ROADSIDE VEGETATION – THE IMPACT ON SAFETY

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Abstract. Trees and other vegetation, called "roadside vegetation", are found along a road lane and have different functions. This paper provides the analysis of the impact of vegetation on water erosion, winter conditions, visibility of formation line, glare effect, inhibition of energy, wind strength, presence of animal habitats and creation of specific microclimate. Apart from typical ecological functions, they also impact the risk for people involved in the traffic flow. These influences have both a positive and negative impact on the safety of vehicle flow on roads. The paper uses the method of data analysis, and accident rates were calculated with the participation of environmental conditions - driving into a tree, hitting an animal, rainfall, snowfall, blinding sun and strong wind gusts. The main conclusions of the study include: (1) roadside vegetation has many positive characteristics and also influences the safety of road users, (2) taking into consideration different environmental conditions, most road accidents are caused by driving into a tree, (3) the overall number of road accidents in Poland influenced by environmental conditions is decreasing despite the growth in the number of vehicles, (4) by employing the standards of woodlot shaping, it is possible to retain the positive influence of the vegetation on the space and, simultaneously, make the space safe for road users.

Keywords: roadside vegetation, hazards on the road.

Introduction

Intensive economic development of Poland drives the need for better and more efficient transport and communication, which directly relates to the development of road transportation [1]. Transport infrastructure may constitute one of the most significant barriers for a country's development. Its improvement should influence the growth of accessibility of many strategic centres and regions on the national, regional and European level and, thus, have an impact on the improvement of competitiveness of particular cities, investor-friendly areas and attracting foreign tourists [2]. Increase of accessibility is not only about building new roads, but also about reconstruction and enhancing the safety of already existing ones. The second factor is related, inter alia, to vegetation growing within the boundaries of the right of way. It encompasses a broad range of natural plant communities to artificial plantings performed manually. Roadside vegetation fulfils many functions [3] including: control of erosion, ensuring aesthetic benefits, protection against snow being blown-in, reducing glare, strengthening the road grade line, creating a noise reducing barrier, decreasing the power of the wind and providing a habitat for animals [4]. The same vegetation also introduces some additional hazards. The problem of road hazards is common and universal. It is a well known fact that Polish roads are not the safest. According to the EuroRap report prepared for 2005-2007 – 61 % of the total length of national roads includes sections characterized by the highest risk level, and 85 % are roads which require undertaking measures that decrease the risk level [5]. The statistics are changing constantly, and according to the report performed for 2009-20011, the total length of the roads with the highest level of risk decreased to 34 %, while sections requiring risk-decreasing measures dropped by 17 % [6]. These beneficial changes are an effect of investments undertaken on Polish roads, introduction of automatic road traffic supervision systems and positive changes in the behaviour of road users. The main goal of the research is to investigate the effect of roadside vegetation on safety on the roads. The study was conducted with the use of road accident statistical analyses, which include the so-called environmental factors.

Many researchers approach the topic of roadside vegetation mainly from the perspective of landscape [7; 8], ecology [9] and road user safety [10]. According to Forman [9], vegetation coverage is a key factor influencing erosion caused by rainfall. First of all, it decreases the force of the rain drops and the speed of water flow, filters chemicals from the flowing water, increases the penetration of water into the soil and increases the evapotranspiration (vertical movement of water to the atmosphere). Securing erosion-prone land happens by maintaining a high percentage of vegetation cover, dense network of roots (shallow and deep) and thick layer of organic substances in the soil. Preventing erosion is supported by three other principles [11]. The first principle refers to limiting exposure, i.e. decreasing the area and time of keeping soil without vegetation. The second, maintaining sediments using filtering devices such as silt fences, baled straw or fences built from remains left after cleaning and raking the area. The third principle deals with managing the water flow, i.e. directing surplus water to the target point [12], e.g., a storage-infiltration reservoir.

Another function of roadside vegetation regards protecting sections of communication routes from excessive snow. Snowfall limits a driver's visibility, and its accumulation on the road limits vehicle mobility. Snow fences are created from vegetation or building materials. They are usually described as artificial anti-snow fences, and they limit the impact of wind and influence the movement, accumulation and disappearance of snow [13]. Snow fences made of vegetation also constitute suitable habitats for wild animals, improve aesthetic values and generate long-term economic benefits [14]. It is considered that living snow fences fulfil their role effectively for a period of 50 years in comparison to the period of 4 to 7 years in the case of standard snow fences. The disadvantage of such solutions is the difficulty in planting in hard-to-access places, time required to achieve appropriate height, initial costs related to maintenance of vegetation and the area of the surface required. The efficiency of living snow fences depends on such attributes as: distance from the road, length of the vegetation belt, species composition, number of rows, distance between the plants and the quality of environmental habitat and biodiversity [9], species contribution of trees and bushes [15], height of the trees, crown porosity (or its density) and height of the branches above ground. Dense crowns of tall trees and low hanging branches stop the largest amount of snow. Increasing the height of the corpus of the road over the surrounding territory usually limits the accumulation of snow, since the snow is blown from the surface. If there is a small difference between the height of the road embankment and the height of the fence, the effectiveness of the fence is low [13]. Decreasing the amount of snow being blown onto the roadway is also currently an important problem for those territories of Poland where around half of road accidents occur in winter, which is related to limited visibility caused by snow being blown onto the surface of the road. Another interesting feature from the point of view of the functions of roadside woodlots is road indication and reducing the glare effect. In the past, indicating the road with woodlots was important, since it prevented travellers from getting lost (on foot and on horseback) in winter or at night. It also constituted protection for travellers from the sun and for the military from the eyes of the enemy and airplane pilots. In the era of hard-surfaced roads, with horizontal marking and lighting, it no longer has such importance. What is especially desirable these days is the introduction of bushes (grass vegetation or bushes) on the external and internal side of road bends, especially those with a small radius [16]. Such an arrangement of vegetation zones planted in belts on roadsides makes the road prism more visible [9]. The setting of the vegetation zones should be clear and placed on long and steep slopes. The surrounding vegetation, e.g., forest, if it is higher than the vegetation on the roadside, decreases the road insolation. The glare effect and blinding of the driver is caused by sunlight being reflected from the road, flashes of the sun between tree crowns and blinding of the driver by approaching cars. This effect is related with rapidly occurring changes of the lighting conditions, to which the human eye gets accustomed too slowly while driving, with the result that the perception of all objects on the road is impaired. Belts of tall condensed trees ensure dimmed lighting conditions, thus protect the roadway, while the porosity of the tree crown is the cause of gleaming sunrays. Strips of bushes planted on the belt dividing the lanes are to decrease the risk of becoming blinded by approaching vehicles. The fourth feature of roadside vegetation that deserves consideration is its ability to mitigate the results of road accidents. In places where the probability of the vehicle sliding off the road is too high, one needs to install barriers, cut large trees and not plant new trees. Another more environmentally friendly option is to plant clumps of bushes in front of an overpass pillar, an information board pillar or a tree in order to partially absorb the force of impact of the car. This can be successfully done by planting from one to four bushes. Another solution would be to install a shock absorbing construction in front of a facility and install it behind bushes. This mitigates the destructive force and damage done to the car, causes less severe injuries, decreases treatment costs and is beneficial to wild animals [9].

Noise caused by machines and various devices is audible both in the construction stage as well as during road exploitation. The noise burden depends on the traffic intensity, types of vehicles, technological solutions and terrain [17]. Avoiding a negative acoustic impact on the inhabited areas is ensured by such route planning that avoids built-up areas and, when this is not possible, by using protective elements such as embankments, noise barriers, greenbelts or a combination of these elements [18]. The research reveals that the level of road noise decreases proportionately to the distance from the road. Near a multi-lane highway with a traffic intensity of 50 000 vehicles a day, the noise intensity drops rapidly at a distance of the first 100 m from the road [19]. In open areas, the noise intensity decreases by about 75 dB to 45 dB at a distance of 800 m from the highway, while in the woods, the noise intensity drops at the same distance from 75 dB to 35 dB [18]. Acoustic waves are dispersed and absorbed by tree, bush and grass covered territory. The more leaves and the denser the woodlots and bushes, the better the sound-absorbing barrier. A typical deciduous hedge with a width of 180 cm and breadth of 160 m with thin leafage reduces noise by 1-2 dB [20]. Trees and bushes planted in belts with a width of 7-8 metres decrease noise by 10-13 dB [21]. Creating broad barriers is not always possible around the roads; however, even narrower rows, despite their smaller noise reduction, absorb and disperse part of the acoustic energy, thus reducing violent surges and drops of noise levels [22].

Rows of trees or bushes, both planted as well as occurring naturally, depending on the location or the design, also influence the flow of wind. Appropriate selection of road vegetation and its properties helps influence such road factors as: strength and alignment of crosswinds, wind velocity, accumulation of dust, snow and ice, as well as location of cool, warm, wet and dry patches. Short wind barriers are not very effective in reducing wind velocity due to the bending of wind direction at the edges of the barrier. Breaks or gaps frequently cause an increase of wind velocity by 20 % or more, affecting, in consequence, passing vehicles and cyclists [9]. A vehicle moving in the quiet zone is hit by a sudden, fast air current, frequently causing the vehicle to swerve onto the other lane.

Roadside vegetation also serves as a dwelling place for animals and birds [23]. The research revealed that the density of smaller mammals on belts dividing highways was highest in spots where an un-mown grassy belt grew next to a belt of trees. Tree crowns on medium width roads, where the branches of trees grow on opposite sides, touch and create a passage for tree-living animals [24]. On wide roads, where tree branches on both sides of the road do not converge, animals cross the road, causing numerous road accidents. Solutions to tackle these problems include so-called artificial bridges, "hammocks" or the construction of other types of crossings for animals. Due to the long, narrow shape of the roads, cutting out woodlands for the purpose of constructing roads creates a vast wood-edge area, which leads to a loss of the habitat for animals typically inhabiting the interior part of woodlands [9]. Another relevant advantage of introducing greenery along roads and streets is the mitigation of the effects of microclimate, including oscillation of air temperature, insolation and winds. The reduction of temperature is possible thanks to planting trees with compact crowns (e.g., chestnuts or lindens), which has a strong dimming effect on streets. In summer, the temperature of the area under a tree crown may drop by even 10 degrees in comparison to areas without trees [25]. Lowering the temperature causes an increase in air humidity. Roads crossing open terrain and woods clearly have different microclimates. Generally, changes can be observed around the roadway as well as the roadside. The biggest changes can be observed in the vicinity of the wood edge. A German study examined the insolation, temperature of the soil and evapotranspiration at distances of 50 m from the road. The shortest distance of the road relevant influence was observed on the impact on soil temperature, which markedly grew at a distance of 2-3 metres from the roadway (mainly within the roadside area), and markedly increased evapotranspiration in the woods that neighboured the road was observed within a distance of not less than 15 metres from the road [26; 27]. The researched features are mainly positive in nature, but some do, in fact, pose threats to drivers.

Materials and Methods

As part of own research, a space-time analysis of road accidents was conducted for 2004-2011 in Poland, and an accident rate was calculated that included selected environmental conditions (driving into a tree, hitting an animal, rainfall, snowfall, blinding sun and strong gusts of wind), taking into account the population (WW1) and the number of engine driven vehicles (WW2):

Accident rate with participation of environmental conditions in per capita (WW1) = Number of people / accidents involving environmental conditions;

Accident rate with participation of environmental conditions in terms of the number of vehicles (WW2) = Number of engine vehicles registered in Poland / number of accidents involving environmental conditions.

The research included road accidents without road collisions. According to [28] – article 177 § 1 and 2 and [29] – article 93 § 1, a road accident is a phenomenon which happens as a result of an unintentional violation of road safety principles, which results in injury of another person or a severe impairment to health. A road collision can be defined as damage of property, e.g., another vehicle, roadside structure, overpass, roadside building. The analysed data were obtained from the General Police Headquarters (Road Traffic Office, Team for Prophylactics and Analyses in Warsaw) and the Central Statistical Office.

Results and discussion

Data analysis (see Fig. 1) shows a clear downward trend in the number of road accidents in consecutive years. Since 2004, the number of road accidents in Poland has dropped by almost 22 %, while the analysed accidents involving environmental factors dropped by as much as 40 %. This is caused not only by the expansion of the road infrastructure, but also modernization of those road sections which pose the largest threat. The analysis of the types of environmental conditions (Fig. 2) indicates that the largest number of accidents include driving into a tree or are due to rainfall. Over the years, this tendency has been gradually decreasing in both cases. The number of accidents involving hitting an animal is not decreasing. At present, on newly built and modernized roads, it is mandatory to install devices which help avoid collisions and accidents involving animals. Such devices include: crossings for animals (so-called green bridges), fences, anti-glare barriers, noise barriers and shelter greenery [18]. Accidents caused by snowfall depend on the variability and amount of snowfall in a given year. Snow in wooded areas tends to stay longer on the road than in a territory without trees, causing localized slipperiness. On the other hand, appropriately designed hedge-barriers prevent the snow from being blown onto the road. Changes in the examined period of time are sinusoidal. Blinding sun is responsible for an increase in the number of accidents. This factor may be mitigated by planting trees that dim the light that reaches the road. Accidents caused by strong gusts of wind also occur with sinusoidal frequency.

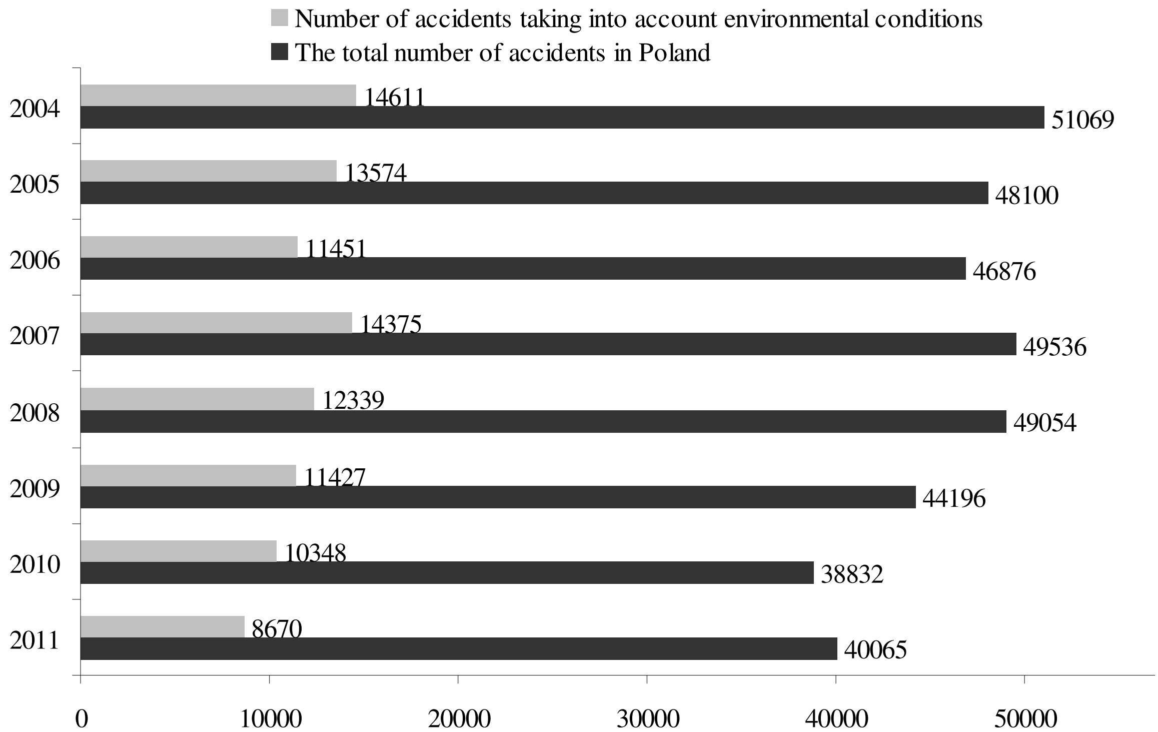

Fig. 1. **Total number of traffic accidents and road accidents involving environmental conditions in Poland (year 2004-2011)**

The WW1 accident rate adjusted for population changes in Poland shows a downward trend. In 2004, 383 accidents happened per 1 million individuals involving driving into a tree, animals, rainfall, snowfall or blinding sun; in 2011, this number dropped by almost 30 %, and there were only 225 such accidents per 1 million individuals. The WW2 accident rate, which includes the number of vehicles, has changed from 9 to 4 per 10 000 motor vehicles. With such a significant increase in the number of motor vehicles (almost 70 % increase between 2004 and 2011), this indicator has decreased by half.

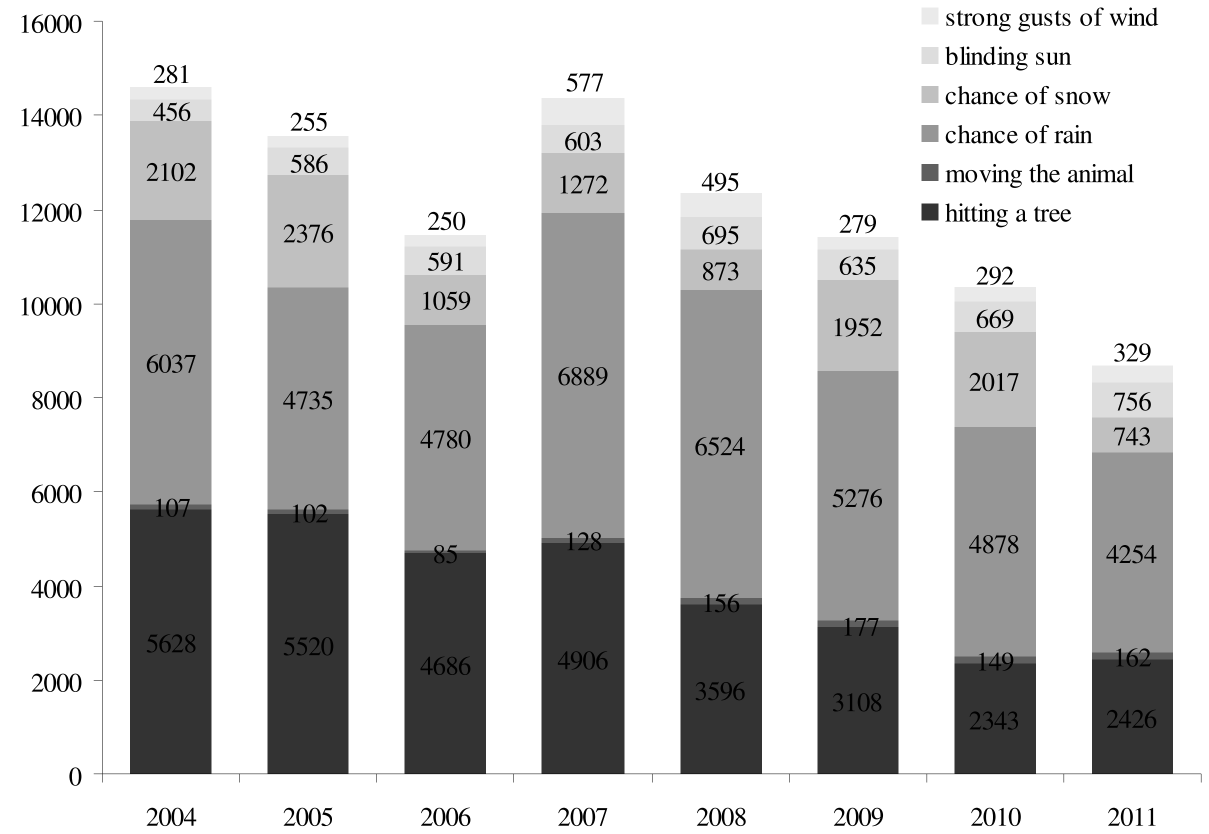

Fig. 2. **Number of road accidents, taking into account environmental conditions in Poland (year 2004-2011)**

The conducted analyses paint a picture of growing road safety. Despite the expansion of road infrastructure and a growing number of motor vehicles, the examined environmental conditions are less frequently the cause of road accidents. Undoubtedly, one of the reasons is the introduction of safety management mechanisms, which are to ensure quicker elimination of dangerous sites and areas.

Table 1

Accident rate with participation of environmental conditions

Year	Number of accidents with environmental conditions	Population, millions	Accident rate with participation of environmental conditions in per capita (WW1)	The number of motor vehicles	Accident rate with participation of environmental conditions in terms of the number of vehicles (WW2)
2004	14 611	38.174	382.75	16 701.072	8.75
2005	13 574	38.157	355.74	16 815.923	8.07
2006	11 451	38.126	300.35	18 035.047	6.35
2007	14 375	38.116	377.14	19 471.836	7.38
2008	12 339	38.136	323.55	21 336.913	5.78
2009	11 427	38.167	299.39	22 024.697	5.19
2010	10 348	38.204	270.86	23 037.149	4.49
2011	8 670	38.512	225.12	23 958.948	3.62

In Finland, France and the USA, three road safety zones have been introduced. Such zones are composed of two components, i.e. the return zone, which makes it possible – if the driver makes an error or if there is an unexpected event that made the driver drive off the road – to safely come back to the right direction of driving. The second component is a lane free from obstacles, e.g., trees, which mitigates the effects of accidentally driving off the road [30]. In some parts of Poland, tree alleys are an element of cultural landscape. They should only be destroyed as a last resort. The safety report indicates tree protection methods, including marking trees with reflective bands, using barriers protecting against driving off the road and hitting a tree, using special barriers near trees, construction of a new road outside the tree alley or building safety lay-bys that enable a safe stop by the road [31].

Conclusions

1. Space-time analysis of the number of accidents involving roadside vegetation clearly indicates that the largest number of accidents involves driving into a tree.
2. Despite the increase in the length of public roads and the number of motor vehicles in Poland, there is a downward trend as far as the number of accidents is concerned.
3. Roadside vegetation in many ways positively influences road safety. However, some of its attributes also pose a danger to road users.
4. International publications are increasingly preoccupied with standards regarding roadside greenery, which include guidelines on shapes of trees or preferred species. They refer, however, to the design phase and thus to the space created by humans. Serious consideration is necessary when it comes to already existing woodlots, which, on the one hand, are an integral element of the natural landscape and positively affect the natural environment in the vicinity of roads and, on the other hand, pose significant threat to road users.

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