Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

Assessing unsignalised pedestrian crossings

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Abstract

The lack of pedestrian safety on crossings is a complex problem and one that is influenced by a number of factors such as the law, road traffic culture, the road and traffic. This paper will focus on the last two by presenting a method for assessing pedestrian crossings for their geometry and roadside using data from 930 pedestrian crossings in Warsaw. The authors of this paper have attempted to systematise the process of assessment of the existing crossings safety. It should be noted that the actions taken in the field of safety assessments were carried out consecutively with a team of lighting experts whose task was to assess the impact of lighting elements on the level of pedestrian safety. The paper will describe the successive steps of the method: detailed safety inspection of crossings, identification of pedestrian hazards, including an assessment of the required sight distance in relation to actual vehicle speeds and safety improvement recommendations. Because not all data were available during the site inspection and seemed to be necessary for the assessment, efforts were made to obtain information about the road traffic volume (from a Warsaw transport model) and the traffic volume of pedestrians and cyclists by age group (own measurements conducted). In addition, the method of required visibility was developed by the authors, taking into account the position of a pedestrian at a distance of 1m from the edge of the road at drivers' speed of V85. The authors will present the preliminary results of work on modelling the effects of selected road and traffic parameters on road safety. The authors will also present the results of analyses looking at the methodology of systematic studies of pedestrian behaviour and the pedestrian-driver relation for 70 locations: cities, small towns and outside built-up areas. The effect of the location of the measurement cross-section, type of cross-section and other selected parameters on driver and pedestrian behaviour at and around pedestrian crossings is demonstrated. Driver behaviour was analysed for pedestrians approaching the crossing, waiting at the edge of the road and in the absence of a pedestrian near the crossing.

Keywords: pedestrian crossing; road safety

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1. Introduction

Walking plays a crucial role in the transport system. This is true of small towns and villages with very little public transport and of big cities where walking is often used to get around the city. Walking is also part of many people's everyday lives (especially children, school youth, older people, people who do not have a car). At the same time, pedestrians in Poland are the most vulnerable road users and most at risk of death in road accidents. In 2016 there were 8,255 accidents involving hitting a pedestrian (25% of all accidents) with 7,838 people injured (19% of all injuries) and 859 people killed (28% of all fatalities). This type of accident tends to occur on pedestrian crossings which represented 52% of all pedestrian accidents and 32% of all pedestrian fatalities in 2016.

The standard of Poland's road network differs from region to region. As a result, the safety of road users differs as well. The risk of being involved in an accident is particularly high for pedestrians. The degree of the risk can be measured using the demographic rate of serious pedestrian accidents (pedestrian fatality and serious injury per 100,000 population). The analysis was applied to the regions and showed that (Fig. 1):
- the highest risk of serious pedestrian accidents was in the regions of Małopolskie and Łódzkie,
- the lowest risk was in the regions of Opolskie and Pomorskie.

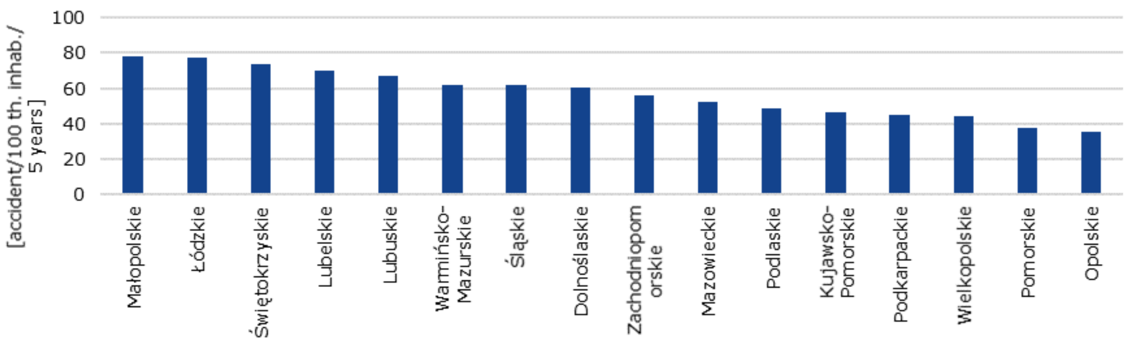

Fig. 1. Ranking of societal risk measured with the demographic indicator of serious pedestrian road accidents

Pedestrian traffic is usually concentrated in urban areas which typically generate traffic (public utility buildings, workplace, education, entertainment). This is why it is important to design this space in a pedestrian-friendly manner as much as possible. Over the analysed period more than 90% of injuries in pedestrian accidents and more than 65% of fatalities happened in built-up areas. Pedestrian accidents usually happen on the road – nearly 60% of all pedestrian accidents. Pedestrian crossings are the next element of road infrastructure where pedestrians are at risk of an accident – more than 30%, and app. 4% on the pavement. The share of injuries is similar while fatalities are as follows: road – 76%, pedestrian crossings – 19%, pavement – 1%.

An overwhelming majority of pedestrian accidents are caused by drivers of passenger cars. The most frequent causes include speed, failure to give way on a pedestrian crossing to a pedestrian and non-compliant manoeuvres. The time when pedestrians are most at risk of an accident is autumn and winter when pedestrians are difficult to spot on the road at night-time. When the economy is good and the country is developing well, people tend to live longer. This trend is also clear in Poland. There is an increasingly higher proportion of road users aged 65 and more. Pedestrians in this age group account for the highest share of injuries (about 15% of all injuries) and fatalities (app. 23-25% of all fatalities). When pedestrians cause an accident it is usually because they:
- stepped on the road in front of a moving vehicle (58% of accidents, 50% of fatalities),
- stepped on the road from behind a vehicle (10%),
- crossed the road where it is not designed for crossing (11%).

2. Literature review

Polish studies have focussed on studying pedestrian behaviour by analysing digital footage from test cameras. This method is used in the MOBIS programme, for example, whose main objective is to develop a method for assessing pedestrian safety using video footage, Olszewski et al. (2015). Polish studies have also examined luminance on pedestrian crossings at night time depending on road lighting. Pedestrian visibility on a pedestrian crossing was found to be the decisive factor of their safety. This suggest the need for properly selecting and designing lighting, Tomczuk (2014). Pedestrian safety on pedestrian crossings was also studied by observing driver reactions to a pedestrian stepping from the right side in a driving simulator, Zdanowicz et al. (2012). Work on the textbook "Pedestrian Safety", Jamroz et al. (2014) included pilot in-the-field tests to collect more reliable data. Another approach to studying pedestrian-driver behaviour was applied in Warsaw for assessing the city's pedestrian transport system, Transeko (2010).

In the United States pedestrian traffic is usually studied using surveys. The analysis looked at the probability of an accident on pedestrian crossings for different parameters such as driver speed, width, a marked or unmarked pedestrian crossing, signalised or unsignalised crossing, with barriers or without them, Garder (2004), Schroeder (2015). In Australia a survey was conducted to establish how familiar road users are with traffic regulations on the priority of road users in different situations, Hatfield et al. (2007). In another study surveys were used to collect the basic parameters such as the respondent's age, gender and education. The analysis also looked at the destination and knowledge of the regulations by asking questions about road users' priorities in different situations, Fildes (1994). A study in France aimed to analyse the behaviour and mutual pedestrian-driver relations. When the results were analysed it was found that when a pedestrian looks at an approaching vehicle, the vehicle is more likely to stop by more than 10%, Gueguen et al. (2015). A survey in the United Kingdom checked three potentially dangerous behaviours: crossing a dual carriageway, crossing on red on a Pelican light controlled crossing and crossing a very busy road between parked cars, Evans and Norman (2015). In Germany behaviour in road traffic at signalised junctions was studied recording the duration of signal phases, time for a pedestrian to cross the whole crossing or part of it (when the road was divided by a dividing lane or refuge), waiting time, pedestrian speed, "type of pedestrian behaviour" and driver-pedestrian conflicts, Ni (2009). In the Netherlands studies showed that excessive vehicle speed is the big-gest problem for pedestrians, especially for people aged >65, Hummel (1999).

3. Methodology for the assessment of pedestrian crossings without traffic lights

3.1. General methodology

Road safety audit for a large number of pedestrian crossings is a challenge. When a single location is audited, the auditors can work with large amounts of data and detailed analyses, taking into account pedestrian behaviour, driver behaviour and geometric parameters. On-site survey should take place in daytime, at night and in poor weather. Input parameters for the analysis should include information about vehicle speeds and their distribution during 24 hours, vehicles volume over 24 hours, pedestrian traffic volume and pedestrian age structure over 24 hours. When auditing a large number of pedestrian crossings, the collection of this data is highly labour intensive and costly, hence using this method for a large number of pedestrian crossings is not possible due to prohibitive costs. Given the above, the methodology for auditing large numbers of pedestrian crossings had to be modified to match the financial capacity of the road network authority.

A simplified methodology has been developed, which still contains elements needed in an audit. Firstly, the audit was carried out by certified, highly experienced road safety auditors. Vehicle speeds were assumed on the basis of speed samples for particular road cross-sections, as typical for the city of Warsaw. Volume and age structure of pedestrians was calculated on the basis of half-hour measurements during morning and afternoon rush hours, and calibrated for rush hour with the use of 6 hour measurements on selected pedestrian crossings.

The most important element of the audit, however, is the on-site visit by the auditor, when user observation is carried out and hazards are identified. The basic risk factors for pedestrians on pedestrian crossings are vehicle speed, length of pedestrian crossing and driver-pedestrian visibility. The auditor collects information on-site about the geometric parameters, and in particular measures the available sight distance which could be limited by solid obstacles, such as buildings, posts, road barriers, road signs, but also temporary obstacles, such as greenery or parked vehicles.

In addition to the basic elements indicated above, the auditor fills in a pre-defined form including: pedestrian crossing location details, pedestrian crossing characteristics (near crossroads, between crossroads, other), any measurable geometric parameters (width, length, distance from crossroads), speed limits, type and condition of road surface, the presence and the geometric parameters of traffic islands, the type of horizontal and vertical road markings and their condition, the distance of parked vehicles and whether parked legally or illegally, correctness of drainage systems, devices for the blind and visually impaired, pavement-roadway ramps, condition of pavements. Collecting the above data will allow the road authority to analyse irregularities by exploring the new data base.

The product of the project is a collective report for each city district, a database with pedestrian hazard assessment form 0 to 5 (0 being highest hazard, 5 being lowest hazard), thirty predefined types of pedestrian safety hazards, twenty nine recommendations for improvement of pedestrian safety and a card with detailed parameters for each pedestrian crossing, including auditor's opinions and photographic documentation.

3.2. Identification of hazards with photographs

In order to create material that would be easy to analyse and economically valuable, the methodology attempted to define types of hazards and problems. Six groups of hazard types have been predefined (lack of facilities for special needs persons, limited visibility, errors in marking, hazards related to the geometry of the pedestrian crossing and the street in front of it, errors in drainage and other unclassified factors.) The methodology covered hazards resulting from the following elements:

- insufficient facilities for disabled persons and persons with impairments: lack/insufficient facilities for the visually impaired, lack/insufficient ramps on the edge of the crossing,
- insufficient driver – pedestrian sight distance due to limited visibility caused by: parked vehicles (Fig. 2.4), fences, posts, billboards, municipal transport stops, greenery, other,
- errors in marking, both horizontal and vertical, due to incompleteness or poor technical condition,
- hazards related to the geometry of the pedestrian crossing and the road in its area related to: pedestrian crossing too long (Fig. 2.2), pedestrian crossing cutting through at least three lanes, pedestrian crossing cutting through lanes that are too wide, the use of “painted” surface which does not protect the pedestrian, insufficient width of traffic islands, very high / high speed of vehicles (Fig. 2.1),
- hazards resulting from insufficient drainage of the area of pedestrian crossing: lack of drains in the area of pedestrian crossing (Fig. 2.3), lowest point of vertical alignment/catchment resulting in the formation of puddles,
- hazards resulting from other factors: poor technical condition of the road surface, the pedestrian crossing or the pavement, pedestrian crossing susceptible to being blocked by parked vehicles, unnecessary pedestrian crossing, e.g. doubling a neighbouring crossing, no room for vehicles before the crossing.
- other not categorised above.

Fig. 2.1.

Fig. 2.2.

Fig. 2.3.

Fig. 2.4

Fig. 2 Examples of the sources of hazards on pedestrian crossings

3.3. Lighting assessment

One of the preventive actions which could improve safety on pedestrian crossings is to assess the condition of the lighting installations located in the area of the pedestrian crossing. The city of Warsaw undertook a comprehensive assessment of pedestrian crossings to find out the level of road safety and the condition of lighting installations.

The tests of the lighting conditions covered pedestrian crossings without traffic lights in three central city districts. The field studies and the work of a team of experts will result in creating tools for assessing the level of hazard due to the lighting conditions measured at night. The newly developed and applied assessment method and the newly acquired experience should constitute a valuable contribution to the development of a comprehensive assessment of hazards in the area of pedestrian crossings in Poland. The authors attempted to systematise the description of the method of assessing the condition of lighting installations fitted in the area of pedestrian crossings.

The lighting of pedestrian crossings is one of the elements of road safety audit, Jamroz (2014). In order to improve the current hazard level for vulnerable road users, a comprehensive audit of pedestrian crossings needs to be done, Montella and Mauriello (2010), Nabors et al. (2007). The identification of crossings that need to be modernised is related to a comprehensive assessment of the other road safety factors. On this basis the risk factors need to be identified and classified. In effect it will be possible to identify pedestrian crossings, where repair of lighting infrastructure is needed. It should be noted that so far no single, comprehensive safety audit procedure has been developed and implemented that would be dedicated to pedestrian crossings and cover parameterised lighting factors. The authors of this paper attempted to systematise the process of lighting assessment for the existing pedestrian crossings for the purposes of modernisation activities in the city of Warsaw. It must be noted that the activities to assess the lighting conditions were carried out in parallel with the work of the team of Road Safety Auditors, whose task was to assess the remaining elements affecting pedestrian safety. One of the elements that were subject to assessment was pedestrian crossing lighting.

In cities the assessment of the condition of the lighting infrastructure is essential from the point of view of maintenance or improvement of the lighting conditions. The city of Warsaw undertook a comprehensive assessment of existing pedestrian crossings to establish the level of road safety and to assess the condition of lighting. The tests covered pedestrian crossings without traffic lights in the city's three central districts: Śródmieście, Praga Południe and Ochota – a total of c.a. 1,000 crossings. It must be emphasised that so far in Poland no similar work had been undertaken.

Due to the specificity of each country in terms of the legal regulations and the local pedestrian and driver behaviours, it was not possible to adopt assessment criteria and their weights on the basis of similar work done in other countries. It was therefore necessary, to develop an entirely new, comprehensive assessment methodology, that would allow the identification of risk factors occurring on the pedestrian crossings which were identified for assessment. One of the assessed elements was the condition of pedestrian crossing lighting. The authors of the Polish assessment method decided to separate the final assessment of lighting parameters from the other road safety parameters (due to the difficulty of defining the partial weight of the particular criteria affecting the final result of a comprehensive road safety assessment on a pedestrian crossing). That is why this chapter only discusses the assessment of the lighting conditions.
The lighting of pedestrian crossings in urban areas is often provided by the street lighting installation or by special, dedicated fixtures. The lighting systems installed on pedestrian crossings should provide:

- the driver – with the right conditions to judge the traffic situation and to observe the silhouette of a pedestrian within sight of the driver;
- the pedestrian – with the right conditions to observe the surrounding of the pedestrian crossing and any approaching vehicles.

Both in Poland and in other countries pedestrian crossings are zones of conflicting interests (such as junctions, interchanges, 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.

A number of lighting parameters for the assessment of the lighting of pedestrian crossings can be used Tomczuk (2012), Tomczuk (2013), Tomczuk et al. (2016). Unequivocal verification of the existing lighting conditions can be carried out using the basic parameters which are the horizontal (Eh) and vertical (Ev) illuminance values. The values in these planes clearly describe the sufficient lighting conditions in the study pedestrian crossing. The research on the lighting of pedestrian crossings in Warsaw was carried out with the use of the illumination parameters described in the standard that were adopted in the measurement geometry. Figure 3 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 were adopted in the planes Eh (plane of the road on which there is a transition together with the waiting area - points from 1 to 30) and Ev (the vertical plane passing through the axis of a pedestrian crossing that defines how a pedestrian will be illuminated from a direction associated with the direction of traffic - points 31 to 50). The measuring points for measuring the value of Ev were located at 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 when the road is being crossed by wheelchair users, short people, children and pushchairs.

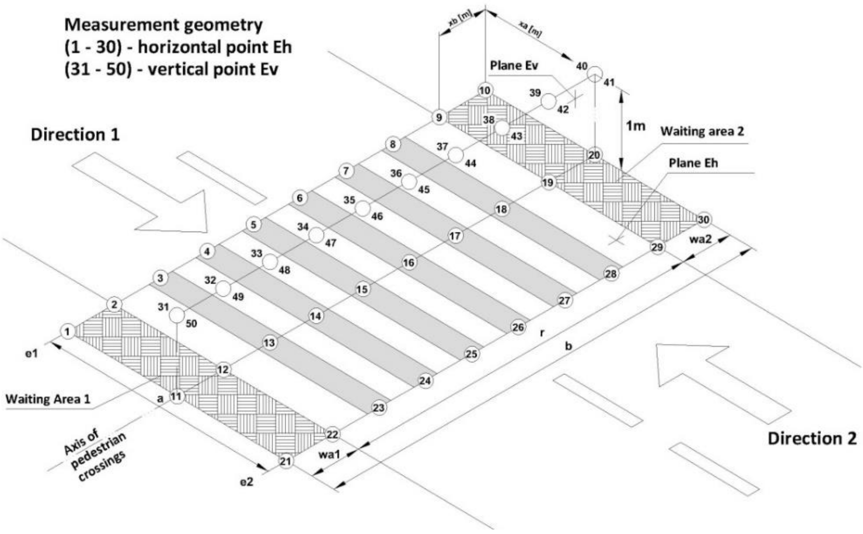

Fig. 3. Basic pedestrian crossing geometry with marked measurement points

While the standard [19] does not define direct lighting requirements for pedestrian crossings, 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 planes. To measure 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 scoring. The Polish Standard (2016)

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
none	< 7.5	-	0

To measure of the vertical intensity of illuminance Ev at pedestrian crossings, the EV lighting class was adopted associated with lighting vertical surfaces (Table 2).

Tab. 2 EV class of lighting and the proposed scoring. The Polish Standard (2016)

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
none	< 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 proprietary 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 was: 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 used to draft the summary report. Using the procedure for assigning points for each class C (Tab. 1, *RC*) and EV (Tab. 2, $REVD_1$, $REVD_2$) it was possible to designate an objective assessment of the lighting of pedestrian crossings depending on the class of lighting:

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

- where:
  OE – 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 pedestrian crossing lighting is delivered on the basis of the sum of partial subjective and objective assessment:

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

- 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). The work helped to produce a cumulative database of illumination parameters. Pedestrian crossings can be filtered through various criteria, e.g. ratings. 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.

In spite of the existing standards and guidelines, the lighting conditions at pedestrian crossings in Poland are not systematically checked. 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 do not define any precise design requirements for contractors. Another problem are the shortcomings at the investment and operational stage with no studies to verify the actual state of the lighting on pedestrian crossings. If developed, a method for assessing the state of the lighting will help with conducting checks and verifying the solutions designed to improve the lighting.

4. Speed at and around pedestrian crossings

Speed at and around pedestrian crossings was studied building on a study carried out in the regions of Pomorskie and Małopolskie. This was under a research project "Methodology for studying driver and pedestrian behaviour at and around pedestrian crossings", Jamroz et al. (2015). The scope of the pilot projects was limited to two regions: Pomorskie – with an average level of pedestrian risk (the second region with the lowest societal risk in relation to the number of fatal and serious injury accidents vs. the population), Małopolskie – with a very high level of pedestrian risk (the worst region for societal risk in relation to the number of fatal and serious injury accidents vs. the population). The areas vary in terms of the development, road cross-section and location of pedestrian crossings (Fig. 4).

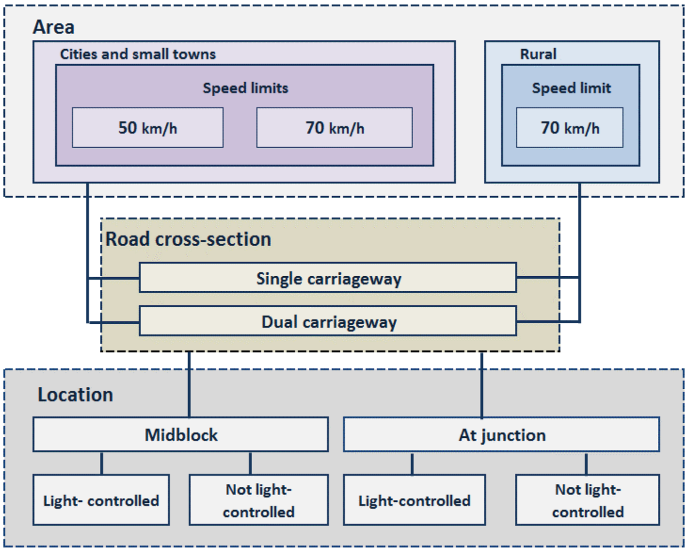

Fig. 4. Diagram of test points selection, Jamroz et al. (2015)

Speed was measured for free-flow vehicles only, i.e. they were not affected by other cars. Within this group the analysis looked at those cars which moved freely along a section of 100 m before the crossing. The following situations were identified for analysing vehicle speeds on pedestrian crossings: no pedestrian, a pedestrian waiting before the crossing, a pedestrian on the pedestrian crossing. Pedestrian behaviour was studied looking at the following characteristics: distance between the pedestrian and road while waiting to cross, whether the pedestrian looked at the traffic before and during crossing, pedestrian age structure and gender. In addition, pedestrians were surveyed after they had crossed the road as well as drivers who parked near selected test points. In both regions 69 test points were designated, 1,890 surveys were conducted with pedestrians, which is on average 30 surveys per one test point. There were also 543 surveys with drivers. The problem which emerged in the pilot and which need to be addressed in national tests is that some pedestrian crossings were used by a very small number of pedestrians throughout the day (less than 20) which is particularly frequent in places outside built-up areas and in small towns. To compare vehicle speeds and pedestrian behaviour cumulative analyses were conducted for the test points. The categories are as follows: type of area, type of cross-section, presence of signalisation, type of section. For each category the location's speed limit was identified. The cumulative reports assumed a speed of 50 km/h and 70 km/h – for speed tests before pedestrian crossings. The article presents results for the 50 km/h speed limit, while survey results are not included and treated as a separate research problem (Tab.3). Type of area:

- urban areas feature lower vehicle speeds on approaching a crossing than small towns, with no pedestrians by 2.5 km/h at 10 m from the crossing and by 10 km/h at 50 m from the crossing.
- in both types of areas vehicle speeds were similar at 10 m from the crossing when a pedestrian is waiting to cross.
- urban areas feature higher vehicle speeds on approaching a crossing than small towns, if a pedestrian is crossing the road by 2 km/h at 10 m from the crossing and by 1 km/h at 50 m from the crossing.
- in both types of areas vehicle speeds were slightly lower at 10 m from the crossing if a pedestrian is waiting to cross as opposed to when there are no pedestrians and speeds were substantially lower when pedestrians were crossing the road.

Table 3. Characteristics of vehicle speeds within pedestrian crossings – type of area, Jamroz et al. (2015)

Situation	**average speed V [km/h] at L[m] from the crossing**								**Speed percentiles**			**Number of vehicles**
	0	10	20	30	40	50	60	70	V.15	V.85	V.95	
Type of area												
urban area												
No pedestrian	44,8	44,6	45,3	46,3	43,7	43,5	45,1	38,8	31,5	52,6	58,9	2908
Pedestrians waiting	43,4	43,4	42,4	44,2	37,4	38,1	38,9	42,1	29,7	51,2	57,3	1319
Pedestrians crossing	0,0	13,2	21,0	27,4	30,2	33,8	33,8	39,0	8,0	26,0	31,9	959
All	36,6	38,4	40,0	42,5	39,6	40,5	42,1	39,6	24,1	54,0	61,2	5186
small town												
No pedestrian	47,0	47,0	46,6	47,6	55,4	53,1	64,6		37,1	56,4	63,6	1223
Pedestrians waiting	43,7	43,7	40,7	35,3	30,1	37,0	55,0		44,2	55,0	58,2	87
Pedestrians crossing	0,0	11,3	17,2	22,0	27,8	34,7	50,5		20,7	27,4	30,4	76
All	44,3	44,8	44,7	45,4	52,1	50,5	64,5		33,3	56,2	63,1	1386

5. Outline of road safety models design for pedestrians

Part of the pedestrian crossing safety audit, models are built to understand whether relations exist between geometric parameters or road user behaviour and the number of pedestrian accidents. As you know, statistically speaking pedestrian crossing accidents and casualties are low. Only some of the pedestrian crossings have had accidents. The authors of the methodology decided to add a subjective assessment for each pedestrian crossing and its hazards. As a result, relations can be built between pedestrian crossing parameters and the hazard assessment for each pedestrian crossing studied. The first step will be to test the correlation between auditors' assessment of pedestrian risks and the hazards actually confirmed because pedestrian accidents took place. The next step will be to build models that will analyse the correlations between the parameters and hazard assessment as identified by the auditors.

One of the elements of safety assessment is assessment of individual risk of pedestrians at pedestrian crossings, Kustra et al. (2016). An initial assessment was conducted for Warsaw's junctions (individual risk expressed as the number of accidents per one billion of vehicles – Fig. 5).

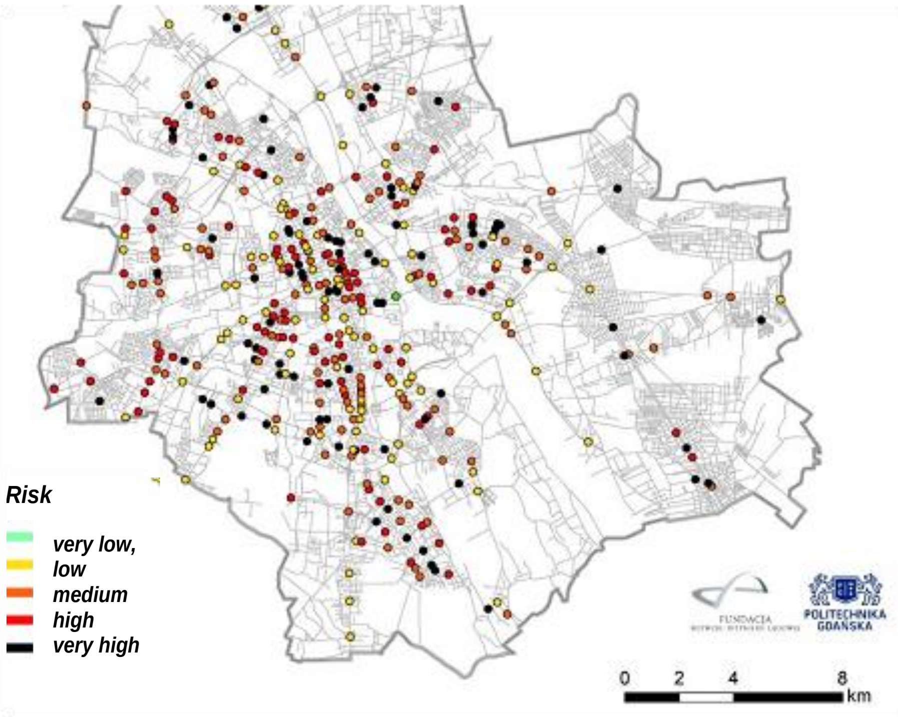

Fig. 5. Individual risk of pedestrians at pedestrian crossings in Warsaw

6. Conclusions

The methodology is designed to create economically viable material and substitute measures in relation to the number of pedestrian accidents which in statistical terms are not frequent. The authors of the methodology plan a systematic assessment of Warsaw's pedestrian crossings. Where pedestrian crossings are considered to be high risk, the assessment should be repeated more often (after two or three years) with less frequent checks for pedestrian crossings that have the lowest risk (every 5 – 10 years). Once built, the database will help to identify the hazards by type and analyse their effects on pedestrian safety. The authors will work to develop a consistent database of measurements and expert assessments and pedestrian incidents. It could serve as the start of a model that will quantify the share of the elements in overall pedestrian hazards.

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