INVESTIGATION IN INFLUENCE OF VEHICLE DRIVER SEATING POSITION ON VISIBILITY

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Abstract. This article examines the influence of a vehicle driver's seating position on visibility. Since sight is the primary way a vehicle operator acquires information about the surroundings, visibility is regarded as a crucial factor in ensuring road safety. This study analyzed driver visibility from the driver's seat, focusing on blind spots generated by the vehicle's structural components. The investigation was conducted using a mannequin, at whose eye level vertical and horizontal lasers were attached. Visibility was assessed in BMW X3, testing five seating positions with varying backrest reclines (0°, 10°, 20°, 30°). The findings revealed that blind spots caused by the roof pillars restrict the driver's field of view, especially at intersections. The largest obstruction angle (9.5°) for the front left roof pillar occurred in the second seating position, while the smallest (7.5°) was recorded in the third. For the right pillar, the largest angle (12°) appeared in the second position, and the smallest (5.5°) in the regulated (0) position. At a 10 m distance, the blind-spot area of the left pillar varied from 7.5 m² to 9.7 m² depending on the seat position. The second seating position increased the right-side blind zone by up to 33% compared to the regulated one. These results demonstrate that even small changes in the seat height and distance can significantly alter visibility and impact road safety.

Keywords: pilar, blind spots, visibility, driver, seating position.

Introduction

Road traffic accidents are identified as a primary cause of mortality worldwide [1]. The main purpose of automotive transport is to ensure safe, fast, and convenient transportation of passengers and goods [2; 3]. As the operator of a vehicle, the human driver is one of the key factors in the road safety system [4]. Statistical studies indicate that most accidents occur due to human error. Authors who have conducted causal research on motor vehicle accidents highlight several contributing elements: loss of attention, inappropriate speed, or incorrect assessment of the situation [5]. A driver's ability to make correct decisions depends directly on his or her physical and psychological state as well as on environmental conditions. Because driver behavior in traffic can be influenced by various external factors, it is crucial – especially within the confines of a cabin or passenger compartment – to ensure good visibility through the windshield in order to minimize the risk of delayed obstacle detection [6]. To reduce risk, it is essential to consider active safety measures based on the "human-vehicle-road-traffic environment" system, in which the dominant links are the human and the vehicle [7].

A vehicle is one of the principal links in the safety system, where a high level of safety must be ensured via active and passive safety systems. Modern vehicles are equipped with various technologies directly related to accident prevention [8]. Advanced Driver Assistance Systems (ADAS) and autonomous vehicles significantly contribute to improving road safety and reducing the risk of human error.

Visibility from the vehicle is defined as a critical factor in ensuring safety on the road. Good visibility allows the driver to detect obstacles and other road users in a timely manner and to react swiftly to potential hazards. Visibility requirements are regulated by international standards, which establish minimum criteria defining the field of view from the vehicle operator's position [9]. Research findings indicate that even minor visibility impairments can substantially influence driving safety [10]. In an effort to lower the risk of accidents, active safety within the "human–vehicle–road–traffic environment" system continues to gain importance. Among these factors, the two most dominant links are unquestionably the human and the vehicle. The vehicle operator remains in a closed cabin or passenger compartment; therefore, ensuring good forward visibility through the windshield is paramount. For the vehicle (abbreviated as TP in some sources) operator, sight provides information about the surroundings [11]. Driver visibility from the vehicle is regarded as one of the primary factors affecting road safety [12]. Ensuring visibility is regulated by international standards that stipulate minimum requirements defining the field-of-view parameters in vehicles.

Based on statistical data, it is observed that, in an active road safety system, the least reliable link is the human factor. Most traffic incidents occur due to this human element [13]. During driver training, instructors often emphasize the importance of checking blind spots. Operators of bicycles enjoy the largest field of view, which can be only slightly restricted by a helmet. In contrast, operators of larger road vehicles face reduced visibility caused by the dimensions of the windshield pillars, seat headrests, door frames, or mirrors. These structural components create blind spots that may impede the driver's ability to observe the environment and react in time to potential hazards. An even more complex situation can arise for drivers of cargo vehicles, such as trucks, where there are no side or rear windows; as a result, the vehicle operator must rely on auxiliary devices that enhance visibility [14].

When evaluating visibility conditions, one inevitably encounters structural design elements. The size and shape of glazed surfaces are constrained by technical factors, such as aerodynamics and aesthetics; larger glass areas can reduce the vehicle body's rigidity and strength [15]. Larger glazed surfaces also complicate maintaining a comfortable interior temperature. Another challenging issue related to visibility is determining practical dimensions for windshield pillars. Any structural solutions implemented in vehicles must maintain an uninterrupted field of view to reduce the risk of collisions on the road. A significant number of traffic incidents occur because drivers fail to notice pedestrians or other vehicles, especially at intersections. The pillars that ensure the vehicle's structural integrity also limit the driver's field of view. Side window pillars create blind spots that can prevent the driver from seeing pedestrians, cyclists, or other objects, particularly when turning left. The right pillar may obscure road signs [16].

On average, the distance between human's eyes is about 65 mm, so narrower pillars can decrease blind spot areas. Modern designs often use pillars that taper toward the driver, improving visibility; however, these solutions are restricted by safety standards and structural strength requirements [17]. Although seat adjustment functions allow drivers to better adapt to the vehicle's design, they do not always guarantee good visibility. Research has shown that the driver's seat position is directly correlated with safe driving behavior and the risk of accidents [18]. Adjusting the driver's seat to the correct position is crucial to ensuring the necessary visibility for safe driving and reducing driver fatigue. An automobile driver's seat features various adjustment options that are integrated around the seat to promote safe driving. An improperly adjusted seat can cause not only physical discomfort but also increase the risk of accidents due to limited visibility or difficulties performing emergency maneuvers. To mitigate all these factors, it is essential and timely to address existing challenges and seek solutions that provide maximum safety for drivers.

The goal of this study is to investigate the influence of the driver's seating position on visibility and to propose solutions that help reduce the impact of "blind spots."

Materials and methods

In this study, the driver's visibility from the driver's seat was analyzed, with particular emphasis on blind spots caused by the vehicle structural elements. The field of vision is defined as the space in which the driver can observe the surroundings either directly or via mirrors [19]. The test examining the impact of the driver's seating position on visibility was conducted using a mannequin equipped with vertical and horizontal alignment lasers at the mannequin's eye level. The height of these lasers was set to correspond to the eye level of a driver who is 182 cm tall.

The test was conducted using an SUV-type BMW X3. Figure 1 depicts the seating positions examined in the study. Initially, the driver's seating position (0) was set according to the regulated seating position specified by the SAE J941_201003 standard [20] currently in effect. When conducting tests in position (0), the seat horizontal location was adjusted and the leg length to the pedals was set. It was ensured that the brake pedal would be pressed by the middle portion of the foot, and the accelerator pedal by the upper portion of the foot. While making these adjustments, the distance from the knees to the front of the instrument panel was maintained at no less than 10 cm. The leg bend angle was 127°.

The seat height was raised so that the driver's eyes were above the top half of the steering wheel, allowing full visibility of both the windshield and the instrument panel. The steering wheel was oriented toward the driver's chest. The seatback recline was set at 20°. When the driver's arm was extended toward the top of the steering wheel, the hand position was aligned with the center of the palm. During testing, a distance of at least 25 cm was maintained between the steering wheel and the driver's chest [21].

In the study, measurements were taken with the front roof pillars (labeled A) and the internal pillars (labeled B) (Figure 2A). Measurements were carried out in each predetermined position using a protractor mounted on the mannequin. The pillar blind-spot obstruction angle was determined by laser beams; the driver's seat position was changed, and measurements were repeated. A total of five driver seating positions were evaluated, and in each position the seatback recline angle was increased by increments of 10°, 20°, and 30° (Figure 1B).

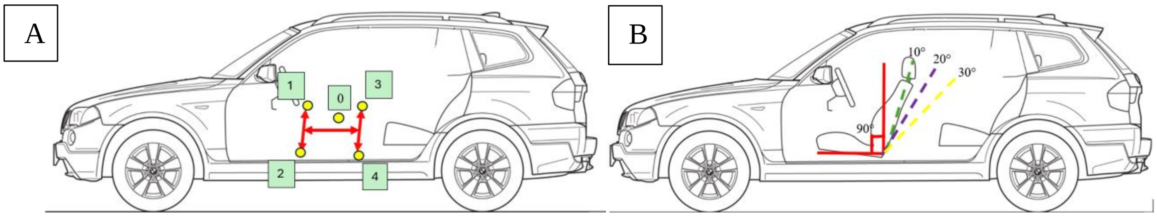

Fig. 1. **A positions: 1 – maximum forward and maximum up; 2 – maximum forward and maximum downward; 3 – maximum to the back and maximum to the top; 4 – maximum to the back and maximum to the bottom; 0 – SAE J1517 regulated seating position. B: for each set position, increasing the seat back by 10°, 20°, 30°**

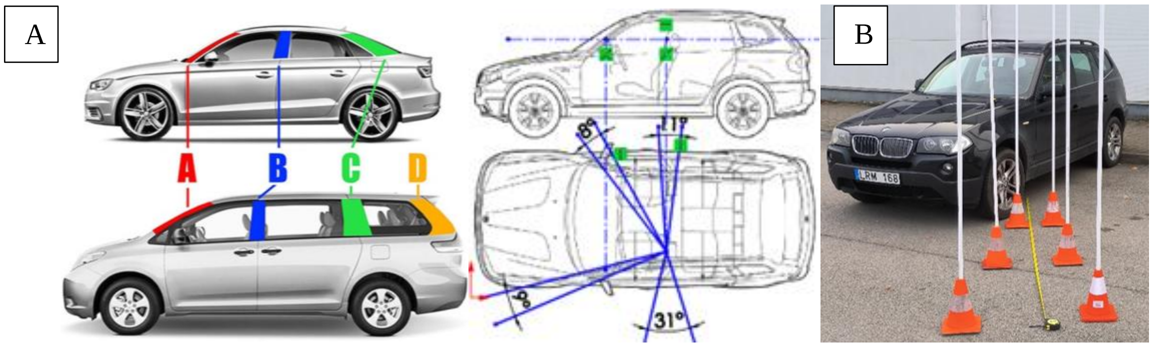

Fig. 2. **Measuring the blind area angles and invisible area**

Using a horizontal laser beam, the width of the blind spot was determined at distances of 1 m, 2 m, 3 m, 5 m, and 10 m from the boundary of the obstructed area (Figure 2B). The blind spot area, expressed in square meters, was calculated using a triangular area formula. The collected data were organized in Microsoft Excel 2019 and represented graphically. The article presents results for the roof pillar (A) at a 20° seatback recline angle.

Results and discussion

Figure 3 presents the measured angles for the front left and right roof pillars (A). Analyzing these data, it can be observed that the largest obstruction angle (9.5°) for the front left roof pillar (A) occurred in the second seating position. Meanwhile, the smallest obstruction angle (7.5°) was noted in the third seating position when the seatback recline angle was set to 20°. The study results indicate that the field of vision is directly dependent on the driver's seating position. An improperly adjusted seating position is often a significant cause of accidents. Automobile manufacturers define the optimal seating position based on the driver's eye location [22].

From the measured coverage angles of the front right roof pillar (A) in relation to the driver's seating position, it can be seen that the largest coverage angle – 12° – occurred in the second position with a seatback recline of 20°. The smallest coverage angle – 5.5° – was recorded in the regulated (0) seating position. As shown, the smallest change in coverage angles at 20° seatback recline was observed in the regulated (0) position, whereas the largest change in coverage angles emerged in the second seating position, which was adjusted further forward and lowered to the maximum extent. These results suggest that the field of vision is closely tied to the driver's seating posture, so proper seat adjustment is essential for safe driving.

Figure 4 presents the blind-spot area data for the front left and right (A) roof pillars, expressed in square meters at a distance of 10 meters. From the graph, it can be seen that with a 20° seatback recline in the 2nd, 3rd, and 4th seating positions, the blind-spot areas of the left front roof pillar are reduced by 16%, 14%, and 4%, respectively, compared to the regulated seating position. The largest blind-spot area of 9.7 m² for the left front pillar was observed in the first seating position, while the smallest area – 7.5 m² – was recorded in the second position.

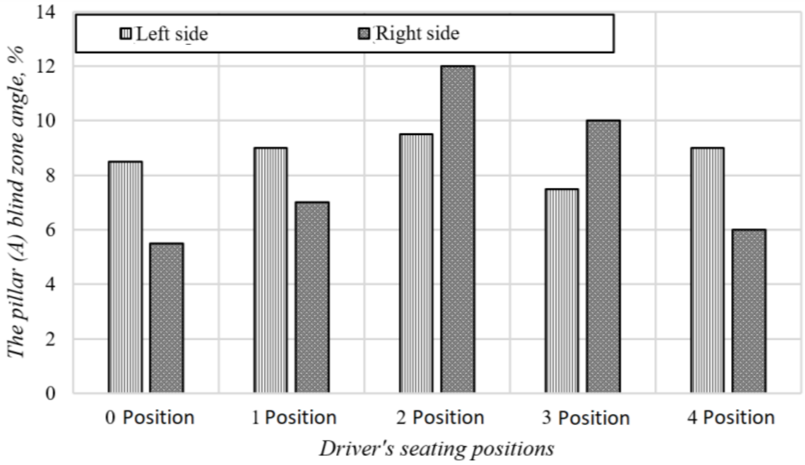

Fig. 3. **Data on the cover angles of the front left side (A) pillar, at a backrest angle of 20°**

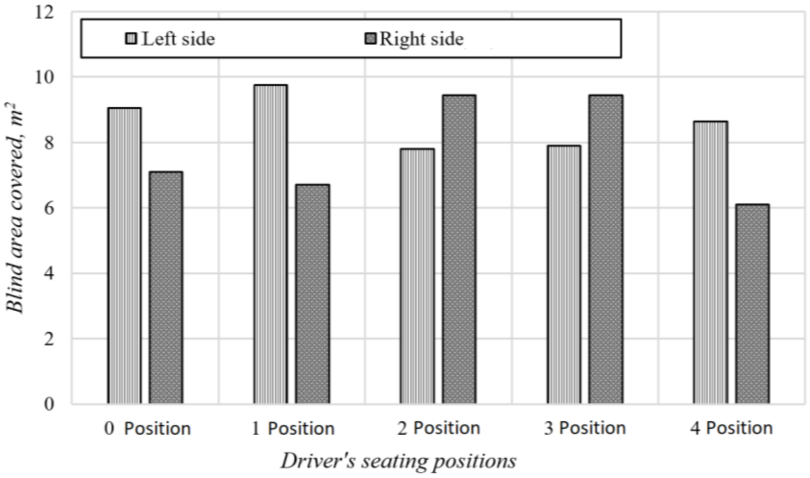

Fig. 4. **Front left side (A) pillar blind zone areas at 10 meters distance, at a backrest angle of 20°**

When evaluating the blind-spot areas of the front right (A) roof pillar in relation to the driver's seating position, it was observed that the largest covered area occurred in the second and third seating positions. From the figure, it is evident that the smallest blind-spot area for the front right (A) roof pillar was recorded in the fourth position. Analyzing the presented graph, one can see that with a 20° seatback recline and the driver in the second or third seating position, the blind-spot areas of the front right roof pillar increase by 33% compared to the regulated driver seating position.

The smallest change in the blind-spot area of the left and right front (A) roof pillars, at a 20° seatback recline, was observed in the fourth seating position. In contrast, the largest change in obstruction angles was recorded in the third seating position, which was adjusted further back and raised to its highest level. With the driver in the fourth seating position (moved further back and lowered), the change in the front roof pillar's blind-spot area was 16% lower compared to the regulated driver seating position.

Fig. 5. **Driver's place of vision image from the reglamented (0) driver seating position**

Fig. 6. **Driver's place of vision image from the fourth driver seating position**

Figures 5 and 6 show the driver's field of view from the driver's seat according to different seating positions. When evaluating the driver's field of view in the fourth seating position, it becomes evident that this position affects the forward field of vision (Figure 6). A reduced field of vision can increase reaction time in critical situations. It can be assumed that a driver who sits too high or too low may have limited visibility through the windshield or mirrors, while sitting closer to the steering wheel can limit the ability to see road signs and traffic lights.

Based on the study findings, it can be stated that the field of vision is closely linked to the driver's seating posture; consequently, proper seat adjustment is essential for safe driving.

Conclusions

1. The largest obstruction angle of 9.5° for the front left (A) roof pillar was observed in the second seating position, while the smallest obstruction angle of 7.5° was noted in the third seating position with a 20° seatback recline.
2. The front right (A) roof pillar had its largest obstruction angle (12°) in the second seating position with a 20° seatback recline. The smallest obstruction angle (5.5°) occurred in the regulated (0) seating position.
3. The smallest change in obstruction angles at a 20° seatback recline was recorded in the regulated (0) position; in contrast, the largest change appeared in the second seating position, which was moved further forward and lowered to the maximum extent.
4. The smallest change in the blind-spot area for the front left and right (A) roof pillars, at a 20° seatback recline, occurred in the fourth seating position; the largest change was found in the third seating position, which was moved farther back and raised to its highest level.
5. Because the field of vision is closely tied to the driver's seating posture, proper seat adjustment is essential for safe driving. An incorrect driver position can be one of the causes of accidents, as it reduces the field of view and may increase reaction time.

Author contributions

Jonas Matijošius (J.M.), Rytis Zautra (R.Z.), Tomas Mickevičius (T.M.). Conceptualization, J.M., R.Z. and T.M.; methodology, J.M., R.Z. and T.M.; software, J.M., R.Z. and T.M.; validation, J.M., R.Z. and T.M.; formal analysis, J.M., R.Z. and T.M..; investigation, J.M., R.Z. and T.M.; data curation, J.M., R.Z. and T.M.; writing – original draft preparation, J.M., R.Z. and T.M.; writing – review and editing, J.M., R.Z. and T.M.; visualization, J.M., R.Z. and T.M.; project administration, T.M.; funding acquisition, T.M. All authors have read and agreed to the published version of the manuscript.

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