Research Article

# Importance of A-pillars of vehicles during intersection approach

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**Abstract:** Pillars are essential since they ensure body strength for vehicles. However, they are solid and opaque parts between the windshield, side and rear windows. Especially the first, A-pillar, and last are designed as thick as possible to improve the body strength. This study focuses on the blind spot caused by the A-pillar of the vehicle. A numerical analysis has been performed to determine the velocity relations between the two vehicles. One stays in the blind place of the other. Nine different driver scenarios have been given. These scenarios depend on the position of the driver and the A-pillar section length. Based on the numerical analysis of the scenarios, vehicles that must give way notice the vehicle passing right 1.62 seconds before they both arrive at the intersection for low speeds. With the increase in speed, the time needed to arrive at the intersection decreases significantly. As a result, the A-pillar design parameters should also be considered when analysing an accident at the intersection.

**Keywords:** Traffic safety, A-Pillar, blind spot

## Kavşak yaklaşımında araçların A-sütunlarının önemi

**Özet:** Sütunlar araçlara gövde sağlamlığı sağladıkları için önemli parçalardandır. Fakat bu sütunlar camlar arasındaki sağlam ve opak parçalardır. Özellikle A-sütunu olarak da adlandırılan ilk sütun ile son sütun, taşıtların şase gücünü artırmak için mümkün olduğunca kalın tasarlanmıştır. Bu çalışma, aracın A-sütununun neden olduğu kör noktaya odaklanmaktadır. Biri diğerinin kör noktasında kalan iki araç arasındaki hız ilişkilerini belirlemek için sayısal bir analiz yapılmıştır. 9 farklı sürücü senaryosu verilmiştir. Bu senaryolar, sürücünün konumuna ve A-sütununun kesit uzunluğuna bağlıdır. Senaryoların sayısal analizine göre yol vermesi gereken araçlar, düşük hızlarda kavşağa gelmeden 1,62 saniye önce yol vermek zorunda olduğu aracın geçişini fark edebilmektedir. Hızın artmasıyla kavşağa ulaşmak için gereken süre önemli ölçüde azalır. Sonuç olarak, kavşaktaki bir kazayı analiz ederken A-sütununun tasarım değerlerinin de dikkate alınması gerektiği açıktır.

**Anahtar Kelimeler:** Trafik güvenliği, A-sütunu, kör nokta

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## 1. Introduction

Intersections are the important geometric parts of the transportation network. The traffic flow is in a strong position in planning the transport network. Especially the urban transport network area should be considered since many roads intersect with each other. Thus, many intersections get built.

Because of the joint points of the roads, intersections are critical geometric parts of the urban transportation network. Suppose no control mechanism is applied to these critical parts. Critical points (Khan et al., 2018) occur at the merger, junction and leaving sections of the roads connecting to the intersection. For a 3-link intersection, the number of these critical points is 9 for an uncontrolled intersection. In contrast, this number can increase to 32 and 79 for 4- and 5-link uncontrolled intersections (Özinal and Uz, 2021). As can be understood from these values, the number of critical points in uncontrolled intersections increases with the increment of the intersection link number. These points are called critical since accident possibilities get higher since two or more vehicles could get into contact.

Traffic accidents are unplanned and uncontrolled events because of people, situations, environmental factors, or combinations (Colling, 1990). Road traffic is one of the significant causes of property damage, health problems, permanent disabilities, and deaths. Thus, traffic accidents are considered a significant health problem globally. About 1.35 million deaths and between 20 and 50 million injuries occur yearly (Irtad, 2020). The daily death rate due to traffic accidents is 3,000 in the world. When the topic focuses on injuries, the count increases to about 30000 for around 240,000 cases yearly (Al Mamlook et al., 2019). These tremendous values and the passenger rate in traffic cause the need for a detailed passenger study (Kashani and Mohaymany, 2011).

According to the World Health Organization's (2018) data for 2016, about $1.35 \times 10^6$ deaths occurred due to traffic accidents worldwide. These traffic accidents affected all road users, including pedestrians, passengers, and drivers. Especially for people aged 15 to 29, traffic accidents are the leading cause worldwide. According to the National Highway Traffic Safety Administration's (2020) data for 2014 and 2018, about 400 thousand deaths and about 25 million injuries occurred because of about 32 million accidents.

Hakkert and Mahalel (1978) put forth how critical intersections are for traffic accidents. A statistical analysis of accidents in the USA has been performed based on the study. The results showed the importance of the intersections, where about 50% of all accidents occurred. Since that year, despite the developments in the vehicle and intersection technology, a recent study published by the General Directorate of Highways (KGM, 2020), which is about 40 years later, shows intersections still have a high accident rate. The KGM's report states that 37.7% of Turkey's traffic accidents occur at intersections. Recent studies (Yan and Shen, 2022) focus on the Traffic Attributes (such as latitude, longitude and distance), Temporal Attributes (such as month, day, hour, and weekday), Weather Attributes (such as pressure, temperature, humidity and visibility) and Point of Interests (such as traffic signal, junction, crossing and stop sign). However, the attribute of the pillars of the vehicles is out of interest.

This study highlights one of the reasons for traffic accidents at intersections. Generally, a vehicle approaching the intersection from the right has the right to drive. However, those approaching the intersection from the left should have noticed the approaching vehicle stop. However, the pillars of the vehicles block the view of the drivers. Especially when two vehicles are approaching the intersection one after the other, the second vehicle could stay in the blind spot. These situations are serious and could cause traffic accidents. This study focuses on two approaching vehicles at the same intersection. The vehicles' velocity and position conditions are analysed numerically to determine when the right-side approaching vehicle stays in the blind spot. So, this study highlights the importance of the pillars of the vehicles during crossing intersections which is very important but needs to be given the necessary attention during the accident analysis.

## 2. Pillars of the Vehicles

A typical vehicle has three or four pillars based on the vehicle's body. The pillar count is three for any sedan and hatchback vehicle, while the number increase to four for a station wagon vehicle. These pillars are essential parts of the vehicles since they provide structural strength to the vehicle's body. However, they are opaque and solid parts that block the view of the drivers.

**Figure 1.** Pillars position of a typical vehicle (Source: Wikimedia.org)

As seen in Figure 1, the pillars are named alphabetically. The front pillar is called an A-pillar, where the letter turns into the next by going backwards on each pillar. This study focuses on the A-pillar since it is placed in front and blocks the front side view of the vehicles. It is assumed that these pillars are 10 cm in width for this study. An inner view of the test vehicle is shown in Figure 2.

As seen in Figure 2, the A-pillar of a typical vehicle blocks a significant amount of view. This blocking is fundamental while passing the uncontrolled intersections. The right and left pillars are built thick to provide safety; however, the view parameter should be considered to ensure traffic safety.

## 3. Theoretical Analysis

As explained in the previous section, the front pillars, A-pillars, block a significant amount of the side view. Because of these A-pillars, the driver could miss the vehicles approaching perpendicularly an x meters away from the vehicle's route (Figure 3).

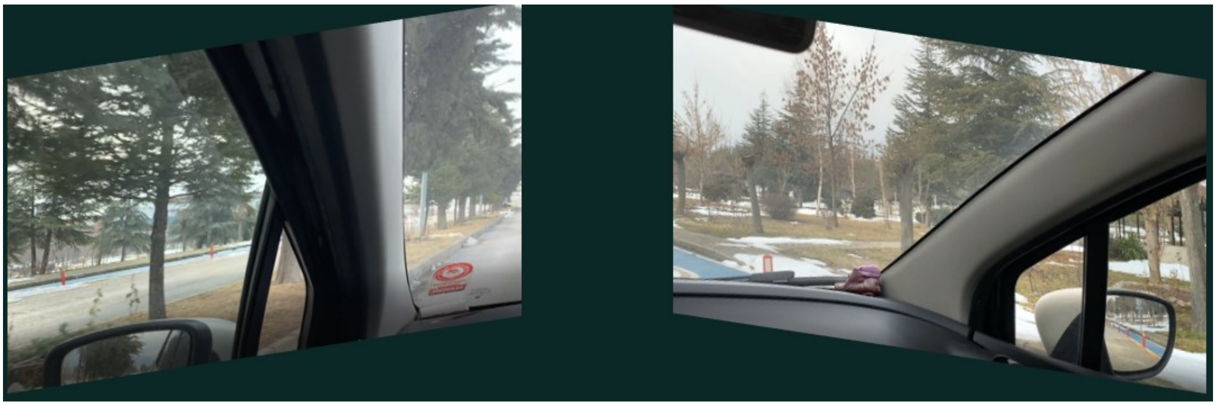

**Figure 2.** Inner view of a vehicle and A-pillars

Figure 3 shows two vehicles approaching the uncontrolled intersection where two roads intersect with the same priority. Both vehicles have four pillar body designs. The yellow area is the blind spot generated by the A-pillar of the vehicle. Both vehicles are driving from Position I to Position II. The vehicle (V1) driving south-north must give way to the vehicle (V2) driving in the east-west direction. However, the right-side A-pillar of the V1 is blocking the driver's view. Thus, V1 cannot notice the V2 until V2 gets too close to the intersection, which causes danger.

The red parts of the vehicles shown in Figure 3 are the pillar sections. One of the triangle yellow area corners is placed in the vehicle. This corner states for the driver's eyes. From this point, two lines are placed to cut the front and rear edges of the right-side A-pillar. When these two lines are extended, the blind spot area is determined. So, this area depends on the driver's position and the A-pillar dimension. V1 can notice the V2 if only the V2 is outside the blind spot area. So, determining whether V2 stays in the blind spot depends on the velocities, size of V2, and the distance to the intersection for both vehicles. This study focuses on two parts; first, to simulate the different blind spot areas formed, and second to determine the velocities and distances. The size has been determined as a 5 m long vehicle to simulate the V2 in 2-Dimensional by putting the cross corners in the blind spot area. The data given in Table 1 is used to simulate the blind spot area. Here the data given in Table 1 is randomly generated for a vehicle with a width of 1.5 meters. In addition, the distance to the windshield is randomly generated for three different drivers.

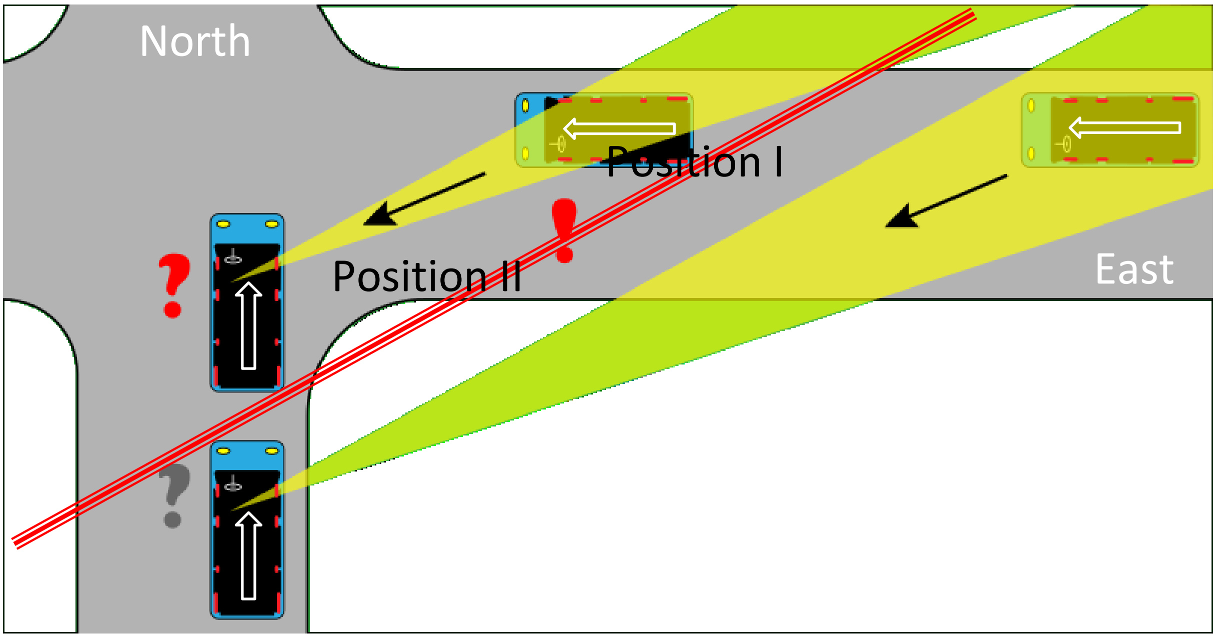


**Figure 3.** A schematic view of a sample intersection without a scale (Adopted from Wikimedia.org)

**Table 1.** Numerical simulation parameters

| Simulation Number | Distance to (m) Left Window | Distance to (m) Windshield | Distance to (m) Right Window | Pillar section length (m) |
|---|---|---|---|---|
| S1 | 0.3 | 0.55 | 1.2 | 0.1 |
| S2 | 0.35 | 0.6 | 1.15 | |
| S3 | 0.4 | 0.65 | 1.1 | |
| S4 | 0.3 | 0.55 | 1.2 | 0.15 |
| S5 | 0.35 | 0.6 | 1.15 | |
| S6 | 0.4 | 0.65 | 1.1 | |
| S7 | 0.3 | 0.55 | 1.2 | 0.2 |
| S8 | 0.35 | 0.6 | 1.15 | |
| S9 | 0.4 | 0.65 | 1.1 | |

Table 1 shows nine simulation scenarios based on the driver's eye position and the A-pillar dimension. When considering the driver and vehicle 2-dimensionally from a bird's eye view, the distance to the left and right window determines the driver's position on a horizontal axis. The total width of the vehicle is accepted as 1.5 m. Distance to the windshield is the space between the driver's eye and windshield on a vertical axis. The distance to the right window varies between 1.1 and 1.2 m, while the distance to the windshield varies between 0.55 and 0.65 m. Three A-pillar dimensions have been adopted for this study which is 0.1, 0.15 and 0.2 m.

Based on these scenarios, the following section determines different V2 approach velocities and the needed minimum V1 velocity values.

## 4. Results

This study investigates the driver's position and the A-pillar's dimension effect on the blind spot that occurred because of the A-pillar. The blind spot areas are shown in Figures 4, 5 and 6 for each pillar section length.

As seen in Figures 4, 5 and 6, the coloured areas are the blind spot areas for different scenarios in Table 1. The areas are overlapped, so the colours shown combine the given legend colours.

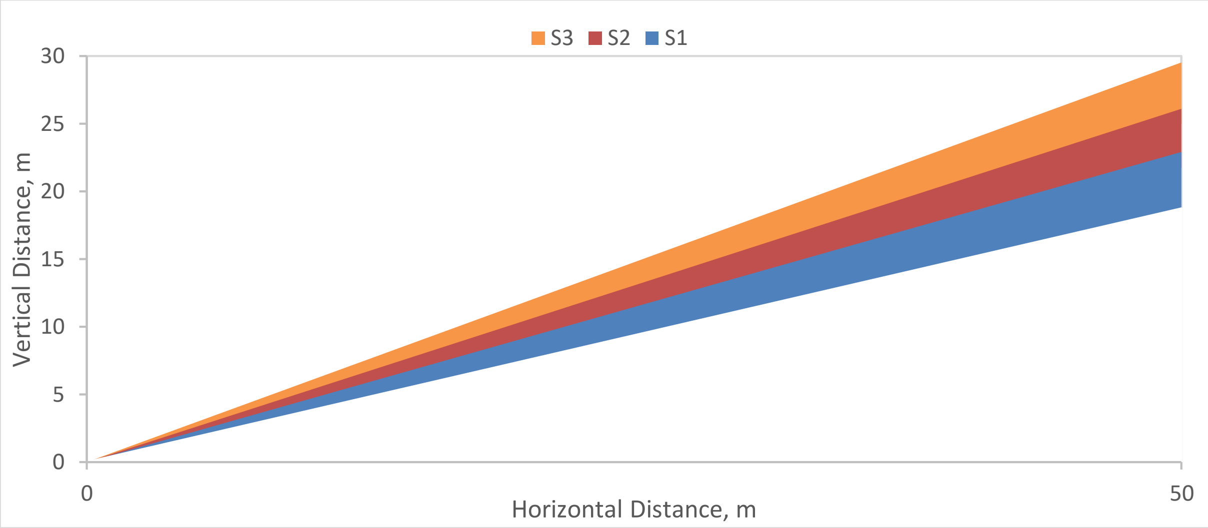


**Figure 4.** Blindspot areas for pillar section length of 0.1 m

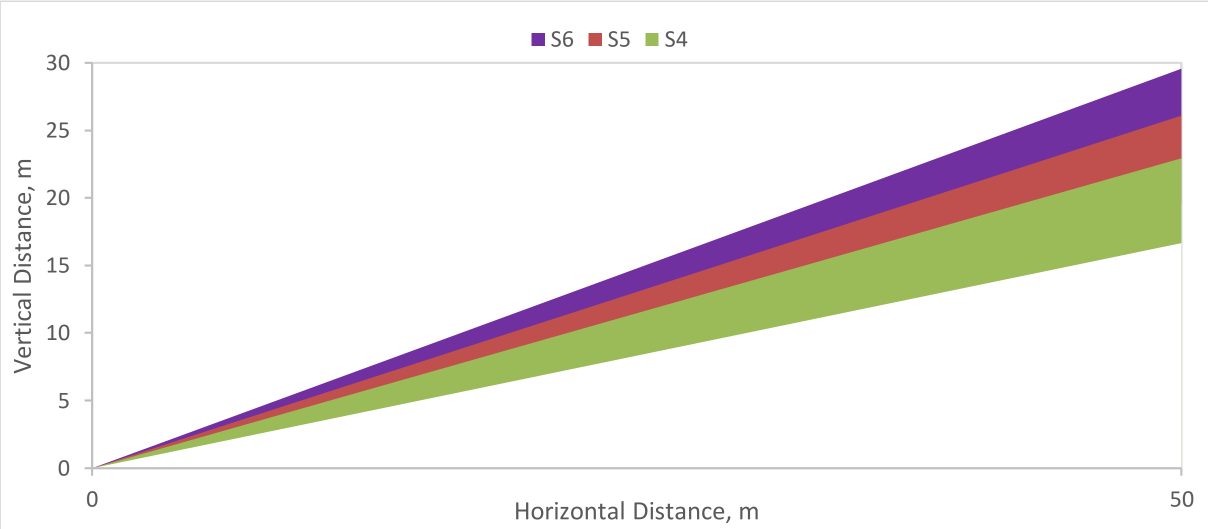


**Figure 5.** Blindspot areas for pillar section length of 0.15 m

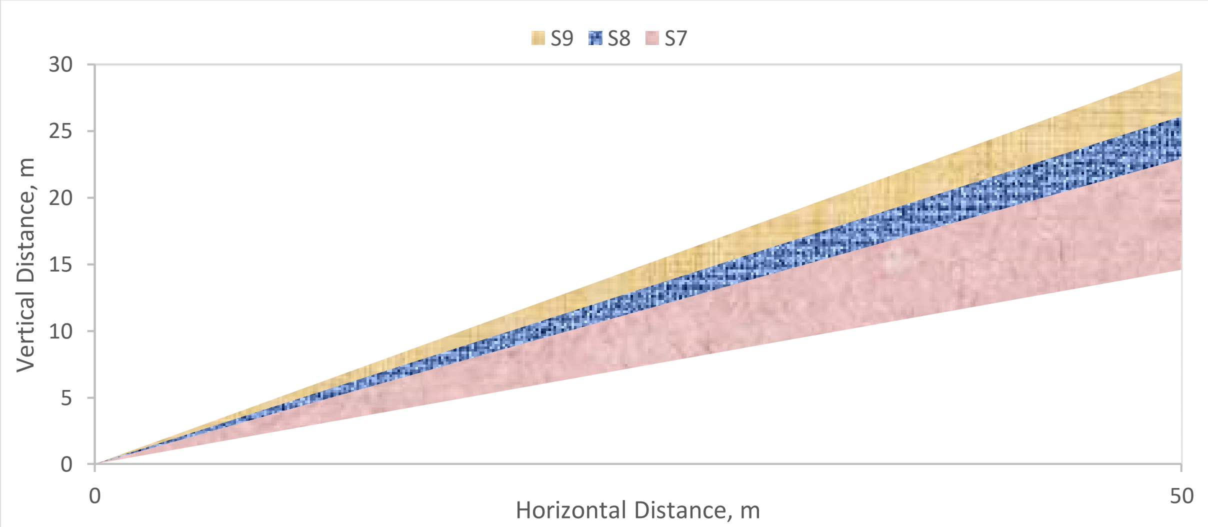


**Figure 6.** Blindspot areas for pillar section length of 0.2 m

The axis in Figures 4, 5 and 6 refer to the horizontal and vertical distances of two vehicles relative to each other. The blind spot area is growing with the increase of the A-pillar section length. With the pillar section length increase, the blind spot's bottom bounder increases about 4 meters for 50 meters in horizontal distance. Considering that V1 and V2 are 5 meters long, the minimum distance to the intersection has been calculated to investigate the velocity relations between V1 and V2. The minimum distances are given in Table 2. These distance values are calculated using Equation 1 (Figure 7). All these Equations are established using geometrical formulas.

$$X_H \times m_1 = (X_H + L_{V2}) \times m_2 \quad (1)$$

$$m_1 = \frac{d_C}{d_R} \quad (2)$$

$$m_2 = \frac{(d_C - l_P)}{d_R} \quad (3)$$

where $X_H$ is the minimum distance of V2 to the intersection (m), $L_{V2}$ is the V2 2-dimensional length (m), $m_1$ and $m_2$ are the slope values, and $d_C$, $d_R$ and $l_P$ are distance to the windshield, distance to the right window and A-pillar section length, respectively. When Equation 1 is simplified, the minimum distance of V2 to the intersection could be calculated using Equation 4.

$$X_H = \frac{L_{V2} \times m_2}{m_1 - m_2} \quad (4)$$

Once the $X_H$ value is calculated, the minimum distance of V1 to the intersection can be determined using Equation 5. The results are given in Table 2.

$$X_V = \frac{X_H}{m_1} \quad (5)$$

The velocity relations could be calculated using the minimum distance data given in Table 2. Thus, a velocity for V2 is assumed. Next, the needed time to drive the distance has been calculated. Finally, the minimum velocity for V1 needed to avoid any accident has been obtained using this information. Equation 6 has been used to determine the relationship between the velocities.

$$V_{V1} = 3.6 \times \frac{X_V + L_{V1}}{\left(\frac{X_H}{0.278 \times V_{V2}}\right)} \quad (6)$$

Here $V_{V1}$ and $V_{V2}$ are the velocity values for V1 and V2, respectively (km/h). The other parameters are as defined before.

**Table 2.** Minimum distances

| Scenario No | Distance to Intersection, m | |
|---|---|---|
| | V1 | V2 |
| S1 | 10.313 | 22.500 |
| S2 | 13.043 | 25.000 |
| S3 | 16.250 | 27.500 |
| S4 | 6.111 | 13.333 |
| S5 | 7.826 | 15.000 |
| S6 | 9.848 | 16.667 |
| S7 | 4.010 | 8.750 |
| S8 | 5.217 | 10.000 |
| S9 | 6.648 | 11.250 |

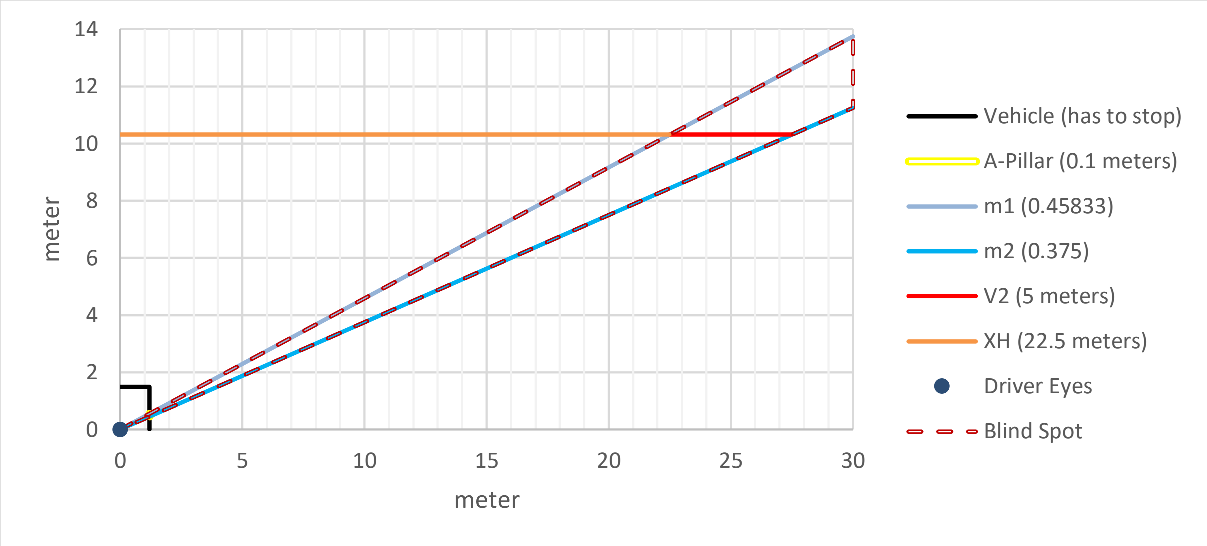


**Figure 7.** Visualisation of sample scenario (S1)

**Table 3.** Velocity relations for each scenario

| Vehicle | Velocity, km/h | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| V2 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| V1 for S1 | 34.028 | 40.833 | 47.639 | 54.444 | 61.250 | 68.056 | 74.861 | 81.667 |
| V1 for S2 | 36.087 | 43.304 | 50.522 | 57.739 | 64.957 | 72.174 | 79.391 | 86.609 |
| V1 for S3 | 38.636 | 46.364 | 54.091 | 61.818 | 69.545 | 77.273 | 85.000 | 92.727 |
| V1 for S4 | 41.667 | 50.000 | 58.333 | 66.667 | 75.000 | 83.333 | 91.667 | 100.000 |
| V1 for S5 | 42.754 | 51.304 | 59.855 | 68.406 | 76.957 | 85.507 | 94.058 | 102.609 |
| V1 for S6 | 44.545 | 53.455 | 62.364 | 71.273 | 80.182 | 89.091 | 98.000 | 106.909 |
| V1 for S7 | 51.488 | 61.786 | 72.083 | 82.381 | 92.679 | 102.976 | 113.274 | 123.571 |
| V1 for S8 | 51.087 | 61.304 | 71.522 | 81.739 | 91.957 | 102.174 | 112.391 | 122.609 |
| V1 for S9 | 51.768 | 62.121 | 72.475 | 82.828 | 93.182 | 103.535 | 113.889 | 124.242 |

As seen in Table 3, the minimum velocity value needed to avoid collusion between the two vehicles where the one with the passing right stays in the blind spot varies. When the V2 drives with a velocity of 50 km/h, the V1 could drive with a minimum velocity of 34 km/h. However, with the growth of the blind spot area formed by the A-pillar, the minimum velocity also increases to about 52 km/h. There is potential collusion when considering the intersection is in an urban area where the limit is 50 km/h. Readers should also note that as soon as vehicles notice each other, the time it takes to reach the intersection is approximately 1 second. Therefore, trying to stop would not work since 1 second is the response time duration. Thus, a thick-designed A-pillar could cause serious problems. Furthermore, the time to reach the intersection decreases with the number of vehicles.

## 5. Conclusion

This study investigated the velocity relations between vehicles approaching the same intersection in the same period, where one stays in a blind spot formed by A-pillar. Therefore, a numerical simulation has been prepared using a spreadsheet. The velocity values for the vehicle with the passing right have been assumed. After, the vehicle's velocity that does not see the ongoing vehicle with the passing rights has been calculated. As a result, the following conclusions could be drawn.

- The A-pillar of the vehicle is an essential part of ensuring body strength. However, too thick designed A-pillars cause serious blind spots. With an increase in the A-pillar section length, the blind spot area also grows simultaneously.
- The velocity value for the vehicle that does not see the ongoing vehicle with the passing rights differs based on the driver's position and pillar section length. For the conditions given in this study, the V1 velocity is 68.05% of the V2 velocity for the minor blind spot conditions. The V1 velocity increases to 103.54% of the V2 velocity for the worst blind spot condition. The V1 velocity value is always a rate of the V2 velocity value, no matter what.

The A-pillar's ergonomic design parameters could also be studied for future studies. This study focused on the minimum velocity values, avoiding possible collusion. However, the maximum velocity values could also be studied. Based on the findings of this study, A-pillar should be considered when investigating an accident at an intersection.

**Conflict of Interest Statement**

The author certify that NO affiliations with or involvement in any organisation or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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