Methodology for assessing the lighting of pedestrian crossings based on light intensity parameters

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Abstract. One of the possible preventive measures that could improve safety at crossings is to assess the state of illumination of the lighting installation located in the transition area for pedestrians. The City of Warsaw has undertaken to comprehensively assess the pedestrian crossings to determine the level of road safety and the condition of lighting. The lighting conditions related to pedestrian crossings without traffic lights in three central districts of the city were investigated. The conducted field research and the work of the team of experts lead to the development of tools to assess the level of risk due to the lighting conditions measured at night. The newly developed and used method of assessment and the experience gained should provide a valuable contribution to the development of uniform risk assessment rules for pedestrian crossings in Poland. The authors of this paper have attempted to systematize the description of the method of evaluation of the lighting installed in the area of pedestrian crossings.

1 Introduction

As is apparent from the reports on road safety [1,2] in Poland for many years, there is large number of accidents at pedestrian crossings (Fig. 1).

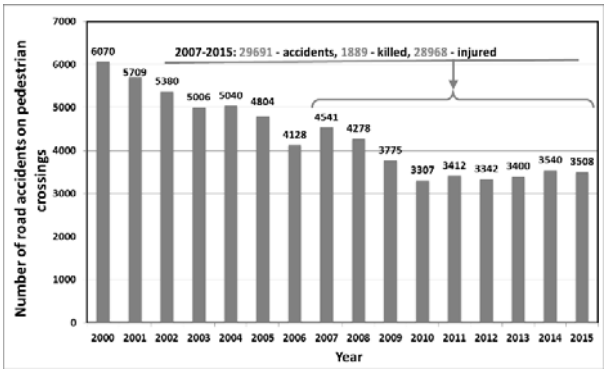

Fig. 1. The number of road accidents on pedestrian crossings in Poland year 2000-2015 [1].

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Action was taken to improve the safety of vulnerable road users in cities [3]. Despite the endeavour to improve the safety of pedestrians in Warsaw in 2011 - 2015, there was no clear trend of any reduction in the number of accidents with pedestrians (434 - 490 accidents / year). Only in 2015 was there a decrease down to 390 accidents. Due to their low statistical numbers, accidents with pedestrians were no longer a map of "black points." To act preventively, a map of the level of hazard for pedestrian crossings should be created, regardless of whether there had been an accident involving pedestrians or not. Acting with the aid of a map of dangers, the road manager can be proactive, not waiting for accidents and fatalities to take place.

The lighting of pedestrian crossings is one of the elements of road safety control [3]. In order to improve the current state of hazards to vulnerable road users a comprehensive inspection of pedestrian crossings must be carried out [4,5]. Recommend the pedestrian crossings to modernize in line with a full assessment of the other road safety factors. On this basis the risk factors should be identified and classified. As a result, it will be possible to mark the pedestrian crossings which require corrective action as regards lighting infrastructure.

It should be noted that uniform and comprehensive safety control procedures, dedicated to pedestrian crossings with a focus on parameterized factors of lighting, have not been developed and implemented in Poland so far. The authors of this publication have made efforts to systematize the process of evaluating the existing lighting of pedestrian crossings for the purposes of the upgrades carried out in Warsaw. It should be noted that the measures taken to evaluate the state of illumination were carried out in parallel with the work of the Road Safety Movement team of auditors, whose task was to assess the other elements affecting the safety of pedestrians.

One of the elements to be evaluated was the lighting of the pedestrian crossings. In urban agglomerations, the assessment of the lighting infrastructure is very important from the point of view of maintaining or improving lighting conditions. The City of Warsaw has undertaken to comprehensively evaluate the existing pedestrian crossings to determine the level of road safety and assess the lighting. Research on pedestrian crossings without traffic lights was carried out in the three central districts of the city. It should be emphasized that no similar project had been carried out in Poland before. The research literature [4–6] preceding the conceptual and field work does not indicate any useful methodologies for the evaluation of lighting parameters. The authors of the literature on the subject encountered just one case [4] where an attempt was made to reach an objective numerical pedestrian risk assessment, giving weight points and weighing the individual parameters of pedestrian crossings. However, in this method the assessment of lighting does not contain the essential quality parameters. Research literature [4,5] indicates that the factor of assessing lighting in the proposed evaluation procedures was treated ambiguously and did not define the lighting parameters and values, or the recommended limits. Balance and weight points cannot be transferred directly from Italian to Polish conditions due to the specificity of the local behaviour of managers and pedestrians and different traffic regulations. Therefore, it had to develop an entirely new, comprehensive evaluation method that allows for the identification of the risk factors for the evaluation of pedestrian crossings. One of them was the state of the lighting of pedestrian crossings. The authors of the Polish methods of assessment decided to split the final evaluation into the lighting parameters and other parameters of road safety (because of the difficulty in determining the gravity of the share of the particular criteria influencing the outcome of the final comprehensive assessment of road safety at pedestrian crossings). Therefore, this article discusses only the assessment of the state of illumination.

2 Assessment of the state of lighting in the area of pedestrian crossings

The lighting of pedestrian crossings in urban areas is often implemented by means of a street lighting installation or using special dedicated luminaires. The lights installed at a pedestrian crossing should also ensure that [7]:

- in the case of the driver - the appropriate conditions to identify the road situation and to see the figure of the pedestrian is in the driver's field of view,
- in the case of the pedestrian - appropriate conditions for the observation of the pedestrian crossing environment and approaching vehicles.

Both in Poland and in other countries [7], pedestrian crossings are zones of conflicting interests (like road junctions etc.), for which there are additional lighting requirements. The guidelines in each country are diverse in terms of the performance and assessment of lighting requirements. In Poland, the basic normative document is the Polish Standard PN-EN 13201-2: 2016-03, Road Lighting, Part 2: Performance requirements [8].

A number of lighting parameters for the assessment of the lighting of pedestrian crossings can be used [6,9–11]. Unequivocal verification of the existing lighting conditions can be carried out using the basic parameters which are the horizontal (E_h) and vertical (E_v) illuminance values [7,11]. The values in these planes clearly describe the sufficient lighting conditions in the study crosswalk. The research on the lighting of pedestrian crossings in Warsaw was carried out with the use of the illumination parameters described in the standard [8] that were adopted in the measurement geometry. Figure 2 shows the basic geometry of pedestrian crossings, indicating the directions of traffic and the points of measurement of light intensity. To study the state of the lighting of pedestrian crossings in field conditions grid points in the planes E_h (plane of the road on which there is a transition together with the expectations for the area - points from 1 to 30) and E_v (the vertical plane passing through the axis of pedestrian crossings that defines lighting figure a pedestrian with the viewing direction associated with the direction of traffic - points 31 to 50) were adopted. The measuring points for measuring the value of E_v located at a height of 1 m above the road surface along the axis of the passage. This measure takes into account the view of a driver approaching a pedestrian crossing in situations where disabled people in wheelchairs, people with short children and baby prams cross the road.

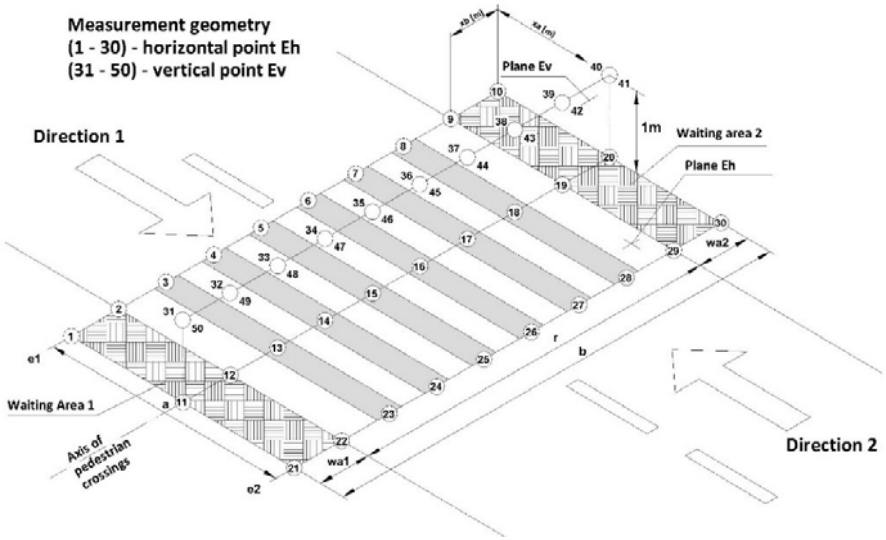

Fig. 2. The basic geometry of pedestrian crossings with the indication of the measurement points.

The standard [8] does not define direct lighting requirements for pedestrian crossings. However, it specifies the requirements for the design and testing of street lighting in the areas of movement on horizontal E_h and vertical E_v. For measurements of the horizontal illuminance E_h at pedestrian crossings the "C" Class of lighting associated with the lighting of conflict zones was adopted (Table. 1).

Tab. 1. C class of lighting and the proposed scale of point marks. Source: [8].

C Class	Horizontal intensity of illuminance E_h		Rating RC
	E_h w [lx] (lowest value, expected value)	U_o [lowest value]	Points
C0	50	0.4	6
C1	30		5
C2	20		4
C3	15		3
C4	10		2
C5	7.5		1
no class	< 7.5	-	0

For measurements of the vertical intensity of illuminance E_v at pedestrian crossings we adopted the EV lighting class [8] associated with lighting vertical surfaces (Tab. 2).

Tab. 2. EV class of lighting and the proposed scale of assessments point. Source: [8].

Vertical intensity of illuminance E_v		Rating $REVD_1$ and $REVD_2$
EV Class	E_v,min w [lx] (maintained)	Points
EV1	50	6
EV2	30	5
EV3	10	4
EV4	7.5	3
EV5	5	2
EV6	0.5	1
no class	< 0.5	0

The measurements of the state of the lighting on pedestrian crossings in Warsaw were carried out by teams of 3 ÷ 4 that included individuals with experience in conducting specialized field studies of road lighting. All the teams carried out measurements using a single author's procedure. The card of each crossing contains all the data from a visit to the location, photographic documentation, evaluation and the subjective opinion of the evaluation team. The subjective assessment *SE* is issued by the evaluation team during an

evaluation in the field and is designed to represent the subjective feelings of the evaluators related to pedestrian crossing zone lighting expectations, illuminating the figure of a pedestrian located on the pedestrian crossing and the condition of the street lighting in the environment where the pedestrians cross. The scale of the scores to describe the subjective *SE* lighting conditions: 0 - very bad 1 - bad lighting, 2 - mediocre, 3 - satisfactory, 4 - good, 5 - very good. The evaluation results are then aggregated in the database of lighting measurements and allow the development of a summary report.

Using the procedure for assigning points for each class C (Table. 1, *RC*) and EV (Tab. 2, $REVD_1$, $REVD_2$) it became possible to designate an objective assessment of the lighting of pedestrian crossings depending on the class of lighting:

$$OE = f_1 RC + f_2 REVD_1 + f_3 REVD_2 \quad (1)$$

where:
- *OE* is objective evaluation,
- *RC* is evaluation associated with lighting the horizontal plane,
- $REVD_1$ is evaluation associated with lighting the vertical plane in direction 1,
- $REVD_2$ is evaluation associated with lighting the vertical plane in direction 2,
- $f_1, f_2, f_3,$ are the weight factor = 0,33.

The final evaluation of the state of lighting pedestrian crossings *FR* is delivered on the basis of the partial assessment of the subjective and the objective:

$$FR = f_4 SE + f_5 OE \quad (2)$$

where:
- *FR* is final ranking,
- *SE* is subjective evaluation,
- *OE* is objective evaluation,
- $f_4, f_5,$ are the weight factor = 0,5.

In the case of incorrect levels of illumination or improper lighting conditions, technical solutions were proposed to improve the view of pedestrians at night both on the crossing itself and in the waiting area (recommendations included a range of solutions ranging from the cheapest and easiest applications to comprehensive improvements in the lighting system). As a result of the work of established data mart lighting parameters. Pedestrian crossings can be filtered through various criteria, e.g. ratings. Part of the work identified a number of irregularities, e.g. 41 of the examined cases where maintenance procedures on the street lighting should be immediately undertaken.

3 Summary

As a result of our activities, using the research literature and the expertise on the subject, a measuring procedure was developed to unambiguously classify the lighting performance on a test of Warsaw pedestrian crossings. The material prepared this way makes it possible to carry out preventive management measures and investment.

In spite of the existing standards and guidelines, the lighting conditions at pedestrian crossings in Poland are not consistently regulated. There is no clear and verifiable research to define the need for the installation of street lighting and/or additional dedicated lighting. Furthermore there is no legislation defining the lighting conditions that should be met at pedestrian crossings. The technical specifications of tenders for the upgrading of street lighting on pedestrian crossings does not directly define any precise design requirements for contractors. Another problem are the shortcomings at the investment stage and concerning the use of the research verifying the actual state of the lighting on pedestrian crossings. In the

future, the development of methods for assessing the state of the lighting will make it possible to continue the work of the monitoring and verification of the solutions to improve lighting conditions.

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