Road lighting: Safety management for urban intersection

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Synopsis

Road intersection reliability depends on several factors, between which road lighting assumes particular importance.
This must reveal the presence of intersection, the directions of the confluent and diverging roads, the position of the sidewalks, the presence of pedestrians and other customers, the obstructions, the movement of the vehicles.
Experimental studies have demonstrated that the visibility of an object on the road depends mainly on the level of luminance of the road, but also on the uniformity of luminance and from the produced conditions of dazzle from luminous sources.
In the intersections, the criterion of the luminance is not always applicable because the observation distances are small or for the calculation difficulty if the intersection is wide; in these cases, then, is used the criterion of the illuminance.
The analysis, lead in our research, consists in the survey of the values of luminance and illuminance of 252 junctions, belonging at the city of Catania, and in the creation of an index to correlate the level of really lighting system with the degree of safety offered from the road intersections.
For every intersection, it has been defined a level of service lighting – technique, from the level A for the intersections to smaller risk of incident until the level E for the intersections to greater risk of incident.
The issues of this research are important because have allowed to find the levels of luminance and illuminance in the intersections and to underline the necessity of detailed study to improve the level of lighting and to reduce therefore the risk of incidents.
The elaborated index, moreover, being born from a general methodology, will be able to concur to extend the safety analysis to all the intersections in varies urban contexts, allowing to improve the liveability, in terms of public safety and of the circulation.

Road lighting: Safety management for urban intersection

A primary purpose of lighting a roadway at night is to increase the visibility of the roadway and its immediate environment, thereby permitting the driver to maneuver more efficiently and safely. The visibility of an object is that property which makes it discernible from its surroundings. This property of an object depends on a combination of the following factors: 1) the differences in luminance, hue, and saturation between the object and its immediate background (contrast); 2) the angular size of the object at the eye of the observer; 3) the luminance of the background against which it is seen; 4) the duration of the observation.
Historically, two complementary measures of lighting system performance have been employed: (1) illuminance, or the amount of light from an installation incident upon a given surface of interest (visibility target) in the roadway environment, and (2) luminance, or the amount of reflected light returned to the driver's eye from the visibility target.
The optimal design of highway lighting systems incorporates photometric properties of light sources, lighting geometry, targets, road conditions, road surfaces, and surroundings. These are the physical properties of a lighting system that are important for defining the visual stimulus. Once the stimulus is defined, the visibility of targets can be calculated using models that are based on psychophysical data on the visual processing of spatial (angular size of target), temporal (exposure duration) and spectral (brightness and color) information. Visibility models must also incorporate age-related changes in visual processing efficiency that have pronounced effects on target visibility.
Visibility factors are extremely important in the design of highway lighting. Illuminance criteria have been proven to be inadequate predictors of the effectiveness of lighting systems. Although the visibility of targets is typically directly proportional to illuminance (all other variables held constant), there are too many intervening variables that determine the visual stimulus and the efficiency with which that stimulus is processed by the visual system. Even if visibility criteria are used in the design of lighting systems, this is not always predictive of lighting system effectiveness, when accident rates are used as the measure of effectiveness (MOE). For example, there have been some reports of accident rates increasing after installation of fixed lighting systems (Gordon and Schwab, 1979). Although the reasons for this are not well-understood, it is hypothesized that some lighting systems can actually reduce the average contrast of targets even though they meet lighting specifications based on pavement illuminance, set prior to 1982 (Keck, 1989).
In the intersections, the criterion of the luminance is not always applicable because the observation distances are small or because of calculation difficulty if the intersection is wide; in these cases, then, illuminance criterion is used.
The analysis, leader in our research, consists in the survey of the values of luminance and illuminance of 252 junctions, belonging at the city of Catania, and in the creation of an index to correlate the level of actual lighting system with the degree of safety offered from road intersections.
For every intersection, it has been defined a level of service lighting – technique, from the level A for the intersections at smaller risk of incident until the level E for the intersections at greater risk of incident.
The elaborated index, moreover, being born from a general methodology, will be able to concur to extend the safety analysis to all the intersections in different urban contexts, allowing to improve the liveability, in terms of public safety and of the circulation.

EFFECTS OF PUBLIC LIGHTING ON ROADS URBAN SAFETY

Public lighting is functional and the effect of lighting depends on the extent to which the task is fulfilled.
The first question relating to effectiveness is: what are the benefits of public lighting? Many researches have been carried out about this subject in the past. This was usually based on before-and-after studies.
The result of these studies can be expressed in a single sentence: on urban roads, with mainly a traffic function, a reduction in accidents involving injuries of approximately 30% can be expected at night, following an improvement in the lighting from very bad to good.
The result of the review conduct in Norway reads: the best current estimate as regards the safety of road lighting is a 65% reduction in night-time injury accident and a 15% reduction in night-time property damage only accidents. This conclusion was based on 142 studies. Most related to lighting within urban areas.
One of the most important studies was carried out in England. All relevant data relating to accidents and lighting were collected in relation to 70 urban arterial dual carriage roads with a speed limit of 40 miles/h. A clear relationship was found between the risk, expressed in the night/day ratio for accidents and the luminance level (Fig. 1).

When the analysis was restricted to accidents with no pedestrians involved, there proved to be a relationship between the n/d ratio and the uniformity, in addition to the relation between the n/d ratio and the luminance level (Fig. 2).
Figure 2 shows a peculiarity: the n/d ratio increased with increasing uniformity.

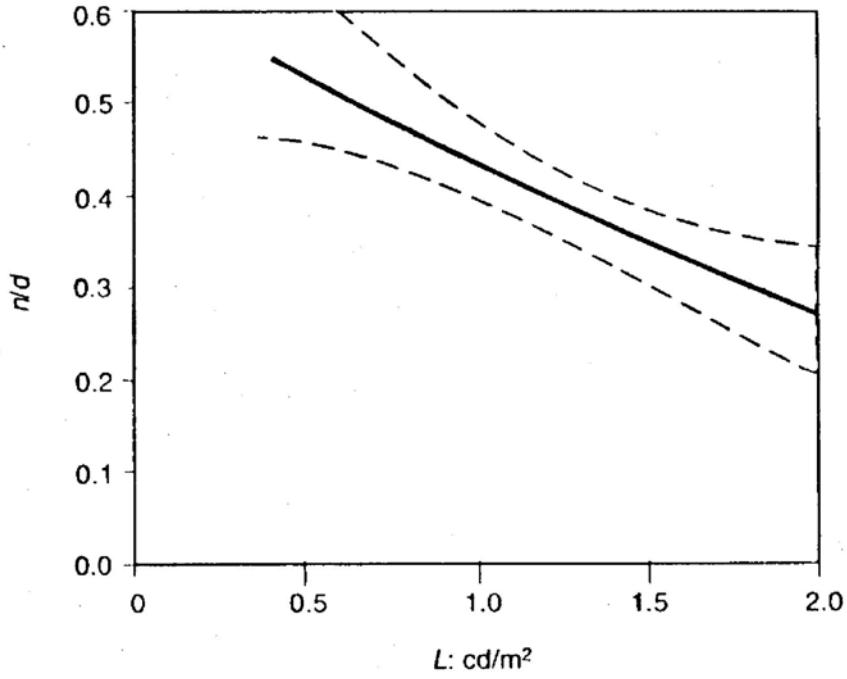

Figure 1: The relationship between the n/d ratio and the luminance level

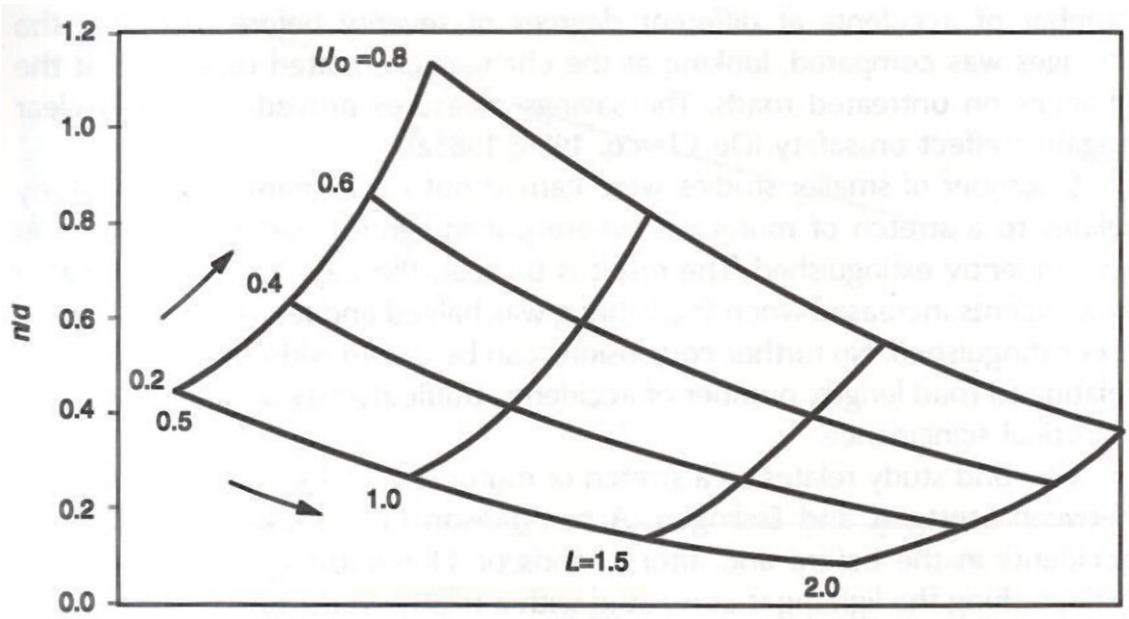

Figure 2: The relationship between the n/d ratio, the luminance level and uniformity. Accidents evolving pedestrations excluded.

SWOV has carried out a series into the relationship between level of lighting and traffic safety. The research was drawn up as a set of correlation studies. Data from Amsterdam, Leeuwarden, Utrecht, Oss and Barendrecht were used. The accident records comprised 22333 recorded accidents, of which 17020 occurred during the day and 5313 in darkness.
The results for the traffic roads and for the residential roads – stretches and crossroads – are shown in figure 3 e 4.

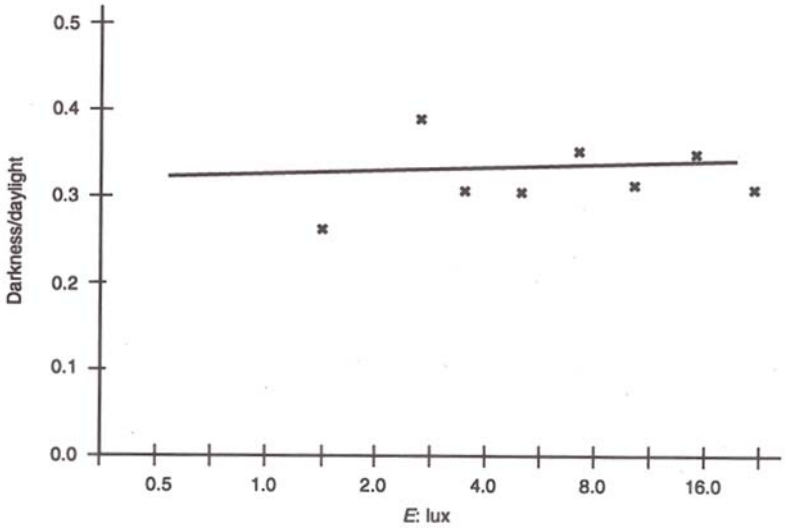

Figure 3: The relationship between accidents during darkness and in daylight on urban roads with a traffic function (road stretches + crossroads)

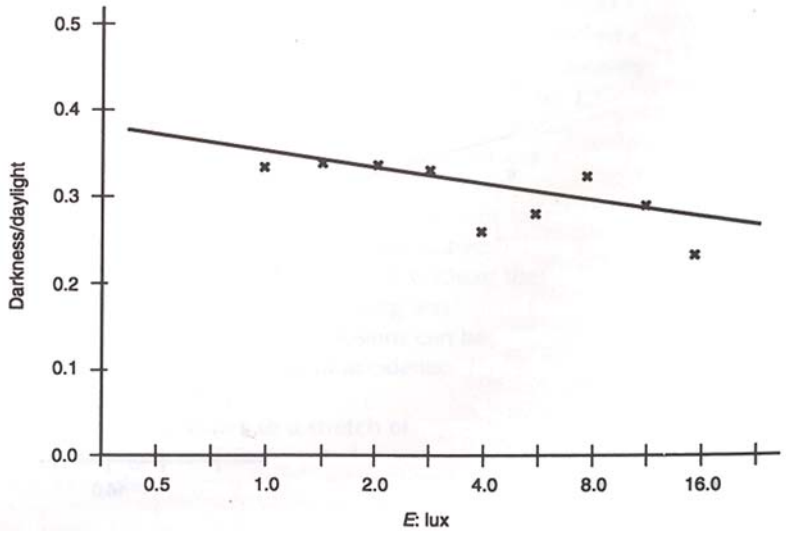

Figure 4: The relationship between accidents during darkness and in daylight on urban roads with a residential function (road stretches + crossroads)

EXPERIMENTAL SURVEY

Illuminance and luminance measures have been carried out on a sample of 252 urban road intersections, belonging to the city of Catania, with at least a night incident in three years (1999-2001).
Before the survey, it has been realized a cartography of the city of Catania, in which the intersections have been quoted. In order to render easier the survey's execution, in the cartography the intersections have been numbered in progressive order, indicating for everyone the names of the ways that they merge in the intersection. Trough a worksheet, it has been realized a schedule in which has been included:

- • the progressive numeration of the intersections;
- • the names of the ways that they merge in the intersection;
- • the presence of the lighting system;
- • the disposition of the poles (in frontal position, staggered, to quincunx, hung);
- • the presence of other sources of lighting system (neon signs, illuminated shop windows, etc.);
- • the presence of obstacles (trees, advertising panels, etc);
- • the measured values of the luminance;
- • the measured values of the illuminance;
- • the illuminance and luminance values recommended by rule CIE 115/95,

The table 1 filler the information deriving from the compilation of the schedules for all the examined intersections.

Table 1.a: Parameters of reference for the study of the 252 road intersections

INTERSECTION	STREET 1	STREET 2	STREET 3	PRESENCE OF THE LIGHTING SYSTEM	DISPOSITION OF POLES	OTHER SOURCES OF LIGHTING SYSTEM	OBSTACLES	LUMINANCE	ILLUMINANCE	LUMINANCE (CIE 115/95)	ILLUMINANCE (CIE 115/95)
1	Viale Ulisse	V.le M. Polo	Via B. Colnago	No		No	No	0,5	1,5	1	7,5
2	V.le M. Polo	Via S. Caboto		No		No	No	1,5	1,5	1	7,5
3	V.le M. Polo	Via Pidatella		Yes	Unilateral	Yes	Yes	1,5	2,8	1	7,5
5	Via B.Grassi	V,le O. Da Pordenone	Via Pietra Dell'Ova	No		Yes	No	1,5	1,5	1	7,5
6	V.le A. Doria	V.le Fleming		Yes	Light tower	Yes	No	2	1,7	1	7,5
7	V.le A. Doria	V.le Fratelli Vivaldi	Via S. Sofia	No		Yes	No	1	1	1	7,5
8	Via Galermo	V.le Fratelli Vivaldi	V.le A Usodimare	No		Yes	No	1	1	1	7,5
9	Via S. Nullo	V.le A Usodimare		No		Yes	No	1	1,1	1	7,5
10	Via S. Catania	V.le A Usodimare		No		No	No	1	1,1	1	7,5
11	V.le L. Bolano	Via F. Durante		No		Yes	No	1	2	1	7,5
12	V.le L. Bolano	Via A. Pacinotti	V.le Fontana	No		Yes	No	2	2	1	7,5
13	Via Galatioto	Via Macaluso		No		No	No	1	1,5	1	7,5
14	Via Galatioto	Via Villaglori		No		No	No	1,5	1,6	1	7,5
15	Via Galatioto	Via Savasta		No		Yes	No	2	2,1	1	7,5
16	Via Galatioto	Via De Caro		No		No	No	1	1,8	1	7,5
17	Via Galatioto	Via Re Martino		No		Yes	No	1,5	3,6	1	7,5
18	Via Galatioto	Via Messina		No		No	No	2,5	1,7	1	7,5
21	Via Del Rotolo	Via Alcide De Gasperi	Via Barraco	No		Yes	No	2	2	1	7,5
22	V.le Artale Alagona	Via Parrocchia	Via Imbert	No		Yes	No	3	1,3	1	7,5
23	Via Principe Nicola	Via Timoleone		No		No	No	1,5	2,2	0,75	10
24	Via Principe Nicola	Via Wrzì		No		No	No	1,5	2,2	0,75	10
25	Via Principe Nicola	Via G. Borrello		No		No	No	1	0,4	0,75	10
26	Via Duca Degli Abruzzi	Via Principe Nicola		No		Yes	No	3,4	2,2	1	7,5
27	Via Duca Degli Abruzzi	Via Falsaperla		No		No	No	1,5	2,9	1	7,5
28	Via Duca Degli Abruzzi	Via Cavaliere		No		No	No	2,5	1,5	1	7,5
29	Via Duca Degli Abruzzi	Via Della Tessitoria	Via Caduti Del Lavoro	No		No	No	1,5	2,7	1	7,5
30	Via Duca Degli Abruzzi	Via Vezzosi		No		Yes	No	1	1,3	1	7,5
31	Via Vezzosi	Via M. Scammacca		No		Yes	No	1	0,8	0,75	10
32	Via Vezzosi	Via Petrella		No		No	No	1	3	0,75	10
33	Via Vezzosi	Via Capriolo		No		No	No	0,5	0,7	0,75	10
34	Via Caduti Del Lavoro	Via Capriolo		No		No	No	1	1,6	0,75	10
35	Via Caduti Del Lavoro	Via Petrella		No		No	No	1,5	1,5	0,75	10
36	Via Caduti Del Lavoro	Via Regina Bianca		No		Yes	No	1,5	1,4	0,75	10
37	V.le Vitt. Veneto	Via Ravenna		No		Yes	No	1,5	2,2	1	7,5
38	V.le Vitt. Veneto	Via R. C. Patanè		No		Yes	No	2	0,9	1	7,5
39	V.le Vitt. Veneto	Via D. Bramante		No		Yes	No	2	0,9	1	7,5
40	V.le Vitt. Veneto	Via Cagliari		No		Yes	No	2	1,1	1	7,5

Table 1.b: Parameters of reference for the study of the 252 road intersections

INTERSECTION	STREET 1	STREET 2	STREET 3	PRESENCE OF THE LIGHTING SYSTEM	DISPOSITION OF POLES	OTHER SOURCES OF LIGHTING SYSTEM	OBSTACLES	LUMINANCE	ILLUMINANCE	LUMINANCE (CIE 115/95)	ILLUMINANCE (CIE 115/95)
41	V.le Vitt. Veneto	Via Napoli		No		Yes	No	1,5	0,8	1	7,5
42	V.le Vitt. Veneto	Via Caserta		No		Yes	No	1,5	1,6	1	7,5
43	V.le Vitt. Veneto	Via G. D'Annunzio	Via G. Leopardi	No		Yes	No	1,5	1,4	1	7,5
44	V.le Vitt. Veneto	Via Milano		No		Yes	No	1,5	1,1	1	7,5
45	V.le Vitt. Veneto	Via Firenze		No		Yes	No	1,5	0,8	1	7,5
46	V.le Vitt. Veneto	C.so Delle Province	V.le Jonio	No		Yes	No	0,5	0,4	1	7,5
47	V.le Vitt. Veneto	V.le Libertà	C.so Italia	No		Yes	Yes	0,5	1,7	1	7,5
48	V.le Libertà	Via Umberto		No		Yes	No	1,5	1,5	1	7,5
49	V.le Libertà	Via Mascagni		No		Yes	No	2	1,9	1	7,5
50	V.le Libertà	Via Costarelli		Yes	Unilateral with two lamps	Yes	No	1	3	1	7,5
51	V.le Libertà	Via Simeto		No		Yes	No	1,5	1,9	1	7,5
52	V.le Libertà	C.so Martiri Della Libertà		No		Yes	No	1	0,9	1	7,5
53	V.le Africa	Via Raffineria		No		Yes	Yes	2	1,2	1	7,5
54	P.za Galatea			No		Yes	No	2	2,3	1	7,5
55	C.so Italia	V.le Ruggero Di Lauria		No		Yes	No	1,5	4,2	1	7,5
56	Via Messina	Via Asiago		No		Yes	No	1	0,9	1	7,5
57	Via Messina	C.so Italia		No		Yes	No	0,5	1,7	1	7,5
58	Via Vecchia Ognina	Via Asiago		No		Yes	No	2,5	0,8	0,75	10
59	Via G. Leopardi	Via G. Macherione		No		Yes	No	0,5	1,1	1	7,5
60	Via G. Leopardi	Via S. Fulci		No		No	No	1,5	1,2	1	7,5
61	Via G. Leopardi	Via Malta		No		Yes	No	1,5	0,7	1	7,5
62	Via G. D'Annunzio	Via Oliveto Scammacca		No		No	No	1,5	1,4	1	7,5
63	Via G. D'Annunzio	Via Padova		No		Yes	No	1,5	0,9	1	7,5
64	Via G. D'Annunzio	C.so Delle Province		Yes	Hung with two lamps	Yes	No	2,5	2	1	7,5
65	Via G. D'Annunzio	Via Vitt. E. Orlando		No		Yes	No	2	1	1	7,5
66	Via Monserrato	Via Caronda		No		No	No	2	0,5	1	7,5
67	Via Monserrato	Via Etnea		No		No	No	2,5	1,9	1	7,5
68	Via S. Nicolò Al Borgo	Via A. Longo		No		No	No	3	1,9	0,75	10
71	Via Cesare Beccaria	Via Cifali		No		Yes	Yes	1	0,7	0,75	10
72	Via Oliveto Scammacca	C.so Delle Province		No		No	No	0,5	0,4	1	7,5
73	Via Oliveto Scammacca	Via Milano		No		No	No	1,5	0,6	1	7,5
74	Via Oliveto Scammacca	Via Aosta		No		Yes	No	1,5	2,4	1	7,5
75	Via Oliveto Scammacca	Via Genova		No		No	No	1	1,8	1	7,5
76	Via Oliveto Scammacca	Via Napoli		No		No	No	1	1,8	1	7,5
77	Via Oliveto Scammacca	Via Sassari		No		Yes	No	2	2,3	1	7,5

Table 1.c: Parameters of reference for the study of the 252 road intersections

INTERSECTION	STREET 1	STREET 2	STREET 3	PRESENCE OF THE LIGHTING SYSTEM	DISPOSITION OF POLES	OTHER SOURCES OF LIGHTING SYSTEM	OBSTACLES	LUMINANCE	ILLUMINANCE	LUMINANCE (CIE 115/95)	ILLUMINANCE (CIE 115/95)
78	Via Oliveto Scammacca	V.le R. Sanzio	Via Bernini	No		Yes	No	2	4,1	1	7,5
79	V.le R. Sanzio	Via Vitt. E. Orlando		No		Yes	Yes	1	2,7	1	7,5
80	Via Vitt. E. Orlando	Via Sassari		No		No	Yes	0,5	0,9	1	7,5
81	Via Vitt. E. Orlando	Via Cagliari		No		Yes	No	1,5	3	1	7,5
82	Via Vitt. E. Orlando	Via Genova		No		No	No	1	1,8	1	7,5
83	Via Vitt. E. Orlando	C.so Delle Province		No		Yes	No	2,5	1,9	1	7,5
84	Via Vitt. E. Orlando	Via Firenze		No		No	No	1	0,8	1	7,5
85	Via Vitt. E. Orlando	C.so Italia		No		Yes	No	2	1,2	1	7,5
86	Via F. Crispi	Via C. Ruggero		No		Yes	No	1	1	1	7,5
87	Via F. Crispi	Via Umberto		No		Yes	No	1	1,4	1	7,5
88	Via F. Crispi	Via D'Amico		No		Yes	No	1	1,6	1	7,5
89	Via F. Crispi	Via Archimede		No		No	No	1	1,1	1	7,5
90	Via F. Crispi	C.so Martiri Della Libertà		No		Yes	No	1	2,4	1	7,5
91	Via F. Crispi	Via Marchese Di Casalotto		No		Yes	No	1	1,2	1	7,5
92	Via F. Crispi	Via A. Di Sangiuliano		No		No	No	2	2	1	7,5
93	C.so Italia	Via Simili		No		Yes	No	2	3,3	1	7,5
94	C.so Italia	Via G. Carnazza		No		Yes	No	4,5	5,1	1	7,5
95	Via V. Giuffrida	V.le XX Settembre		No		Yes	No	1,5	1,8	1	7,5
96	V.le XX Settembre	Via Musumeci		No		Yes	No	4	1,9	1	7,5
97	V.le XX Settembre	Via G. Oberdan		No		Yes	No	2	1,6	1	7,5
98	V.le XX Settembre	Via Grotte Bianche		No		Yes	No	2	2,2	1	7,5
99	Via Musumeci	Via C. Ruggero		No		No	No	2,5	1,6	0,75	10
100	V.le XX Settembre	Via R. Imbriani		Yes	Lateral to wall	Yes	No	2	2,1	1	7,5
101	V.le XX Settembre	Via Etnea	V.le Regina Margherita	No		Yes	No	2	3,1	1	7,5
102	V.le Regina Margherita	Via S. Euplio		No		No	No	0,5	1,2	1	7,5
103	V.le Regina Margherita	Via A. Longo	Via Tomaselli	Yes	Hung	Yes	No	1,5	2,5	1	7,5
104	V.le Regina Margherita	Via Ipogeo		No		No	No	2,5	1,7	1	7,5
105	V.le M. Rapisardi	Via Lavaggi	Via F. Filzi	No		Yes	No	3	1,9	1	7,5
106	C.so Martiri Della Libertà	Via E. De Nicola		No		Yes	Yes	1,5	4,6	1	7,5
107	Via Cardinale Dusmet	P.za S. Francesco Di Paola		Yes	Hung	Yes	No	1,5	1,2	1	7,5
108	Via Cardinale Dusmet	Via Calì		No		Yes	No	1	1,3	1	7,5
109	Via Calì	P.za M. Cutelli		No		Yes	No	1	1,1	0,75	10
110	Via V. Emanuele II	Via Ventimiglia		No		Yes	No	3,5	2	1	7,5
111	Via A. Di Sangiuliano	Via Ventimiglia		No		Yes	No	1	2,3	1	7,5
112	Via G. Di Prima	Via Ventimiglia		No		No	No	1,5	1,7	0,75	10
113	C.so Martiri Della Libertà	Via Fischetti		No		Yes	No	1	2,8	1	7,5

Table 1.d: Parameters of reference for the study of the 252 road intersections

INTERSECTION	STREET 1	STREET 2	STREET 3	PRESENCE OF THE LIGHTING SYSTEM	DISPOSITION OF POLES	OTHER SOURCES OF LIGHTING SYSTEM	OBSTACLES	LUMINANCE	ILLUMINANCE	LUMINANCE (CIE 115/95)	ILLUMINANCE (CIE 115/95)
114	C.so Martiri Della Libertà	Via Ventimiglia		No		Yes	No	2	1,5	1	7,5
115	Via Mons. Ventimiglia	Via G. Bruno		No		No	No	1	1,3	0,75	10
116	Via Mons. Ventimiglia	Via G. Verdi		No		No	No	1	1,3	0,75	10
117	Via Mons. Ventimiglia	Via L. Capuana		No		No	No	1	1,3	0,75	10
118	Via Mons. Ventimiglia	Via Finocchiaro Aprile		No		No	No	1	1,3	0,75	10
119	Via Mons. Ventimiglia	Via Umberto		No		No	No	1	1,5	1	7,5
120	Via Mons. Ventimiglia	Via C. Ruggero		No		No	No	1	0,9	0,75	10
121	Via V. Giuffrida	Via Firenze		No		Yes	No	5	1,3	1	7,5
122	Via V. Giuffrida	Via Della Fiaccola		No		No	No	2	2,4	1	7,5
123	Via V. Giuffrida	Via Napoli		No		No	No	1,5	0,4	1	7,5
124	Via V. Giuffrida	V.le R. Sanzio		No		No	No	3	2,3	1	7,5
125	Via V. Giuffrida	Via Siena		No		No	No	0,5	1,8	1	7,5
126	Via V. Giuffrida	Via G. Carducci		No		Yes	No	1	1,1	1	7,5
127	Via L. Sturzo	Via Fischetti		No		Yes	No	1	1,2	0,75	10
128	Via Torino	Via L. Pirandello	Via F. Fusco	No		Yes street-lamp	No	1	4,4	1	7,5
129	Via Torino	Via Siena		No		Yes	No	1,8	3,6	0,75	10
130	Via R. Imbriani	Via Dei Miti		No		Yes	No	1	1,6	0,75	10
131	Via R. Imbriani	Via Passo Di Aci		No		Yes	No	1	1,1	0,75	10
132	Via R. Imbriani	Via Canfora		No		Yes	No	1	2,1	0,75	10
133	C.so Delle Province	Via Guardia Della Carvana		No		Yes	No	1	1,3	1	7,5
134	C.so Delle Province	Via Cagliari		No		No	No	1	1	1	7,5
135	Via Balduino	Via Enna		No		No	No	2	2,5	0,75	10
136	Via Caronda	Via Passo Di Aci	Via Fulci	No		No	No	1,5	2,5	0,75	10
137	Via Caronda	Via Canfora		No		Yes					
138	Via Caronda	Via Sisto		No		Yes	No	1,5	0,8	0,75	10
139	Via Caronda	Via G. De Felice		No		Yes	No	1	2,5	0,75	10
140	Via Caronda	Via Umberto (luce bianca)	Via Etnea	No		No	Yes	1	2,2	1	7,5
141	Via Etnea	P.za Stesicoro		No		Yes	No	2	1,9	1	7,5
142	Via Etnea	P.za Stesicoro		No		Yes	No	2	1,4	1	7,5
143	Via S. M. Betlem	Via C. F. Gambino		No		Yes	No	2,5	2,6	0,75	10
144	Via Umberto	Via G. Oberdan		No		Yes	No	4	2,3	1	7,5
145	Via Umberto	Via Grotte Bianche		No		Yes	No	1	1,2	1	7,5
146	C.so Sicilia	Vi a L. Rizzo		No		Yes	No	2	2,2	1	7,5
147	C.so Sicilia	Via G. Puccini		No		Yes	No	1,5	1,8	1	7,5
148	C.so Sicilia	Via S. M. Betlem		No		Yes	No	3	2,8	1	7,5
149	Via Cappuccini	Via S. Euplio		No		Yes	No	1	1,1	0,75	10
150	Via P. Garofalo	Via Cappuccini		No		Yes	No	1,5	1,6	0,75	10

Table 1.e: Parameters of reference for the study of the 252 road intersections

INTERSECTION	STREET 1	STREET 2	STREET 3	PRESENCE OF THE LIGHTING SYSTEM	DISPOSITION OF POLES	OTHER SOURCES OF LIGHTING SYSTEM	OBSTACLES	LUMINANCE	ILLUMINANCE	LUMINANCE (CIE 115/95)	ILLUMINANCE (CIE 115/95)
151	Via Del Plebiscito	Via Antico Corso	Via M. Martoglio	No		No	No	1	1,4	1	7,5
152	Via Del Plebiscito	Via Osservatorio		No		Yes	No	1	1,5	1	7,5
153	Via A. Di Sangiuliano	Via Delle Finanze		No		No	No	1	0,6	1	7,5
154	Via A. Di Sangiuliano	Via Coppola		No		No	No	2	2,2	1	7,5
155	Via A. Di Sangiuliano	Via Etnea		No		Yes	No	3	2,5	1	7,5
156	Via V. Emanuele II	Via Landolina		No		No	No	1,5	0,8	1	7,5
157	Via V. Emanuele II	Via Raddusa		No		Yes	No	0,5	0,7	1	7,5
158	Via V. Emanuele II	Via S. G. Al Duomo		No		No	No	1	1,1	1	7,5
159	Via V. Emanuele II	Via S. M. Delle Grazie		No		No	No	0,5	1,1	1	7,5
160	Via V. Emanuele II	Via Pozzo Canale		No		No	No	0,5	1,1	1	7,5
161	Via V. Emanuele II	Via Della Palma		No		No	No	2	1,5	1	7,5
162	Via Del Tempio	Via Del Principe		No		Yes	No	2	1,9	1	7,5
163	Via G. Garibaldi	Via Del Plebiscito		No		Yes	No	1,5	1,9	1	7,5
164	Via G. Garibaldi	Via SS. Trinità		No		No	No	3	1,9	1	7,5
165	Via G. Garibaldi	Via S. Chiara		No		Yes	No	2	1,2	1	7,5
166	Via G. Garibaldi	Via Castello Ursino		No		Yes	No	2	1,2	1	7,5
167	Via Cardinale Dusmet	Via S. Gaetano		No		No	No	1,5	1	1	7,5
168	Via C. Colombo	Via Del Tempio	Via Mulino S. Lucia	No		Yes	No	1,5	0,8	1	7,5
169	Via Del Plebiscito	Via S. M. Dell'Aiuto		No		Yes	No	2	1,7	1	7,5
170	Via L. Sturzo	Via G. Puccini		Yes	Hung	Yes	No	1,5	1,9	0,75	10
171	Via Biondi	Via G. Di Prima		No		No	No	2	2,4	0,75	10
172	Via Etnea			No		Yes	No	1,5	4,6	1	7,5
173	Via Etnea	Via Andronico		No		Yes	No	0,5	2,2	1	7,5
174	Via Muscatello	Via A. Longo		Yes	Hung	No	No	1,5	1,4	0,75	10
175	Via S. Euplio	Via A. Longo		Yes	Hung with two lamps	No	Yes	2,5	2,5	0,75	10
176	Via F. Ciccaglione	Via A. Longo		No		Yes	No	2	1,5	0,75	10
177	P.za Cavour	Via Etnea		No		Yes	No	2,5	1,1	1	7,5
178	Via Etnea	Via Empedocle		No		Yes	No	2	1,1	1	7,5
179	Via Etnea	Via Finocchiaro	Via Lopis	No		No	No	1,5	0,7	1	7,5
180	Via Etnea	Via Ingegnere		No		No	No	0,5	0,9	1	7,5
181	Via S. Tomaselli	Via Dott. Consoli		No		Yes	No	1	1,4	1	7,5
182	L.go Paisiello	Via Pacini		Yes	Unilateral with two lamps	Yes	No	1	0,9	1	7,5
183	Via Androne	Via Morosoli		No		Yes	No	2,5	1,6	1	7,5
184	Via Lago Di Nicito	Via Dott. Consoli		No		No	Yes	1,5	1,7	0,75	10
185	Via N. Martoglio	Via Ughetti		Yes		No	No	1,5	1,2	0,75	10
186	Via Lago Di Nicito	Via Ughetti		No		No	No	2	1,1	0,75	10
187	Via F. Filzi	Via Ughetti		No		Yes	No	1	1,7	0,75	10

Table 1.f: Parameters of reference for the study of the 252 road intersections

INTERSECTION	STREET 1	STREET 2	STREET 3	PRESENCE OF THE LIGHTING SYSTEM	DISPOSITION OF POLES	OTHER SOURCES OF LIGHTING SYSTEM	OBSTACLES	LUMINANCE	ILLUMINANCE	LUMINANCE (CIE 115/95)	ILLUMINANCE (CIE 115/95)
188	Via C. Forlanini	Via Citelli		No		No	No	1	1,2	0,75	10
189	Via Macallè	Via Rocca Romana		No		No	No	1	1,3	0,75	10
190	Via Lago Di Nicito	Via Rocca Romana		No		No	Yes	1	3,3	0,75	10
191	Via N. Martoglio	Via Rocca Romana		No		No	No	1,5	1,9	0,75	10
192	Via Cifali	Via Chisari		No		No	No	1	1,9	0,75	10
193	Via Aporti	Via Lavaggi	Via C. Beccaria	No		No	No	2	2,8	1	7,5
194	Via Lavaggi	Via R. Franchetti		No		No	No	1,5	2,9	1	7,5
195	Via Cantone	P.za V. Spedini		No		Yes	No	1,5	0,8	0,75	10
196	Via Maratona	P.za V. Spedini		No		Yes	No	1,5	0,8	0,75	10
197	Via Aporti	Via Amm. Toscano	Via G. Fava	No		Yes	No	2	1,9	1	7,5
198	Via G. Fava	Via R. Franchetti		No		No	No	2	2	1	7,5
199	Via G. Fava	V.le M. Rapisardi		No		No	No	1,5	0,9	1	7,5
200	Via Rasa	V.le M. Rapisardi		No		No	No	1,5	0,8	1	7,5
201	Via Stazzone	V.le M. Rapisardi		No		Yes	No	1,5	1	1	7,5
202	Via Mandrà	V.le M. Rapisardi		No		Yes	No	2	1,9	1	7,5
203	Via Cardì	V.le M. Rapisardi		No				2	1,8	1	7,5
204	Via A. Merlino	Via V. Casagrandi		No		Yes	No	1,5	1,4	0,75	10
205	Via P. Carrera	Via V. Casagrandi		No		No	No	1,5	1,6	0,75	10
206	Via Cibele	Via V. Casagrandi		No		No	No	2	1,7	0,75	10
207	Via Nuova	Via V. Casagrandi	Via Susanna	Yes	Central 4 street-lamps	Yes	No	1	3,1	0,75	10
208	Via Amm. Caracciolo	Via Cronato		No		Yes	No	1	0,9	1	7,5
209	Via Amm. Caracciolo	Via Saffi		No		Yes	No	1	0,9	1	7,5
211	Via Delle Medaglie D'Oro	Via Montenero		No		No	No	1	1,6	1	7,5
212	Via Delle Medaglie D'Oro	Via Ghiaioti		No		No	No	2	1	1	7,5
213	Via Acquedotto Greco	Via S. M. Della Catena		No		No	No	1	0,3	0,75	10
214	Via Delle Medaglie D'Oro	Via S. M. Della Catena		No		No	No	1	1	1	7,5
215	Via V. Emanuele II	Via Case Sante		No		No	No	1,5	1,2	1	7,5
217	Via Aurora	Via Palermo		No		No	No	1	0,7	1	7,5
218	Via Aurora	Via A. Giusti	Via Missori	No		No	No	1	0,9	1	7,5
219	Via Cernaia	Via Palermo		No		Yes	No	2	0,4	0,75	10
220	Via Milo	Via Orto Limoni		No		No	No	1,5	1,8	0,75	10
221	Via A. Merlino	Via Marletta		No		No	No	0,5	0,9	0,75	10
222	Via Nuova	Via Stella	Via G. Verdura	No		No	No	1	1,4	0,75	10
223	Via Gallo	V.le M. Rapisardi		No		No	No	1,5	2,3	1	7,5
224	Via E. Cosenz	V.le M. Rapisardi		No		No	No	1	1,5	1	7,5
225	Via E. Cosenz	Via Sapri		No		No	No	1	1,2	0,75	10
226	Via XXXI Maggio	Via Sapri		No		No	No	1	1	0,75	10
227	Via Agira	Via Maroncelli		No		No	No	0,5	1,4	0,75	10
228	Via Della Bainsizza	C.so IV Novembre		No		No	No	1	1,2	0,75	10

Table 1.g: Parameters of reference for the study of the 252 road intersections

INTERSECTION	STREET 1	STREET 2	STREET 3	PRESENCE OF THE LIGHTING SYSTEM	DISPOSITION OF POLES	OTHER SOURCES OF LIGHTING SYSTEM	OBSTACLES	LUMINANCE	ILLUMINANCE	LUMINANCE (CIE 115/95)	ILLUMINANCE (CIE 115/95)
229	Via Della Concordia	Via Scaldara		No		No	No	0,5	0,5	0,75	10
230	Via Della Concordia	Via Adamo		No		No	No	1	1,8	0,75	10
231	Via Della Concordia	Via Belfiore		No		No	No	0,5	0,5	0,75	10
232	Via Della Concordia	Via De Lorenzo		No		No	No	0,5	0,5	0,75	10
233	Via Della Concordia	Via Cordai		No		No	No	0,5	0,5	0,75	10
234	Via Della Concordia	Via Mulino A Vento		No		No	No	0,5	0,5	0,75	10
235	Via G. Ballo	Via Paradiso	Via F. De Sanctis	No		No	No	1	1,8	0,75	10
237	Via A. Diaz	Via S. Grasso	Via A. Locatelli	No		No	No	3	2,2	0,75	10
238	V.le M. Rapisardi	Via G. Ferraris		No		Yes	No	1	2,6	1	7,5
239	V.le M. Rapisardi	Via M. Lessona		No		No	No	1	2,6	1	7,5
240	V.le S. Pio X	Via N. Dato		No		Yes	No	2	2,3	0,75	10
241	Via E. Barsanti	Via T. Tasso		No		No	No	1	2	0,75	10
242	Via E. Barsanti	V.le M. Rapisardi		Yes	Street lamp with 6 lamps	Yes	No	3	0,9	1	7,5
243	Via A. Pacinotti	V.le M. Rapisardi		No		Yes	No	1	1,2	1	7,5
244	Via Palermo	V.le M. Rapisardi		Yes	Street lamp with 4 lamps	Yes	No	2,5	2,5	1	7,5
245	C.so Indipendenza	Via A. Umbria		No		Yes	No	1,5	1,3	1	7,5
246	C.so Indipendenza	C.so IV Novembre		No		Yes	Yes	3	0,8	1	7,5
247	Via Palermo	Via Goito		No		Yes	No	1	1,7	0,75	10
248	Via G. Ballo	Via Scannapieco		No		Yes	No	1	0,7	0,75	10
249	Via S. Sofia	Via Varese		Yes	Unilateral with 1 lamp	No	No	2	1,1	0,75	10
250	Via M. Sangiorgi	Via Umberto		No		Yes	No	1,5	1,5	1	7,5
251	Via Ficarazzi	Via C. Vivante		No		No	No	1	1	0,75	10
252	Via E. D'Angiò	Via Calatabiano		No		Yes	No	5	3,8	0,75	10

Procedure of survey's execution

In roads with low density of traffic, the surveys have been carry out from the 21.00 until the 4.00. In the roads with more intense traffic, they have been executed after the 24.00; in fact the greater presence of vehicles would have distorted the survey, because of the light coming from the systems of lighting of the vehicles.

The surveys have been execute in some days of the week, from Monday to Thursday, avoiding the weekend. In the rain days, the surveys have been avoided: in fact on wetting road, the measures would have been influenced from the reflections caused by water. The measures have been executed using a quanto-photo-radiometer of medium precision coupled to an adjustable tripod (Figure 5).

The instrumentation, product from "Delta Ohm" is called 9021 HD: it is a portable instrument with interchangeable probes and is equipped with two input connector A and B, that concur to carry out two measures at the same time.

Have been used two probes:

1. HD 9021 PHOT/C: photometric probe for measuring light illuminance, with measuring range from 0 to 200.000 lux;
2. HD 9021/Cd: probe for measuring luminance, with measuring range from 0 to $1999*10^3$ cd/m^2.

Both are equipped of photopic correction filter, according to the human eye, complying with CIE rules.

Figure 5: Quantum-photo-radiometer and photometric probes

The measure of illuminance has been carried out with the probe situated on the point to survey, at eye-level from road surface (1.10 m). The measure of the medium luminance, instead, has been carried out with the probe on the tripod, fixed at 1,10 m from the road surface. The instrument, that measure the luminance, collects the light reflected from internal surface to the visual cone of magnitude of 6°, having the same axis of the probe.
The portion of the road concerned from the survey is comprised between 60 m and 160 m from the observation point; in fact, if we consider driver's eye at 1,10 m of height, its field of vision is delimited from lines slanted of an angle that goes from 0,5 to 1,5 degrees compared with horizontal. In order to make so that the supremum of the visual cone falls to 160 m from the point of observation and the infimum to 10 m from the observation point, the probe, for the measure of the luminance has been situated on the tripod with an angle of 3,4° compared with horizontal.
In all the intersections, the survey has been carried out placing the tripod to 60 m from the point in which we must measure the luminance, and placing the probe, for the measure of the illuminance, in correspondence of the same point.
For the execution of the measures, the presence of other sources of lighting system or obstacles has been kept in account, which illuminated shop windows or trees that might negatively influence the propagation of the light.
Moreover, the intersections, illuminated from specific lighting-tecnique dispositions, are little, because the greater part of these receive the light from the merging street.
The results of the survey are quoted in table 1.

Definition of an index for the correlation between artificial brightness and safety of road intersections

After having found all the values of luminance and illuminance for the 252 intersections, an index has been elaborated that allows to correlate the values of luminance and illuminance with the number of night incidents. It has been used a diagram, obtained experimentally: it exhibits the relationship of darkness/daylight incidents with the relative level of lighting (luminance or illuminance).
For a level of lighting higher than the recommended value, this relationship grows after a point of inflection. Generally since the level of street lighting does not exceed the values recommended by the rules, we have considered only the part of curve with decreasing trend. From such diagram, it is possible to extract the number of darkness/daylight incidents in function of the relationship between the value of real lighting and the value of lighting given from the rules; noted this value, can be calculated the increment rate of incidents, I_P, with the following relation:

$$I_p = \left(\frac{y_i}{0{,}92} - 1 \right) \cdot 100 \qquad [1]$$

in which:

- y_i is the relationship darkness/daylight of incidents extracted from the diagram of figure 6 in correspondence of the various relationships of lighting;
- 0,92 are the value of y_i in correspondence of zero (Figure 6).

In order to define an appropriate index to correlate the increment of night incidents with the level of lighting, we have observed that the luminance is more important respect the illuminance in the smaller intersections, while in those wide the illuminance plays a more important role. The intersections are wide if the approaches are wide more than 4.00 m and have more than one lane.
The index has been calculated attributing to a greater weight (70%) to the luminance and a smaller weight (30%) to the illuminance, for the smaller intersections; conversely, for the wide intersections, it has been attributed to a weight of 30% to the luminance and 70% to the illuminance.

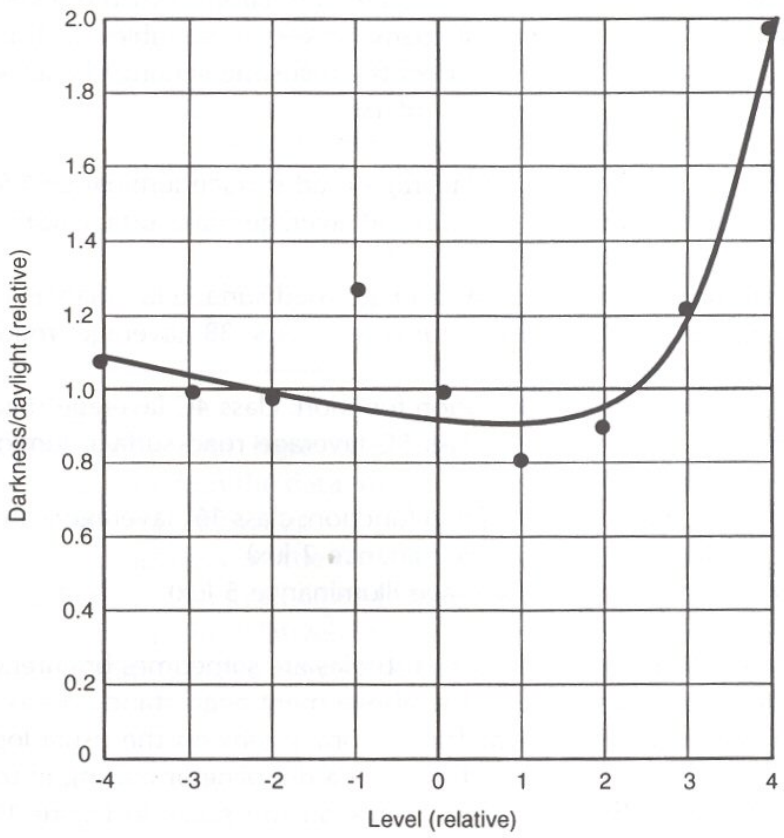

Figure 6: A possible optimum level of lighting. The relative darkness/daylight ratio in relation to the relative level of lighting (0: it corresponds to the NSVV Recommendations).

The index of correlation between safety and lighting is given by the following relations:

- $I.S.I.N._{(1)} = (70 \cdot I_{p(L)} + 30 \cdot I_{p(E)})/100$ [2]
- $I.S.I.N._{(2)} = (30 \cdot I_{p(L)} + 70 \cdot I_{p(E)})/100$ [3]

where:
$I.S.I.N._{(1)}$ is the safety index correlated to the smaller intersection lighting;
$I.S.I.N._{(2)}$ is the safety index correlated to the wide intersection lighting;
$Ip_{(L)}$ is the increment rate of incidents associated to the variability of the parameter luminance (estimated through relation [1]);
$Ip_{(E)}$ is the increment rate of incidents associated to the variability of the parameter illuminance (estimated through relation [1]).
Additionally it has been defined lighting levels of service (LOS)i, in function of the index value (I.S.I.N.) (Table 2).

Table 2; Lighting Levels of Service

$(LOS)_i$	I.S.I.N.
A	$I.S.I.N. \leq 5$
B	$5 < I.S.I.N. \leq 10$
C	$10 < I.S.I.N. \leq 15$
D	$15 < I.S.I.N. \leq 20$
E	$20 < I.S.I.N. \leq 25$
I	$I.S.I.N. > 25$

The level of service A (I.S.I.N. $\leq$ 5) is associate to a level of physiological and practically ineliminable dangerousness.
The level B (5 < I.S.I.N. $\leq$ 10) is indicative of a meaningful, but still tolerable contribution of the conditions of brightness to the degree of risk of the junctions.
The level of service C (10 < I.S.I.N. $\leq$ 15) is indicative of a level of safety seriously conditioned from night vision insufficient supported by the artificial lighting.
The level D (15 < I.S.I.N. $\leq$ 20) represents an extremely critical operating condition.
The level E (20 < I.S.I.N. $\leq$ 25) , finally, reveals conditions of insufficient or null brightness.
With I (I.S.I.N. > 25), instead, we have been indicates the bright pollution, that is the cases in which the increment of the number of incidents is due to high brightness.
Finally a table has been realized showing the following data (table 3):

- number of the node;
- effective luminance, L_r;
- optimal medium luminance L_o;
- relationship between effective luminance and optimal medium luminance, L_r / L_o;
- effective illuminance, E_r;
- optimal medium illuminance, E_o;
- relationship between real illuminance and optimal medium illuminance, Er/Eo;
- increment rate of incidents associated to the variability of the parameter luminance, $I_{p(L)}$;
- increment rate of incidents associated to the variability of the parameter illuminance, $I_{p(E)}$;
- safety index associated at junctions brightness, I.S.I.N., estimated with the relation [2] or [3] based on the type of intersection;
- lighting level of service, $(LOS)_i$.

In figure 7 it is related a graphical description of the levels of service associates to the road junctions.

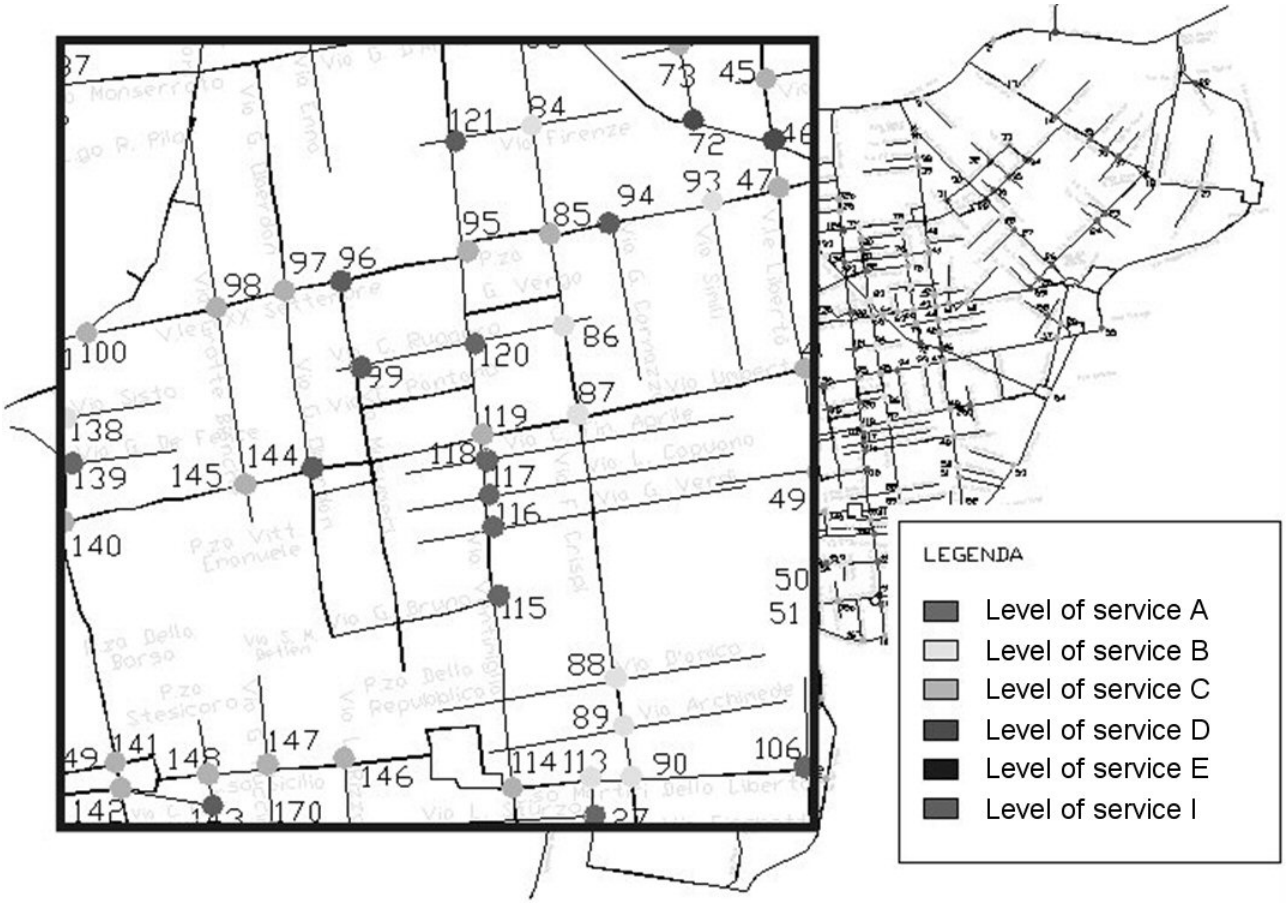

Figure 7: Graphical description of the Levels of Service

Table 3.a: Relative Levels of Service to the 252 analyzed road intersections

Intersection	L_r	L_o	L_r/L_o	E_r	E_o	E_r/E_o	$I_{p(L)}$	$I_{p(E)}$	I.S.I.N.	$(LOS)_i$
17	1,50	1,00	1,50	3,60	7,50	0,48	-3,65	9,93	0,43	A
81	1,50	1,00	1,50	3,00	7,50	0,40	-3,65	12,01	1,05	A
27	1,50	1,00	1,50	2,90	7,50	0,39	-3,65	12,37	1,16	A
194	1,50	1,00	1,50	2,90	7,50	0,39	-3,65	12,37	1,16	A
29	1,50	1,00	1,50	2,70	7,50	0,36	-3,65	13,11	1,38	A
190	1,00	0,75	1,33	3,30	10,00	0,33	-3,07	13,95	2,03	A
207	1,00	0,75	1,33	3,10	10,00	0,31	-3,07	14,53	2,21	A
32	1,00	0,75	1,33	3,00	10,00	0,30	-3,07	14,82	2,30	A
14	1,50	1,00	1,50	1,60	7,50	0,21	-3,65	17,45	2,68	A
139	1,00	0,75	1,33	2,50	10,00	0,25	-3,07	16,31	2,74	A
250	1,50	1,00	1,50	1,50	7,50	0,20	-3,65	17,86	2,81	A
241	1,00	0,75	1,33	2,00	10,00	0,20	-3,07	17,86	3,21	A
122	2,00	1,00	2,00	2,40	7,50	0,32	-1,51	14,24	3,22	A
192	1,00	0,75	1,33	1,90	10,00	0,19	-3,07	18,18	3,30	A
154	2,00	1,00	2,00	2,20	7,50	0,29	-1,51	15,02	3,45	A
247	1,00	0,75	1,33	1,70	10,00	0,17	-3,07	18,82	3,50	A
15	2,00	1,00	2,00	2,10	7,50	0,28	-1,51	15,41	3,57	A
34	1,00	0,75	1,33	1,60	10,00	0,16	-3,07	19,15	3,59	A
106	1,50	1,00	1,50	4,60	7,50	0,61	-3,65	6,79	3,66	A
172	1,50	1,00	1,50	4,60	7,50	0,61	-3,65	6,79	3,66	A
92	2,00	1,00	2,00	2,00	7,50	0,27	-1,51	15,81	3,69	A
222	1,00	0,75	1,33	1,40	10,00	0,14	-3,07	19,80	3,79	A
136	1,50	0,75	2,00	2,50	10,00	0,25	-1,51	16,31	3,84	A
115	1,00	0,75	1,33	1,30	10,00	0,13	-3,07	20,13	3,89	A
116	1,00	0,75	1,33	1,30	10,00	0,13	-3,07	20,13	3,89	A
117	1,00	0,75	1,33	1,30	10,00	0,13	-3,07	20,13	3,89	A
118	1,00	0,75	1,33	1,30	10,00	0,13	-3,07	20,13	3,89	A
127	1,00	0,75	1,33	1,20	10,00	0,12	-3,07	20,47	3,99	A
225	1,00	0,75	1,33	1,20	10,00	0,12	-3,07	20,47	3,99	A
228	1,00	0,75	1,33	1,20	10,00	0,12	-3,07	20,47	3,99	A
109	1,00	0,75	1,33	1,10	10,00	0,11	-3,07	20,80	4,09	A
23	1,50	0,75	2,00	2,20	10,00	0,22	-1,51	17,24	4,12	A
24	1,50	0,75	2,00	2,20	10,00	0,22	-1,51	17,24	4,12	A
226	1,00	0,75	1,33	1,00	10,00	0,10	-3,07	21,14	4,19	A
123	1,50	1,00	1,50	0,40	7,50	0,05	-3,65	22,75	4,27	A
120	1,00	0,75	1,33	0,90	10,00	0,09	-3,07	21,48	4,29	A
111	1,00	1,00	1,00	2,30	7,50	0,31	0,00	14,63	4,39	A
31	1,00	0,75	1,33	0,80	10,00	0,08	-3,07	21,82	4,39	A
191	1,50	0,75	2,00	1,90	10,00	0,19	-1,51	18,18	4,40	A
55	1,50	1,00	1,50	4,20	7,50	0,56	-3,65	7,99	4,50	A
112	1,50	0,75	2,00	1,70	10,00	0,17	-1,51	18,82	4,59	A
184	1,50	0,75	2,00	1,70	10,00	0,17	-1,51	18,82	4,59	A
150	1,50	0,75	2,00	1,60	10,00	0,16	-1,51	19,15	4,69	A
205	1,50	0,75	2,00	1,60	10,00	0,16	-1,51	19,15	4,69	A
35	1,50	0,75	2,00	1,50	10,00	0,15	-1,51	19,47	4,79	A
25	1,00	0,75	1,33	0,40	10,00	0,04	-3,07	23,21	4,81	A
36	1,50	0,75	2,00	1,40	10,00	0,14	-1,51	19,80	4,88	A
174	1,50	0,75	2,00	1,40	10,00	0,14	-1,51	19,80	4,88	A
204	1,50	0,75	2,00	1,40	10,00	0,14	-1,51	19,80	4,88	A
213	1,00	0,75	1,33	0,30	10,00	0,03	-3,07	23,57	4,92	A
212	2,00	1,00	2,00	1,00	7,50	0,13	-1,51	20,02	4,95	A
16	1,00	1,00	1,00	1,80	7,50	0,24	0,00	16,62	4,99	A
82	1,00	1,00	1,00	1,80	7,50	0,24	0,00	16,62	4,99	A
185	1,50	0,75	2,00	1,20	10,00	0,12	-1,51	20,47	5,08	B
128	1,00	1,00	1,00	4,40	7,50	0,59	0,00	7,38	5,17	B
88	1,00	1,00	1,00	1,60	7,50	0,21	0,00	17,45	5,23	B
13	1,00	1,00	1,00	1,50	7,50	0,20	0,00	17,86	5,36	B
78	2,00	1,00	2,00	4,10	7,50	0,55	-1,51	8,31	5,36	B
87	1,00	1,00	1,00	1,40	7,50	0,19	0,00	18,29	5,49	B
138	1,50	0,75	2,00	0,80	10,00	0,08	-1,51	21,82	5,49	B
195	1,50	0,75	2,00	0,80	10,00	0,08	-1,51	21,82	5,49	B

Table 3.b: Relative Levels of Service to the 252 analyzed road intersections

Intersection	L_r	L_o	L_r/L_o	E_r	E_o	E_r/E_o	$I_{p(L)}$	$I_{p(E)}$	I.S.I.N.	$(LOS)_i$
196	1,50	0,75	2,00	0,80	10,00	0,08	-1,51	21,82	5,49	B
30	1,00	1,00	1,00	1,30	7,50	0,17	0,00	18,72	5,61	B
133	1,00	1,00	1,00	1,30	7,50	0,17	0,00	18,72	5,61	B
91	1,00	1,00	1,00	1,20	7,50	0,16	0,00	19,15	5,74	B
89	1,00	1,00	1,00	1,10	7,50	0,15	0,00	19,58	5,87	B
86	1,00	1,00	1,00	1,00	7,50	0,13	0,00	20,02	6,01	B
134	1,00	1,00	1,00	1,00	7,50	0,13	0,00	20,02	6,01	B
214	1,00	1,00	1,00	1,00	7,50	0,13	0,00	20,02	6,01	B
182	1,00	1,00	1,00	0,90	7,50	0,12	0,00	20,47	6,14	B
218	1,00	1,00	1,00	0,90	7,50	0,12	0,00	20,47	6,14	B
84	1,00	1,00	1,00	0,80	7,50	0,11	0,00	20,91	6,27	B
217	1,00	1,00	1,00	0,70	7,50	0,09	0,00	21,37	6,41	B
153	1,00	1,00	1,00	0,60	7,50	0,08	0,00	21,82	6,55	B
93	2,00	1,00	2,00	3,30	7,50	0,44	-1,51	10,95	7,21	B
101	2,00	1,00	2,00	3,10	7,50	0,41	-1,51	11,65	7,70	B
3	1,50	1,00	1,50	2,80	7,50	0,37	-3,65	12,74	7,82	B
50	1,00	1,00	1,00	3,00	7,50	0,40	0,00	12,01	8,41	B
193	2,00	1,00	2,00	2,80	7,50	0,37	-1,51	12,74	8,46	B
103	1,50	1,00	1,50	2,50	7,50	0,33	-3,65	13,86	8,61	B
244	2,50	1,00	2,50	2,50	7,50	0,33	6,41	13,86	8,65	B
74	1,50	1,00	1,50	2,40	7,50	0,32	-3,65	14,24	8,87	B
113	1,00	1,00	1,00	2,80	7,50	0,37	0,00	12,74	8,92	B
223	1,50	1,00	1,50	2,30	7,50	0,31	-3,65	14,63	9,15	B
79	1,00	1,00	1,00	2,70	7,50	0,36	0,00	13,11	9,18	B
83	2,50	1,00	2,50	1,90	7,50	0,25	6,41	16,21	9,35	B
37	1,50	1,00	1,50	2,20	7,50	0,29	-3,65	15,02	9,42	B
238	1,00	1,00	1,00	2,60	7,50	0,35	0,00	13,48	9,44	B
239	1,00	1,00	1,00	2,60	7,50	0,35	0,00	13,48	9,44	B
18	2,50	1,00	2,50	1,70	7,50	0,23	6,41	17,03	9,60	B
183	2,50	1,00	2,50	1,60	7,50	0,21	6,41	17,45	9,72	B
54	2,00	1,00	2,00	2,30	7,50	0,31	-1,51	14,63	9,79	B
77	2,00	1,00	2,00	2,30	7,50	0,31	-1,51	14,63	9,79	B
28	2,50	1,00	2,50	1,50	7,50	0,20	6,41	17,86	9,85	B
227	0,50	0,75	0,67	1,40	10,00	0,14	5,64	19,80	9,89	B
90	1,00	1,00	1,00	2,40	7,50	0,32	0,00	14,24	9,97	B
98	2,00	1,00	2,00	2,20	7,50	0,29	-1,51	15,02	10,06	C
146	2,00	1,00	2,00	2,20	7,50	0,29	-1,51	15,02	10,06	C
51	1,50	1,00	1,50	1,90	7,50	0,25	-3,65	16,21	10,26	C
163	1,50	1,00	1,50	1,90	7,50	0,25	-3,65	16,21	10,26	C
100	2,00	1,00	2,00	2,10	7,50	0,28	-1,51	15,41	10,34	C
221	0,50	0,75	0,67	0,90	10,00	0,09	5,64	21,48	10,39	C
129	1,80	0,75	2,40	3,60	10,00	0,36	4,37	13,11	10,48	C
140	1,00	1,00	1,00	2,20	7,50	0,29	0,00	15,02	10,51	C
95	1,50	1,00	1,50	1,80	7,50	0,24	-3,65	16,62	10,54	C
147	1,50	1,00	1,50	1,80	7,50	0,24	-3,65	16,62	10,54	C
33	0,50	0,75	0,67	0,70	10,00	0,07	5,64	22,17	10,60	C
12	2,00	1,00	2,00	2,00	7,50	0,27	-1,51	15,81	10,61	C
21	2,00	1,00	2,00	2,00	7,50	0,27	-1,51	15,81	10,61	C
198	2,00	1,00	2,00	2,00	7,50	0,27	-1,51	15,81	10,61	C
49	2,00	1,00	2,00	1,90	7,50	0,25	-1,51	16,21	10,90	C
141	2,00	1,00	2,00	1,90	7,50	0,25	-1,51	16,21	10,90	C
162	2,00	1,00	2,00	1,90	7,50	0,25	-1,51	16,21	10,90	C
197	2,00	1,00	2,00	1,90	7,50	0,25	-1,51	16,21	10,90	C
202	2,00	1,00	2,00	1,90	7,50	0,25	-1,51	16,21	10,90	C
11	1,00	1,00	1,00	2,00	7,50	0,27	0,00	15,81	11,07	C
42	1,50	1,00	1,50	1,60	7,50	0,21	-3,65	17,45	11,12	C
203	2,00	1,00	2,00	1,80	7,50	0,24	-1,51	16,62	11,18	C
132	1,00	0,75	1,33	2,10	10,00	0,21	-3,07	17,55	11,36	C
2	1,50	1,00	1,50	1,50	7,50	0,20	-3,65	17,86	11,41	C
5	1,50	1,00	1,50	1,50	7,50	0,20	-3,65	17,86	11,41	C
48	1,50	1,00	1,50	1,50	7,50	0,20	-3,65	17,86	11,41	C

Table 3.c: Relative Levels of Service to the 252 analyzed road intersections

Intersection	L_r	L_o	L_r/L_o	E_r	E_o	E_r/E_o	$I_{p(L)}$	$I_{p(E)}$	I.S.I.N.	$(LOS)_i$
6	2,00	1,00	2,00	1,70	7,50	0,23	-1,51	17,03	11,47	C
169	2,00	1,00	2,00	1,70	7,50	0,23	-1,51	17,03	11,47	C
75	1,00	1,00	1,00	1,80	7,50	0,24	0,00	16,62	11,63	C
76	1,00	1,00	1,00	1,80	7,50	0,24	0,00	16,62	11,63	C
43	1,50	1,00	1,50	1,40	7,50	0,19	-3,65	18,29	11,71	C
62	1,50	1,00	1,50	1,40	7,50	0,19	-3,65	18,29	11,71	C
97	2,00	1,00	2,00	1,60	7,50	0,21	-1,51	17,45	11,76	C
245	1,50	1,00	1,50	1,30	7,50	0,17	-3,65	18,72	12,01	C
230	1,00	0,75	1,33	1,80	10,00	0,18	-3,07	18,50	12,03	C
235	1,00	0,75	1,33	1,80	10,00	0,18	-3,07	18,50	12,03	C
114	2,00	1,00	2,00	1,50	7,50	0,20	-1,51	17,86	12,05	C
161	2,00	1,00	2,00	1,50	7,50	0,20	-1,51	17,86	12,05	C
135	2,00	0,75	2,67	2,50	10,00	0,25	10,34	16,31	12,13	C
211	1,00	1,00	1,00	1,60	7,50	0,21	0,00	17,45	12,21	C
171	2,00	0,75	2,67	2,40	10,00	0,24	10,34	16,62	12,22	C
187	1,00	0,75	1,33	1,70	10,00	0,17	-3,07	18,82	12,25	C
170	1,50	0,75	2,00	1,90	10,00	0,19	-1,51	18,18	12,27	C
60	1,50	1,00	1,50	1,20	7,50	0,16	-3,65	19,15	12,31	C
107	1,50	1,00	1,50	1,20	7,50	0,16	-3,65	19,15	12,31	C
215	1,50	1,00	1,50	1,20	7,50	0,16	-3,65	19,15	12,31	C
142	2,00	1,00	2,00	1,40	7,50	0,19	-1,51	18,29	12,35	C
130	1,00	0,75	1,33	1,60	10,00	0,16	-3,07	19,15	12,48	C
220	1,50	0,75	2,00	1,80	10,00	0,18	-1,51	18,50	12,50	C
119	1,00	1,00	1,00	1,50	7,50	0,20	0,00	17,86	12,51	C
152	1,00	1,00	1,00	1,50	7,50	0,20	0,00	17,86	12,51	C
224	1,00	1,00	1,00	1,50	7,50	0,20	0,00	17,86	12,51	C
44	1,50	1,00	1,50	1,10	7,50	0,15	-3,65	19,58	12,61	C
80	0,50	1,00	0,50	0,90	7,50	0,12	9,43	20,47	12,74	C
151	1,00	1,00	1,00	1,40	7,50	0,19	0,00	18,29	12,80	C
181	1,00	1,00	1,00	1,40	7,50	0,19	0,00	18,29	12,80	C
206	2,00	0,75	2,67	1,70	10,00	0,17	10,34	18,82	12,88	C
167	1,50	1,00	1,50	1,00	7,50	0,13	-3,65	20,02	12,92	C
201	1,50	1,00	1,50	1,00	7,50	0,13	-3,65	20,02	12,92	C
53	2,00	1,00	2,00	1,20	7,50	0,16	-1,51	19,15	12,95	C
85	2,00	1,00	2,00	1,20	7,50	0,16	-1,51	19,15	12,95	C
165	2,00	1,00	2,00	1,20	7,50	0,16	-1,51	19,15	12,95	C
166	2,00	1,00	2,00	1,20	7,50	0,16	-1,51	19,15	12,95	C
64	2,50	1,00	2,50	2,00	7,50	0,27	6,41	15,81	12,99	C
176	2,00	0,75	2,67	1,50	10,00	0,15	10,34	19,47	13,08	C
108	1,00	1,00	1,00	1,30	7,50	0,17	0,00	18,72	13,10	C
189	1,00	0,75	1,33	1,30	10,00	0,13	-3,07	20,13	13,17	C
63	1,50	1,00	1,50	0,90	7,50	0,12	-3,65	20,47	13,23	C
199	1,50	1,00	1,50	0,90	7,50	0,12	-3,65	20,47	13,23	C
40	2,00	1,00	2,00	1,10	7,50	0,15	-1,51	19,58	13,25	C
178	2,00	1,00	2,00	1,10	7,50	0,15	-1,51	19,58	13,25	C
67	2,50	1,00	2,50	1,90	7,50	0,25	6,41	16,21	13,27	C
173	0,50	1,00	0,50	2,20	7,50	0,29	9,43	15,02	13,34	C
145	1,00	1,00	1,00	1,20	7,50	0,16	0,00	19,15	13,40	C
243	1,00	1,00	1,00	1,20	7,50	0,16	0,00	19,15	13,40	C
188	1,00	0,75	1,33	1,20	10,00	0,12	-3,07	20,47	13,40	C
186	2,00	0,75	2,67	1,10	10,00	0,11	10,34	20,80	13,48	C
249	2,00	0,75	2,67	1,10	10,00	0,11	10,34	20,80	13,48	C
41	1,50	1,00	1,50	0,80	7,50	0,11	-3,65	20,91	13,55	C
45	1,50	1,00	1,50	0,80	7,50	0,11	-3,65	20,91	13,55	C
156	1,50	1,00	1,50	0,80	7,50	0,11	-3,65	20,91	13,55	C
168	1,50	1,00	1,50	0,80	7,50	0,11	-3,65	20,91	13,55	C
200	1,50	1,00	1,50	0,80	7,50	0,11	-3,65	20,91	13,55	C
65	2,00	1,00	2,00	1,00	7,50	0,13	-1,51	20,02	13,56	C
131	1,00	0,75	1,33	1,10	10,00	0,11	-3,07	20,80	13,64	C
149	1,00	0,75	1,33	1,10	10,00	0,11	-3,07	20,80	13,64	C
9	1,00	1,00	1,00	1,10	7,50	0,15	0,00	19,58	13,71	C

Table 3.d: Relative Levels of Service to the 252 analyzed road intersections

Intersection	L_r	L_o	L_r/L_o	E_r	E_o	E_r/E_o	$I_{p(L)}$	$I_{p(E)}$	I.S.I.N.	$(LOS)_i$
10	1,00	1,00	1,00	1,10	7,50	0,15	0,00	19,58	13,71	C
126	1,00	1,00	1,00	1,10	7,50	0,15	0,00	19,58	13,71	C
158	1,00	1,00	1,00	1,10	7,50	0,15	0,00	19,58	13,71	C
104	2,50	1,00	2,50	1,70	7,50	0,23	6,41	17,03	13,85	C
61	1,50	1,00	1,50	0,70	7,50	0,09	-3,65	21,37	13,86	C
179	1,50	1,00	1,50	0,70	7,50	0,09	-3,65	21,37	13,86	C
38	2,00	1,00	2,00	0,90	7,50	0,12	-1,51	20,47	13,87	C
39	2,00	1,00	2,00	0,90	7,50	0,12	-1,51	20,47	13,87	C
251	1,00	0,75	1,33	1,00	10,00	0,10	-3,07	21,14	13,88	C
7	1,00	1,00	1,00	1,00	7,50	0,13	0,00	20,02	14,02	C
8	1,00	1,00	1,00	1,00	7,50	0,13	0,00	20,02	14,02	C
73	1,50	1,00	1,50	0,60	7,50	0,08	-3,65	21,82	14,18	C
219	2,00	0,75	2,67	0,40	10,00	0,04	10,34	23,21	14,20	C
52	1,00	1,00	1,00	0,90	7,50	0,12	0,00	20,47	14,33	C
56	1,00	1,00	1,00	0,90	7,50	0,12	0,00	20,47	14,33	C
208	1,00	1,00	1,00	0,90	7,50	0,12	0,00	20,47	14,33	C
209	1,00	1,00	1,00	0,90	7,50	0,12	0,00	20,47	14,33	C
125	0,50	1,00	0,50	1,80	7,50	0,24	9,43	16,62	14,46	C
71	1,00	0,75	1,33	0,70	10,00	0,07	-3,07	22,17	14,59	C
248	1,00	0,75	1,33	0,70	10,00	0,07	-3,07	22,17	14,59	C
47	0,50	1,00	0,50	1,70	7,50	0,23	9,43	17,03	14,75	C
57	0,50	1,00	0,50	1,70	7,50	0,23	9,43	17,03	14,75	C
240	2,00	0,75	2,67	2,30	10,00	0,23	10,34	16,93	14,95	C
148	3,00	1,00	3,00	2,80	7,50	0,37	20,12	12,74	14,95	C
66	2,00	1,00	2,00	0,50	7,50	0,07	-1,51	22,28	15,14	D
1	0,50	1,00	0,50	1,50	7,50	0,20	9,43	17,86	15,33	D
177	2,50	1,00	2,50	1,10	7,50	0,15	6,41	19,58	15,63	D
155	3,00	1,00	3,00	2,50	7,50	0,33	20,12	13,86	15,74	D
102	0,50	1,00	0,50	1,20	7,50	0,16	9,43	19,15	16,23	D
124	3,00	1,00	3,00	2,30	7,50	0,31	20,12	14,63	16,27	D
59	0,50	1,00	0,50	1,10	7,50	0,15	9,43	19,58	16,54	D
159	0,50	1,00	0,50	1,10	7,50	0,15	9,43	19,58	16,54	D
160	0,50	1,00	0,50	1,10	7,50	0,15	9,43	19,58	16,54	D
180	0,50	1,00	0,50	0,90	7,50	0,12	9,43	20,47	17,16	D
105	3,00	1,00	3,00	1,90	7,50	0,25	20,12	16,21	17,38	D
164	3,00	1,00	3,00	1,90	7,50	0,25	20,12	16,21	17,38	D
229	0,50	0,75	0,67	0,50	10,00	0,05	5,64	22,86	17,70	D
231	0,50	0,75	0,67	0,50	10,00	0,05	5,64	22,86	17,70	D
232	0,50	0,75	0,67	0,50	10,00	0,05	5,64	22,86	17,70	D
233	0,50	0,75	0,67	0,50	10,00	0,05	5,64	22,86	17,70	D
234	0,50	0,75	0,67	0,50	10,00	0,05	5,64	22,86	17,70	D
157	0,50	1,00	0,50	0,70	7,50	0,09	9,43	21,37	17,79	D
46	0,50	1,00	0,50	0,40	7,50	0,05	9,43	22,75	18,75	D
72	0,50	1,00	0,50	0,40	7,50	0,05	9,43	22,75	18,75	D
22	3,00	1,00	3,00	1,30	7,50	0,17	20,12	18,72	19,14	D
242	3,00	1,00	3,00	0,90	7,50	0,12	20,12	20,47	20,36	E
246	3,00	1,00	3,00	0,80	7,50	0,11	20,12	20,91	20,67	E
110	3,50	1,00	3,50	2,00	7,50	0,27	39,61	15,81	22,95	E
58	2,50	0,75	3,33	0,80	10,00	0,08	32,47	21,82	25,02	I
143	2,50	0,75	3,33	2,60	10,00	0,26	32,47	16,01	27,53	I
175	2,50	0,75	3,33	2,50	10,00	0,25	32,47	16,31	27,62	I
99	2,50	0,75	3,33	1,60	10,00	0,16	32,47	19,15	28,47	I
137	2,50	0,75	3,33	1,50	10,00	0,15	32,47	19,47	28,57	I
26	3,40	1,00	3,40	2,20	7,50	0,29	35,25	15,02	29,18	I
144	4,00	1,00	4,00	2,30	7,50	0,31	64,88	14,63	29,70	I
96	4,00	1,00	4,00	1,90	7,50	0,25	64,88	16,21	30,81	I
237	3,00	0,75	4,00	2,20	10,00	0,22	64,88	17,24	31,53	I
94	4,50	1,00	4,50	5,10	7,50	0,68	95,94	5,37	32,54	I
68	3,00	0,75	4,00	1,90	10,00	0,19	64,88	18,18	50,87	I
121	5,00	1,00	5,00	1,30	7,50	0,17	132,78	18,72	98,56	I
252	5,00	0,75	6,67	3,80	10,00	0,38	297,36	12,55	211,92	I

From the analysis of the table 3, it can be deduced the elevated night riskiness of great part of the intersections used like sample.
The calculation of index I.S.I.N. has shown that the percentage of junctions with a level of service A is equal to 21%, that one with a level of B service is of 18%, while the junctions with a level of service C, D and E are respective 45%, 9% and 1% of the total. That means that only 21% of the junctions have a level of risk bonded to physiological aspects of driver, the 18% introduces a level of brightness that gives a meaningful contribution to the degree of risk of the junctions, while 55% of the intersections have a level of safety highly compromised from the nocturnal poor visibility with consequent risk of incidents.
That happens because no urban road intersection is provided with a lighting system and presents, therefore, a brightness offered from the system of street lighting of the merging road; therefore, the luminous contribution of these junctions is clearly inferior to what it could be supplied from "dedicated" system of lighting system and in compliance with the prescription of the norm.
The situation is aggravated significantly in the little intersections, because, not having own lighting system, they are not visible to the driver eye if not in the moment in which he it arrives to the same one; the consequences of this situation are undoubtedly serious because the driver, not seeing the intersection, is not induce to slow down neither to increase its attention level.
It shows moreover, a percentage of 5% of junctions with level of service I, that is with brightness so elevated to provoke luminous pollution and to render therefore the junctions extremely dangerous.

CONCLUSIONS

The systems of public lighting system supply an elevated contribution to the reduction of the accident number that can potentially be taken place during the night hours.
It is obvious that the realization of lighting system costs money, but the benefits in terms of safety exceed the maintenance and equipment costs.
The experimental analysis consists in the survey of the luminance and the illuminance on a sample of intersections of the city of Catania. The obtained values have been then confront with those supplied from the lighting-tecnique norm; that has allowed to find nearly always equal values of luminance or advanced to the minimums prescribed from the norm; while, as far as the illuminance, the measured values are often under the minimum advised.
The successive step has been to define the index I.S.I.N. (Index of Nocturnal Safety of the Intersections), that it has the function to quantify, for every intersection, the increment percentage of the accident number in relation to the luminance and the illuminance of the same intersection. For the definition of the I.S.I.N., it has attributed to a greater weight to the luminance in the case of the intersections of small dimensions and a greater weight to the illuminance for the intersections of great dimensions.
It is, finally, defined a Level of lighting-tecnique service to leave from the level A for safe intersections, until the level E for intersections to greater risk of accident; it is assigned the level I to those intersections in which the index exceeds 25, that is those in which the level of lighting system is so high to cause the dangerous phenomenon of the luminous "pollution ".
We think that the results of this study are important because they have allowed to quantify the levels of luminance and illuminance in urban intersections, and, also, they have evidenced the necessity to realize or adjust the lighting system to improve the level of perception during night hours and to reduce therefore the accident risk.
The formulated index, moreover, could be estimated for all the urban intersections, allowing therefore to evidence that criticality that, once resolved, can lead to improve the liveability conditions, in terms of safety and traffic.

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