Improved Visibility – Solar Powered Road Markers on Polish Roads

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Abstract. The article discusses safety of road users as well as traffic accidents and collisions between 2014 and 2017 in Poland and other European countries. The author proposes an alternative method of improving safety through increasing the visibility of road users. Alternative methods allow to use the latest technological solutions related to storing and using renewable energy in various weather conditions.

1. Introduction
Road accidents have been a part of driving since the discovery of the first means of transport. Greater mobility results in a higher and higher journey adverse consequences rate. Despite using technologically advanced vehicles, improved infrastructure and social activities promoting safety, the number of casualties and seriously injured in road accidents has not been substantially decreasing. Compared to other EU Member States, Poland has one of the highest casualties rate per 100 hundred thousand residents, and a decrease in this rate noted in 2005-2014 lowers the average rate for the entire EU. [1]

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results, [1].

1.1 Led technology
At the beginning of the 60ties of the 20th century, a revolutionary solution has been introduced: light-emitting diodes (LEDs). LEDs are currently used in TV sets or PC screens and traditional bulbs in houses are often replaced by them. Light-emitting diodes are environmentally friendly, highly efficient and very durable (over 30 thousand hours of lighting), small and characterized by small power consumption and low energy losses. [2], [9]

The potential of LEDs is still growing and new opportunities of their application are emerging [13], e.g. in road engineering. Presently, LEDs are used in street lighting [10], road signs[11], [14], ITS devices [12], [15] as well as active, spot reflective elements (the so-called solar cat’s eyes). The LED technology introduces new possibilities of visibility improvement.
1.2 Road users
Data published by the National Road Traffic Safety Council (KRBBD) [1] on the average speed of vehicles unambiguously indicate exceeding the permitted speed (50 km/h during the day and 60 km/h at night) by a majority of drivers. One in three drivers exceeds the permitted speed by over 10 km/h.

Compared to the findings of the surveys, over 55% of pedestrians are not satisfied with the speed of vehicles in their surroundings. The significant statistics affecting dangerous conduct of pedestrians include a manner of crossing the street on a pedestrian crossing. Nearly 50% of unprotected road users cross the street when the red light is on, 70% of people do not wear any reflective elements or wear them occasionally.

2. Improvement of visibility on road as way to improve road safety
A significant number of accidents in summer is a result of increased traffic being a consequence of the holiday period.[3][4] In autumn and winter a number of accidents is regularly increasing (October and December are the months when the most people die), (figure 1, figure 2).

![Figure 1. Road accidents in 2014-2017](image1)

Billboards, street lighting and lights of approaching vehicles temporarily blind the driver, thus distorting his depth perception and increasing response time. Almost twice more accidents happen on the illuminated road than on the road without lighting.

![Figure 2. Casualties of road accidents in 2013-2015](image2)
Horizontal marking supposed to lead the driver is often poorly visible and unreadable. There are situations, especially when performing road works, where marks and signs are mutually exclusive and may result in a collision or an accident.

Particularly dangerous places have been surrounded by spot reflective elements. Their purpose is to improve visibility on the road or its part, e.g. a pedestrian crossing. This solution is applied both on state roads and on streets (the photograph beside was taken at ul. Raclawicka in Warsaw, Poland (figure 3)).

![Figure 3. Spot, luminous LED elements – own photograph](image)

Road reflective elements (so-called cat’s eyes) were discovered in the 30ties of the 20th century in Great Britain by Percy Shaw who had been inspired by an image of the vehicle lamps reflected in cat’s eyes. The first sets of cat’s eyes consisted of 4 glass spheres (2 on each side), mounted in a cast-iron housing. Further modifications resulted in 2 most commonly used products: reflective elements and light emitters, the so-called active LED cat’s eyes (figure 4).

![Figure 4. Active LED cat’s eye with solar charging system – own photograph](image)

Reflective elements have been used in Poland for a dozen or so years and are positively perceived by drivers. The problem with the traditional solution is the function of the device which only reflects
light emitted by vehicle lamps. The driver has a short, often insufficient time to respond to a situation. An alternative is the use of LED cat’s eyes, e.g. as part of the solar system. Their operation range is approximately 1,000 m, which allows to shorten the response time from risky 3 seconds to 30 seconds at a speed of 100 km/h.

3. Should led reflective elements be used?
At night, the driver is guided by light emitted by his vehicle lamps or foreign devices, e.g. street lighting. In particular, in autumn and winter the road and its sides are insufficiently illuminated or started to be illuminated with delay (lights are turned on with delay). Norwegian researchers have shown [5] that when driving at night, for most of the time the vehicle uses dipped beam headlamps. A beam of light emitted by vehicle lamps is limited and its range is approximately 30-50 m for dipped beam headlamps and approximately 90 m for main beam headlamps. According to Boyce [6], only slight uneveness in the road can make light reflect without temporarily blinding the driver. The effect is significantly greater when reflective elements are used. Reflection, however, is a problem under adverse weather conditions such as rain or fog.

3.1 Use under specific weather conditions.
3.1.1 Rain
Driving in rain requires greater focus and shorter response time. Greater focus when driving results in fatigue faster and in slower response time. On wet road surface light is reflected from water and results in the mirror effect, which reduces visibility [7]. If a street is illuminated, during the rain white horizontal marks and signs are hardly or not visible. Light emitted by cat’s eyes is directed accurately, which does not result in the mirror effect on the road and allows the driver to assess his position on the road well.

3.1.2 Fog
During the fog light particles are dispersed, hindering light penetration. Horizontal marks and signs are sometimes insufficient. Time for response is too short. LED cat’s eyes make the road at least twice as visible (figure 5).

Figure 5. LED cat’s eyes in road edge –view during fog (9)
3.2 Current impact on safety
The British Department for Transport has introduced LED cat’s eyes in over 120 places all over the country. Those handpicked places are the so-called black spots. Research of the local authorities shows that the number of accidents at night has been reduced by about 70% over the year.

In Great Britain, a test, 6-mile section on M25 motorway (a part of London bypass) was constructed on which over 4,500 solar LED elements were installed as an alternative source of road lighting. The tests showed that the cat’s eyes used positively affected drivers who overtook other vehicles more seldom and avoided dangerous maneuvers. Breaks were used more effectively and traffic flow was improved. From the environmental perspective, carbon dioxide emissions and the cost of driving on a given section have been reduced [8]. The tests also showed that lighting the road with solar LED cat’s eyes may be an alternative to more expensive traditional lighting. [13]

4. Results and discussions
In order to assess the effectiveness of LED cat’s eyes, the author of the paper tested these elements. The tests involved using two elements that emitted red and orange colors. To mirror the real operation of such elements as best as possible, they were subjected to atmospheric light before the tests. LED cat’s eyes are equipped with solar batteries which, when charged, power LEDs. The elements were charged for a whole day, but the tests were performed in a foggy day in December. Then, due to shorter days of the year and weather preventing light from reaching the surface of the earth, LEDs are expected to work for a shorter time period. Despite this, LEDs emitted light for about 5 hours.

A doubtless disadvantage of these elements is the fact they are turned off when light is emitted from other sources. Thus there is a risk that LED cat’s eyes may not work properly. Such a situation may occur when a light beam emitted by headlamps of an approaching vehicle are directed to the batteries of the elements described here. Therefore, the author tested the effectiveness of LED elements under the aforementioned conditions.

The first test was performed on the road without street lighting. Such a test is useful since certain pedestrian crossings are not illuminated. The way the diodes work when a passenger car drives by them was tested. It turned out that the diodes are visible from a distance of a few hundred meters. Even if they work for a longer time period at night, once they were drained, the diodes started to work again because the light beams emitted by the car headlamps illuminated the solar batteries from a distance. A disadvantage of these elements is the fact that they went out when the vehicle was at a distance of 9 m away from them, as light emitted by the headlamps was so bright that the LED elements “perceived” it as daylight. However, drivers need LED light most importantly at a distance of at least 50 m away from a pedestrian crossing. Then, this disadvantage becomes insignificant.

The second test was performed on the road with street lighting. Most of the pedestrian crossings are situated just near street lamps. Similarly, the diodes were visible from a distance of a few hundred meters and started to work again when the light beams emitted by the car headlamps illuminated the solar batteries from a distance. A disadvantage of these element is also the fact that the diodes did not emit light if they were installed 3 m away from a street lamp or closer. Also, the diodes went out when the vehicle was 6 meters away from them. It can be noticed that these elements may somehow adapt to incoming light beams because the approaching vehicle could approach the LED elements before they went out. However, just like in the previous test, drivers need light emitted by LEDs most importantly at a distance of at least 50 m away from a pedestrian crossing. Then, the said disadvantage becomes insignificant.

5. Conclusion
Road lighting and visibility of all road users are of extreme importance. A right response time resulting from the visibility of a risk or an obstacle allows to mitigate consequences of accidents or completely eliminate them. The solar LED cat’s eyes described in this article are very beneficial for
both road users and the society. The article describes their usefulness supported by own tests, though one must bear in mind that LEDs will work properly at a certain distance from such a source light as a street lamp. Cat’s eyes should be made from the best quality materials and should be used in sensitive places (road edges, crossroads, pedestrian crossings or lines indicating directions).

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