Clark & Clark (21) suggests a much higher value - 10 lux, and Simmons (22) suggests a much lower value - some 0,2 lux.

C. The illuminance on a vertical plane at important locations within the woonerf should be about 20 lux. This is sufficient to be able to recognise facial expressions; a requirement that is important for the social aspects of life, like meeting people or playing. This value is based on the investigations of Fischer (23) (24).

D. The liveliness of the surroundings is favoured by a certain variation of the lighting in different spots. Based on the suggestions of a minimum illuminance of 1 lux and a vertical illuminance of 20 lux or more, a value of 20:1 for the horizontal illuminance seems adviseable as well. A more uniform lighting might be dull; a greater non-uniformity might be unfavourable for visibility. It should be noted that this non-uniformity is greater than what is normally recommended for interior and for road lighting.

E. Because the requirements relate to amenity, the colour of the light should be pleasant and the colour rendition should be quite good. It is suggested that the colour temperature be lower than some 3500 K or the colour rendition factor Ra over 60 and preferably both combined. This implies that most types of fluorescent tubes can be used, and to a certain extent also fluorescent high pressure mercury and high pressure sodium lamps - and, of course, incandescent lamps. Which lamp type is to be selected is to a large extent dependent on other considerations, notably costs, but also glare restriction and the preferred mounting height.

F. Glare should not be excessive, and light should not shine directly into the houses. This puts considerable restrictions to the type of luminaire and to the mounting height. Quantitative data, however, are difficult to give.

G. And finally a very important general statement: it is essential that all the (physical and visual) obstacles, which are placed in the street in order to reduce the speed of driving, should be made very clearly visible, particularly at night under adverse weather conditions. In order to ensure this, the positioning of the luminaires must be considered very carefully. Usually the obstacles are fitted with retro-reflectors.

In a woonerf, just as in any street, the road surface is an important factor to consider. More specifically, the surface should have a high, diffuse reflection in dry, damp and wet conditions, and it should enable certain variations in aspects. Bricks or paving stones are most suitable, although asphalt concrete can be acceptable as well.

5. VEHICLE LIGHTING; USE OF RETRO-REFLECTORS

The recommended values of the luminance and of the illuminance suggested above do usually not provide a level of visibility similar to that of the day-time. This implies that additional means are required, means for illumination and for marking of motor vehicles and of bicycles. Furthermore, the use of retro-reflectors is to be considered.

Regarding the lighting of motor vehicles, the following remarks can be made.
- present-day side lights are often too weak for marking purposes although most modern cars in good technical condition have lights of some 10 cd (25);
- the luminous intensity of normal European or Anglo-American low beam headlamps is much higher than the optimum intensity for marker lights at night; the intensity should be between 20 and 100 cd (25);
- the visibility of obstacles on the road will improve when low beam headlamps are used only when the object is very close to the car (important for slow traffic), when the level of street lighting is under about 0.2 cd/m^2 (26) or when the objects carry retro-reflectors (27) (28).

Based on these considerations, in many circles the use of an intermediate light ("town beam") has been advocated (29) (30) (31) (32). The town beam concept, however, dit not always meet a favourable reception, the major argument being the statement that the town beams are specially designed, and specially effective on the (small number of) well-lit streets. This, however, is not true. As indicated by Knudsen (26) low beams do not help when the luminance is over 0.2 cd/m^2. This corresponds in most cases to some 3 to 5 lux. Therefore, only in class D 3 (quiet residential streets) visibility with low beams is better than with town beams. In view of the simple traffic situations in those streets, and the prevailing low driving speed, it is highly questionable whether this improvement in visibility really is worth-while.
Glare, however, is important and becomes more disturbing when the

adaptation luminance (i.e. the average road-surface luminance) is lower.

In the woonerf the situation is quite different. Because the speed is low, the stopping distance may be short, and so the required visibility distance. Furthermore, the obstacles which are placed on purpose in the woonerf usually carry reflectors. So low beams do not seem to be necessary. Glare, however, in a woonerf is even more disturbing than in a residential street as all road users (drivers, cyclists and pedestrians) use the same paved area (33).

In summary it can be stated that the town beam concept seems to be suited particularly well for urban streets. Low beam headlamps can be used on well lit, important roads as these are usually wide and even have often a central reserve.

The lighting and signalling of other vehicles, notably pedal bicycles and mopeds, is an important but grossly neglected area. It has been pointed out repeatedly - and supported by accident data - that two-wheelers are a very vulnerable group, both at day and at night. However, the regulations and the technology of bicycle lighting is often very poor.
The use of retro-reflectors does receive more attention. Particularly for pedal bicycles and for pedestrians a wide variety of retro-reflective materials and devices are available.
Although much of the research and regulatory effort is concentrated on the rural situation, it must be stressed that reflectorisation may be an important accident counter-measure in urban areas as well (27) (28) (34).

6. CONCLUSIONS

- When considering public lighting, urban roads which have both travel and origin/destination functions can be classified in five groups, that differ primarily in traffic intensity.
- Different levels of luminance (in some cases of illuminance) can be allotted to the different groups of roads.
- The woonerf requires a somewhat different design of public lighting, particularly at its main purpose is to enhance the amenity.
- Low beam headlamps are not very well suited to be used as marker lights in built-up areas.
- In most urban conditions, town beams are to be preferred to low beam headlamps. In the other urban cases the two are more or less equivalent.
- Lighting and marking of pedal bicycles and mopeds deserves serious attention.
- The application of retro-reflective devices for obstacles (particularly in the woonerf) and for pedestrians is to be considered as an important accident counter-measure.

LITERATURE

1. Schreuder, D.A., 1977. "The relation between lighting parameters and transportation performance". Institute for Road Safety Research SWOV, Voorburg.

2. CIE, 1979. "Light signals for road traffic control. Technical Report. Commission Internationale de l'Eclairage, Paris. (In press).

3. CIE, 1977. "Recommendations for the lighting of roads for motorised traffic". Publication No. 12/2. Commission Internationale de l'Eclairage, Paris.

4. De Boer, J.B., 1951. "Fundamental experiments on visibility and admissible glare in road lighting". Commission Internationale de l'Eclairage, Stockholm.

5. De Boer, J.B. (ed.), 1967. "Public lighting". Centrex, Eindhoven.

6. Tan, T.H., 1978. "Openbare verlichting buiten de bebouwde kom" (Rural public lighting). Electrotechniek 56, 921-926.

7. Tan, T.H., 1978. "Appraisals of the lighting of residential streets". Report to the NSvV. (Unpublished).

8. NSVV, 1974/1975. "Richtlijnen en aanbevelingen van openbare verlichting" (Recommendations for public lighting). Electrotechniek 52, No. 15; 53, No. 2, No. 5.

9. NSVV, 1977. "Het lichtniveau van de openbare verlichting in de bebouwde kom" (Urban public lighting levels). Electrotechniek 55, 90-91.

10. Hendriks, J.H., 1978. "Openbare verlichting in de bebouwde kom" (Urban public lighting). Electrotechniek 56, 917-920.

11. Janssen, S.T.M.C., 1974. "Verkeersveiligheid als criterium voor het wegontwerp" (Road safety as a criterion for road design). Vereniging Het Nederlandsche Wegencongres, 's-Gravenhage.

12. Anon, 1975. "Woonerven". Groene reeks No. 21. Vereniging van Nederlandse Gemeenten, 's-Gravenhage.

13. ANWB, 1976. "De inrichting van een woonerf" (The equipment of a woonerf). Koninlijke Nederlandse Toeristenbond ANWB, 's-Gravenhage.

14. De Jaeger, W.G., 1977. "Residential yards". IV World Transportation Engineering Conference, Mexico.

15. Van den Bogaerde, G.H., 1977. "Transportation policy in relation tot the environmental values in The Netherlands". IV World Transportation Engineering Conference, Mexico.

16. Schreuder, D.A., 1977. "Integration of motor traffic in residential areas". IV World Transportation Engineering Conference, Mexico.

17. Schreuder, D.A., 1978. "Woonerven en hun verlichting" (The lighting of the woonerf). Electrotechniek 56, 633-639.

18. Schreuder, D.A., 1978. "Die Beleuchtung in der Strasse als Wohnviertel". Lichttechnische Gemeinschaftstaging, Amsterdam.

19. NNI, 1971. "Veiligheidsvoorschriften voor laagspanningsinstallaties" (Safety standards for low tension installations). NEN 1010. Nederlands Normalisatie-instituut, Rijswijk.

20. CIE, 1977. "Guide on the emergency lighting of premises". Draft. (Not published).

21. Clark, F. & Clark, R., 1978. "Emergency; one man's answers". Lighting Design and Appl. 8 (10), 16-19.

22. Simmons, R.C., 1975. "Illuminance, diversity and disability glare in emergency lighting". Lighting Res. & Technol. 7, 125-132.

23. Fischer, D., 1972. "Beleuchtungsstärken, Leuchtdichten und Farben in Arbeitsräumen". Lichttechnik 24, 411-415.

24. Fischer, D., 1973. "A luminance concept for working interiors". Journ. IES, 92-98.

25. Schreuder, D.A., 1976. "Voertuigverlichting binnen de bebouwde kom (Vehicle lighting within built-up areas). Institute for Road Safety Research SWOV, Voorburg.

26. Knudsen, B., 1968. "Dangerous points in street lighting" (in Danish). Dansk Vejtidsskrift 8, 153-164.

27. OECD, 1975. "Road marking and delineation". Organisation for Economic Co-operation and Development, Paris.

28. OECD, 1976. "Final report and conclusions of the OECD initiated group on Lighting, visibility and accidents". Organisation for Economic Co-operation and Development, Paris.

29. CIE, 1976. "Statement from the Commission Internationale de l'Eclairage on vehicle front lighting used on urban traffic routes". CIE bull., 6-7.

30. OECD, 1979. "Road safety at night". Organisation for Economic Co-operation and Development, Paris. (In press).

31. Sabey, B.E., 1971. "A fully automatic headlight dimming system". Commission Internationale de l'Eclairage, Barcelona.

32. SWOV, 1969. "Side-lights and low-beam headlamps within built-up areas". Institute for Road Safety Research SWOV, Voorburg.

33. Ten Grotenhuis, D.H., 1976. "Inrichting van woonerven: voorwaarden voor functioneren" (Equipment of the woonerf; conditions for functioning). Verkeerstechnische leergang Koninklijke Nederlandse Toeristenbond ANWB, 's-Gravenhage.

34. OECD, 1978. "Safety of two-wheelers". Organisation for Economic Co-operation and Development, Paris.