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# ANALYSIS OF ROAD SAFETY IN THE CONTEXT OF HORIZONTAL VISIBILITY WITHIN INTERSECTIONS – FIELD STUDIES

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**Natalia Brycht Eng., MSc.**[1]–*orcid id: 0000-0002-7372-7492*
[1] Czestochowa University of Technology, Faculty of Civil Engineering, **Poland**

**Abstract:** One of the important factors on which road safety depends is adequate visibility. This article analyses horizontal visibility within road intersections. The visibility condition depends on many factors, primarily on the geometric parameters of road elements and the location of buildings, fences, vegetation etc., neighboring the road. The aim of the research presented in the study was to determine the current condition of horizontal visibility, on the example of twenty two intersections located mostly in built-up rural area along a provincial road near Czestochowa. The research was carried out by two methods (the analysis of satellite photographs and the visual method) and the obtained results were compared. The assessment of the security level was based on applicable regulations and technical guidelines. It was found that the results of the visibility assessment based only on the analysis of maps and satellite photographs are in many cases overestimated, due to the fact that many small elements not visible in the photographs are not taken into account and the occurrence of convex vertical road arches within the field of visibility. However, the main reason for the insufficient visibility at the many intersections is the fact that the geometrical parameters of roads and their surroundings were shaped in the past when the traffic conditions were completely different. It was also noted that road managers perceive this problem and take measures to increase safety within road intersections.
**Keywords:** road intersections, road safety, road signage, visibility within intersections

## 1. ROAD SAFETY IN THE CONTEXT OF HORIZONTAL VISIBILITY

Road safety is dependent on many factors. One of the most important ones is proper horizontal visibility. The Polish legal regulations (Official Journal of the Republic of Poland, 1999) define the relevant design conditions regarding the geometric parameters of road arches (curves) and intersections. Checking the requirements comes down to determining the so-called fields of visibility. These are areas, where there should be no elements hindering visibility, among others buildings, fences, vegetation. Of course, these conditions are checked for newly designed roads. In the case of existing road network, especially in the built-up areas, the real visibility is

determined by existing obstacles, which are most commonly difficult or even impossible to remove by the road managers.
The visibility on the road in real conditions was the subject of many studies. Among others, the dependence of visibility on road junctions on weather conditions (Pulugurtha et al., 2019), the influence of fog and smoke on the number of road accidents (Abdel-Aty et al., 2011), and the visibility in conditions of artificial road lighting (Chenani et al., 2016; Wood et al., 2018) were investigated. Road intersections are one of the most common places where road accidents and collisions occur. The causes of accidents at the intersections may be different, but one of the most important ones is the failure to yield of right of way, which is often a consequence of poor horizontal visibility (Mussone et al., 2017), although there are also opinions (Charlton, 2003) that the deliberate limitation of visibility within intersections results in greater caution of drivers, which increases road safety. Of course, the comfort of access to the intersection especially from the side of a subordinated road, is also dependent on other factors, such as: the condition of road pavement, the condition of vertical and horizontal signs, lighting, drainage (Respondek, 2019). Therefore, intersections and their surroundings should be subjects of special care of road managers. Determination of the current condition of horizontal visibility, on the example of twenty two intersections located mostly in a built-up rural area along a provincial road near Czestochowa, was the aim of the research presented in the study. The research was carried out by two methods (the analysis of satellite photographs and the visual method) and the obtained results were compared. The carried out analysis was complemented with photographic documentation.

## 2. METHODOLOGY OF RESEARCH

Detailed research of visibility was carried out along an exemplary provincial road No. 491, on the section of 15 km in Biala, Kamyk, Lobodno and Miedzno. Twenty two intersections located within the boundaries of these villages were assessed. The research consisted in assigning a rating describing the visibility from the point of view of the driver of a vehicle traveling on a subordinated road. The assessment was carried out using two methods:

- Method I – through the analysis of maps and satellite photographs available on the Google Maps internet platform (https://www.google.com/maps/),
- Method II – based on field studies (visual assessment) in real road traffic conditions.

The rating scale from ”0” to “5” was used in the both methods. The assessment by method I was based on an analysis of the fields of required visibility graphically determined in accordance with the recommendations of the applicable regulations (Official Journal of the Republic of Poland, 1999) and the fields of real visibility plotted taking into account obstacles identified in the satellite photographs. It was assumed that the driver of the vehicle stopping to yield the right of way, is located 3 m from the edge of the provincial road. It was also assumed that the stopping distance for the driver of a vehicle with the right of way is 70 m. It was assessed whether the obstacles were found inside the fields of visibility and what kind of obstacles they were. A rating of “5” means there are no obstacles in the required field of visibility and the lines limiting the field of visibility do not intersect. A rating of “0” means that a field of real visibility is negligible. The exemplary fields of visibility are shown in Fig. 1.

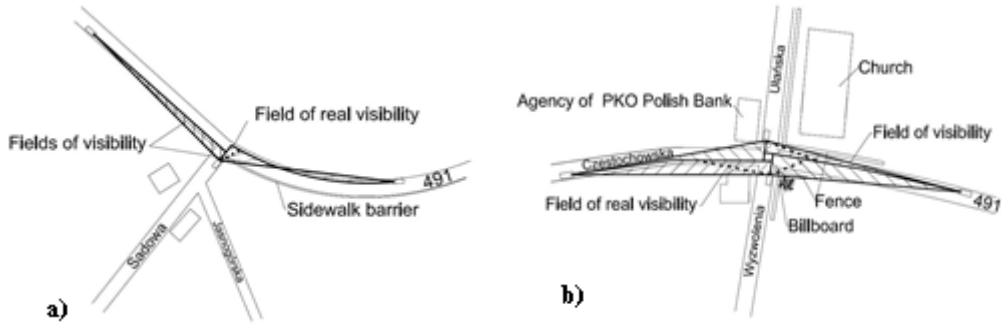


Fig. 1. Exemplary fields of visibility: a) intersection no 2, b) intersection no 16

The assessments by method II were made by a visual observation from the position of the driver whose eyes were at a height of about 120 cm. A visual assessment is often used as an important element of quality control (Szklarzyk, 2014). A rating of "5" means full comfort of entry into the traffic, while a rating of "0" means the inability to observe the traffic on the road with the right of way without having to partially extend the vehicle's outline on this road. Other factors related to driving comfort could also have influenced the assessment: the condition of the road pavement when reaching the intersection, vertical and horizontal signs (e. g. whether the stop line was marked). The research was carried out in autumn in the absence of unfavorable weather conditions.

## 3. RESULTS OF THE STUDY

The ratings resulting from the study of visibility at intersections are presented in Table 1. The intersections were marked with consecutive numbers from 1 to 22. The terms "right/left" of the inlets of the subordinated road result from assumed direction of the driving on the provincial road. As already mentioned, an assessment of visibility was made from the point of view of the driver on the subordinated road – the symbols "L" and "R" therefore indicate the direction of observation. The main reasons for deterioration of visibility identified during the research are also shown in Table 1. The term „turn" means a horizontal road arch restricting visibility, the term „hill" means a convex vertical road arch in the field of visibility, the term "sign" means a vertical road sign or a road panel obstructing a visibility. The percentage of individual ratings is shown in Fig. 2.

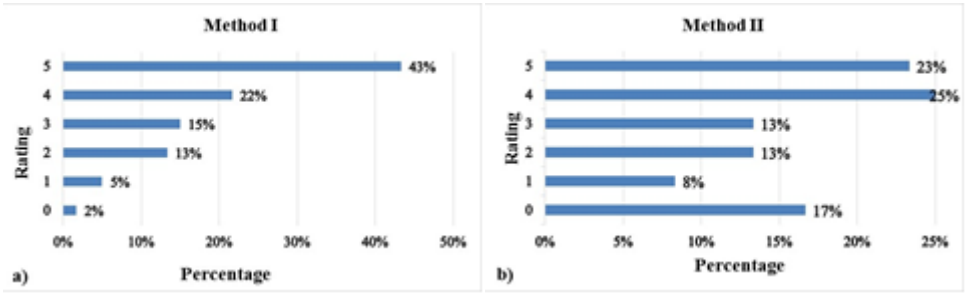


Fig. 2. The percentage of ratings determined on the basis of: a) satellite maps and photographs, b) field studies

Table 1
Assessment of horizontal visibility of intersections with a subordinated road

| No | Inlet side | Method I | | Method II | | The reasons of deterioration of visibility | |
|---|---|---|---|---|---|---|---|
| | | L | R | L | R | L | R |
| 1 | right | 4 | 4 | 4 | 1 | sidewalk barrier | sidewalk barrier |
| 2 | left | 5 | 3 | 5 | 1 | - | sidewalk barrier |
| 3 | right | 3 | 2 | 2 | 0 | sidewalk barrier | sign, fence |
| 4 | right | 5 | 2 | 4 | 0 | hill | fence, turn |
| | left | 2 | 4 | 1 | 3 | column, fence | column, sign |
| 5 | left | 4 | 5 | 4 | 5 | turn | - |
| 6 | left | 1 | 2 | 0 | 2 | trees, sidewalk barrier, turn | turn |
| 7 | right | 3 | 3 | 3 | 1 | turn | building, sidewalk barrier, sign |
| | left | 2 | 2 | 0 | 0 | turn | fence, turn |
| 8 | left | 5 | 5 | 5 | 4 | - | sign |
| 9 | right | 3 | 1 | 2 | 0 | hill | fence |
| | left | 5 | 4 | 4 | 2 | bus stop | fence |
| 10 | right | 3 | 3 | 3 | 2 | fence | fence, turn |
| | left | 5 | 5 | 5 | 4 | - | sign, hill |
| 11 | right | 5 | 4 | 4 | 2 | pole | trees |
| | left | 4 | 5 | 3 | 5 | trees, sign, hill | - |
| 12 | right | 5 | 5 | 5 | 5 | - | - |
| | left | 5 | 5 | 4 | 5 | sign | - |
| 13 | right | 5 | 5 | 5 | 4 | - | sign |
| 14 | right | 4 | 4 | 3 | 3 | sign | sign |
| | left | 3 | 2 | 1 | 0 | fence, trees | fence |
| 15 | right | 5 | 2 | 4 | 0 | trees | fence, column, turn |
| 16 | right | 1 | 3 | 0 | 2 | building | sign, column, turn |
| | left | 0 | 5 | 0 | 5 | fence | - |
| 17 | right | 5 | 5 | 5 | 5 | - | - |
| 18 | left | 5 | 5 | 4 | 4 | sign | bushes |
| 19 | right | 5 | 4 | 4 | 2 | sign | hill |
| 20 | left | 5 | 4 | 5 | 3 | - | hill |
| 21 | left | 4 | 5 | 4 | 5 | hill | - |
| 22 | right | 5 | 4 | 4 | 3 | sign | sign |
| Mean rating | | 3.80 | | 2.92 | | | |
| Standard deviation | | 1.35 | | 1.79 | | | |

Source: Author's study

The conducted research has shown that the results of assessing visibility at the intersections carried out only on the basis of satellite maps and photographs can be overstated. The main reason for this is the inclusion of obstacles impossible to identify in satellite photographs in real conditions, e.g. road signs and panel, vegetation. In addition, the impact of vertical convex road arches is visible, which further limits the field of horizontal visibility. It should also be remembered that in real conditions, the assessment is also influenced by some additional factors related to driving comfort. For example, the lack of conditional or absolute stop strips on the surface, poor technical condition of the road pavement may worsen this comfort. During the

research, it was noticed that road managers perceive this problem and take measures to increase safety within road intersections by: making and complementing roads signs, installing mirrors in particularly dangerous places, designating pedestrian crossings, installing railings separating the sidewalk from the road, removing unnecessary vegetation etc. However, some shortcomings in this area are visible, for example, vehicle stop lines are made only at approx. 30% of inlets of subordinate roads.

## 4. REASONS FOR LIMITED VISIBILITY - EXAMPLES

During the research, photographs were taken, based on which the examples below illustrate the actual visibility conditions within the analyzed road. An example of visibility being limited by the sidewalk barrier is shown in Figure 3a. A sidewalk barrier improves pedestrians' safety by making it difficult for them to enter the road, but at the same time it significantly worsens the drivers'. A driver driving on the subordinate road is in a sitting position and the barrier is at his eye level. In this case, the sidewalk barrier was not identified on satellite photographs, which resulted in a decrease in visibility rating from "4" (method I) to "1"(method II).

Limited visibility caused by the location of the intersection on the inside of the horizontal road arch of the main road is shown in Fig. 3b. Due to too small radius of the arch on the main road, as well as roadside vegetation, it is very difficult to get into the road traffic safely, especially when turning left. In addition, the problem is the high speed of vehicles coming from the left, which, moving "downhill" often exceed the speed limit on this section.


Fig. 3. Limited visibility caused by:
a) a sidewalk barrier, b) location of the intersection on a road arch

The examples of almost complete lack of visibility caused by a building (Fig. 4a) or a fence, an electricity pole and vegetation (Fig. 4b) adjacent to the road, are shown in Fig. 4. In both cases, an outward-facing arch of the main road is located directly behind the intersection. The examples of visibility limited by a convex vertical road arch are shown in Fig. 5a. An unfavorable longitudinal profile of the road obstructs the field of visibility, which means that the driver must be particularly careful here – fast moving vehicles on the main road (non-built-up area) appear in the field of vision suddenly. Visibility may also be impeded by roads signs and panels and roadside trees (Fig. 5b). Existing roads are mostly located on the track of old unpaved roads and there was no fast traffic of vehicles. These roads were planted with trees, mainly to protect travelers from the sun. Currently, roadside trees located close to the edge

of the road can be dangerous in the context of the possibility of a vehicle hit, as well as impair visibility.


Fig. 4. Limited visibility caused by: a) a building and a road arch, b) a fence and vegetation


Fig. 5. Limited visibility caused by: a) an unfavorable vertical profile of the main road, b) location of road signs and roadside trees

The common example of uneven pavement on a subordinate road within the connection with the main road is shown in Fig. 6a (this is also seen in Fig. 5a). The reasons here are some administrative barriers - the renovation of the municipal road (the new pavement) was brought only to the border of the provincial road lane. There is also no conditional stop line. The described shortcomings do not have a direct impact on a visibility at this intersection, which is correct, but constitute a certain difficulty in the context of comfortable entry into the traffic. An example of a correct field of visibility is shown in Fig. 6b. The lack of obstacles and road curves makes it easier to entry into the traffic.


Fig. 6. Intersections: a) with uneven surfaces, b) with a correct horizontal visibility field

## 5. CONCLUSIONS

The research shows that the assessment of visibility at existing intersections, consisting only in the analysis of available maps and satellite photographs (method I) may be incorrect. It is therefore recommended to perform such an assessment by visual method in the real road traffic conditions (method II). In many cases, an assessment made with method II is lower than with method I, never vice versa. There are two main reasons for these discrepancies. Firstly, there may be obstacles in the field of visibility that are not identifiable on maps and satellite photographs. There are often seemingly small elements, such as sidewalk barriers and road signs, as well as trees or bushes. The second reason for the discrepancy is the vertical arches of the road. If the vertical curve is convex in the field of visibility on the main road, it may limit visibility, which was clearly felt during the field study.

The mean of horizontal visibility ratings obtained by method I is 3.8 and by method II 2.92, which illustrates the described effect well. According to method I, the high ratings, i.e. “5” or “4” were obtained for 65% of the results, while “1” or “0” for 7% of the results. In the case of the field studies, these rates are 48% and 25% respectively. The research shows that the visibility conditions are bad in many cases. The main reason for the insufficient visibility at the many intersections is the fact, that the geometrical parameters of roads and their surroundings were shaped in the past, when traffic conditions were completely different. First of all, there was no fast vehicle traffic and associated noise. For this reason, the buildings were often built in the immediate vicinity of the road, which is currently a problem. Near the edge of the road, trees were also planted that previously had no effect on a road safety.

It is noted that the awareness of road managers regarding safety at intersections is increasing, as evidenced by the observed positive actions increasing road safety. Mention can be made here of vertical and horizontal signage, setting mirrors in particularly dangerous places, as well as measures to increase the pedestrian safety. Paradoxically, some of these activities may contribute to the deterioration of the visibility of drivers commuting to the intersection from the side of the subordinate road. The obstructing elements may be road sings and panels, as well as sidewalk barriers on the border of the sidewalk and the road, whose handrail is located at the eye level of the driver.

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