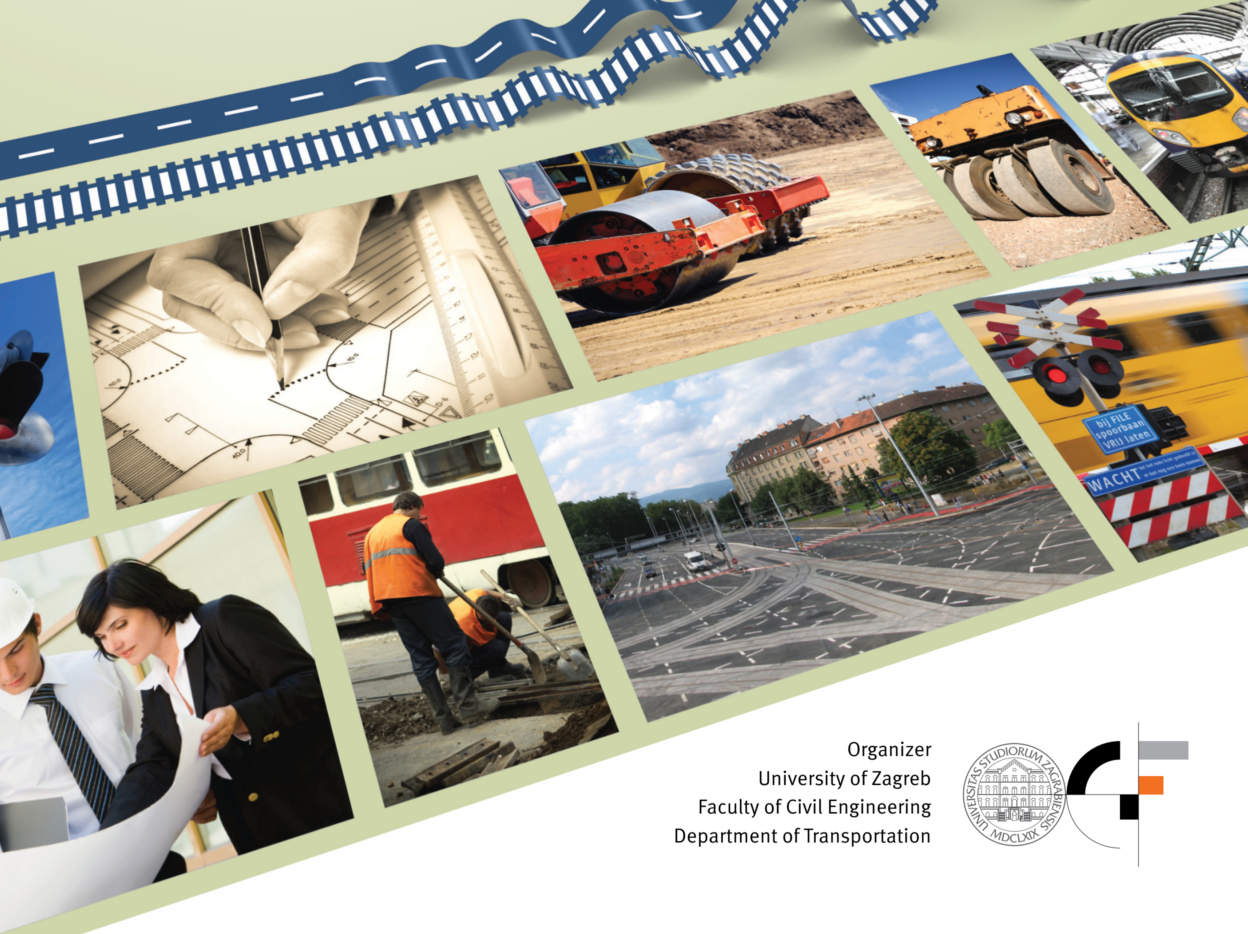
CETRA[2012]

2[nd] International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA^{2012}
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

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Proceedings of the
2nd International Conference on Road and Rail Infrastructures – CETRA 2012
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SIGHT DISTANCE TESTS AT ROAD INTERSECTIONS WITH UNFAVOURABLE ANGLES

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Abstract

Due to the limited field of view of the driver on the secondary road safety assessment capabilities of performing the desired action of turning and crossing at the road intersections with unfavourable angles (< 70° and > 110°) becomes uncertain. Since all the intersections from the standpoint of traffic safety services must have sufficient sight distance at the road intersections with unfavourable angles it is common to perform reconstruction of the secondary road axis, so that main and secondary road axis intersects at approximately right angle.
This paper will present how sight distance tests based on measurements of the driver visual field from different types of vehicles (passenger car and heavy vehicles) were performed on the road intersections with unfavourable axis angles. Test results will show for which road intersection angles it is possible to keep the secondary road axis in the direction, without the need for reconstruction.

Keywords: intersections, sight distance, driver field of view

1 Introduction

The main goal in designing road intersections is safe and undisturbed traffic flow as well as the rational utilization of surfaces. One of the prerequisites for the safe traffic flow at intersections is ensuring sufficient sight distance. Ensuring sight distance at intersections is achieved by additional berm widening, land reclamation and prohibition of construction of buildings so that nothing can encroach upon the space bounded by sight distance triangle. In addition to the mentioned research other studies [1, 2, 3, 4] have shown that at-grade intersections with intersection angles smaller than 70° and bigger than 110° limited field of view from the vehicle should also be taken into consideration in sight distance testing. Limited field of view from the vehicle at skewed intersections is mostly influenced by human factors (driver's field of view) and construction properties of the vehicle. The negative consequence of the limited field of view from the vehicle is manifested in the fact that the driver on the minor road at intersections with a skew angle cannot estimate well if the vehicles on the major road are at the sufficient distance for the safe performance of the required traffic maneuver. The usual procedure for solving this problem in designing practice comes down to the reconstruction of minor road axis so that it crosses the major road axis at approximately right angles [5, 6]. However, if the reconstruction of minor road axis is not possible due to space restrictions it is important to determine minimum (< 90°) and maximum (> 90°) intersection angles that allow minor road axis to be in the direction ensuring the safe traffic flow at the intersection.

2 Sight distance testing

Sight distance tests at four-leg intersections with a skew angle was based on testing visibility from the vehicle aimed at determining minimum (‹ 90°) or maximum (› 90°) allowable intersection angles up to which it is possible to keep minor road axis in the direction. Due to different factors that influence the visibility from the vehicle, sight distance testing is divided into two parts:

- for intersection angles › 90° (influence of the vehicle cabin B – pillar),
- for intersection angles ‹ 90° (influence of the driver's field of view and driver's head rotation angle).

In order to test the visibility from the vehicle three European vehicles were chosen:

- passenger car – brand VW, model Golf VI,
- van (maximum allowed mass ≤ 3.5 t) – brand VW, model Transporter,
- truck tractor (maximum allowed mass ≤ 16,0 t) – brand MB, model Actros.

Test vehicles were selected according to the availability criteria and the number of sold (newly registered) vehicles in Europe. According to the Jato Dynamics data [7] VW – Golf VI was the most sold vehicle on the European market in 2009 and 2010. VW – Transporter was used in testing for the reason of its availability (owned by the Department for Transportation of the Faculty of Civil Engineering in Zagreb), and Actros was chosen for the fact that in 2010 MB vehicles were leading according to the number of newly registered heavy vehicles in the European union [8].

2.1 Sight distance testing at intersections with intersection angles bigger than 90°

Sight distance tests started with measuring the driver's field of view from the vehicle in the similar way as in the previous researches [1, 2]. Measurements of the driver's field of view (VA) were conducted from test vehicles for three different head positions:

1 the driver's head leaned against the back of the seat (SB – sit back),
2 comfort position of the driver's head, the usual position in driving (CP – comfort position),
3 the driver's head leaning towards the steering wheel (LF – lean forward).

The procedure of measuring the driver's field of view came down to measuring the visibility angle (VA) between the two looks, the straight ahead look and look to the right, by means of measuring battens. Figure 1. shows the position of battens for measuring visibility angle (VA) on the van.

Visibility angle measurement started with positioning batten 1 vertically on batten 3 (at the center of the driver's head when looking to the right), on the external part of the vehicle (Figure 1). By positioning batten 2 on the floor (perpendicular to batten 3) at the same position with the batten 1 and the driver's eyes, the position of the driver's eyes was transferred to batten 4. In that way the start position of batten 1 was defined on batten 4. The end position was obtained by moving batten 1 backwards on batten 4 all the way to the position in which the driver could see batten 1 in its full width through the right window of the vehicle. The move of batten 1 from the start to the end position was measured by the measuring band placed on batten 4. Visibility angle VA1 was calculated on the basis of the move of batten 1 on batten 4, the distance between battens 3 and 4 (3.0 m) and the distance between the driver's eyes and batten 1, while total visibility angle VA equals the value of VA1 increased by 90°.
The described procedure of measuring the visibility angle (VA1) from the vehicle was done on ten drivers on all test vehicles and for all three head (eye) positions. The blueprints of test vehicles (driver's cabs) [9, 10] were used as help in determining the visibility angle. Mean values of the measured visibility angles (VA) from Table 1 show that the best visibility from the vehicle is achieved when the driver's head leaning towards the steering wheel and the worst when the driver's head leaned against the back of the seat.

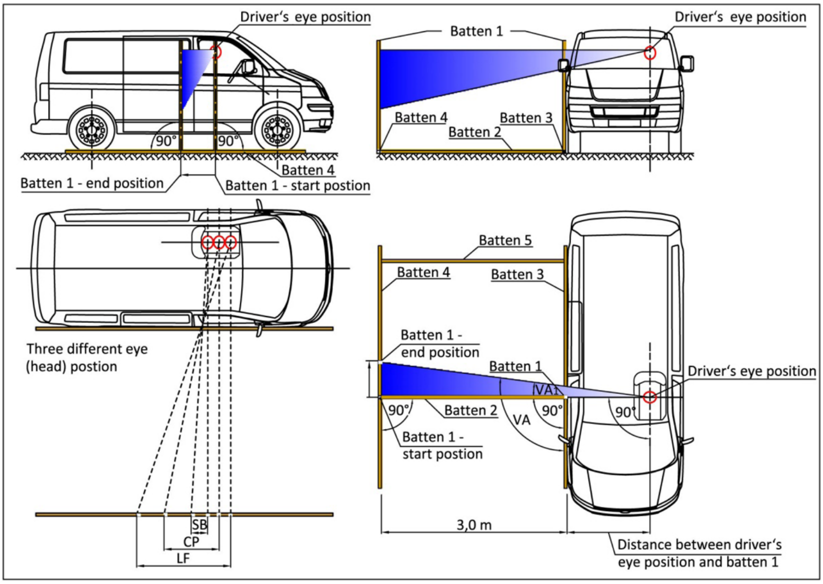

Figure 1 Schematic illustration of measuring the visibility angle (VA) from the vehicle (VW Transporter)

In order to determine the available sight distance (ASD) on the basis of visibility angles from Table 1 the scheme of four-leg channelized intersection at grade (Figure 2) with three 3.25 m wide traffic lanes on the major road (two through-traffic lanes and one for the left turn) was drawn.

Table 1 Mean values of the measured visibility angle (VA) on test vehicles

Vehicle type	VA - visibility angles [°]		
	VA_{SB}	VA_{CP}	VA_{LF}
Passenger car	94	99	110
Van (≤ 3,5 t)	94	98	108
Truck tractor (≤ 16 t)	94	97	104

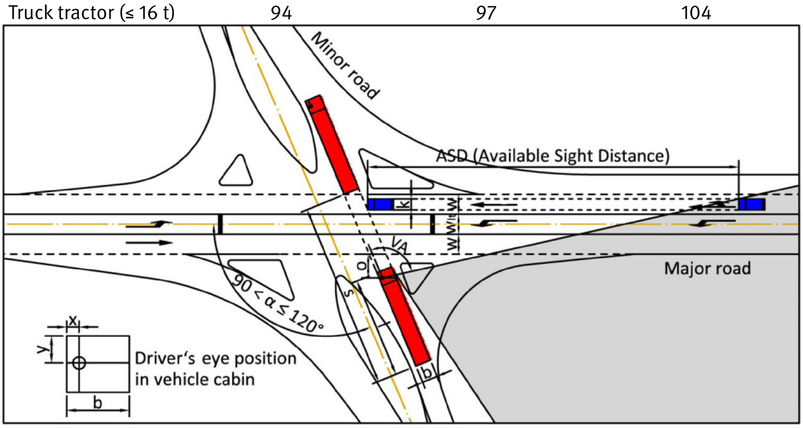

Figure 2 The scheme of the intersection for the calculation of available sight distance (ASD)

The scheme of the intersection (Figure 2) shows the position of the vehicle on the major and minor road, the driver's visibility angle from the vehicle (VA), the available sight distance (ASD) and the path (s) which the vehicle has to pass across the major road. The position of the vehicle on the minor road is defined by the distance of the driver's head from the major road edge and the position of the driver's eye (head) in the vehicle (x, y), while the position of the vehicle on the major road is determined on the basis of the visibility angle (VA) from the minor road vehicle. The dimensions of the vehicle and the position of the driver's eye are given in Table 2. For the purpose of setting the minimum and maximum allowable intersection angle of crossing roads a semi-trailer was added to the truck tractor so that the total length of the vehicle was 16.5 m (Table 2).
Available sight distance (ASD) is the distance between two positions of the vehicle on the major road, the initial determined by the visibility angle, and the final which is the crossing point of the trajectories of the vehicles from the major and minor road (Figure 2). Since the available sight distance does not depend only on the visibility angle but also on the driver's eye position (the bigger the distance from the major road edge the bigger is the available sight distance) for calculating the available sight distance it was determined that the driver's head is 3.0 m away from the edge of the major road. The driver's head (eye) distance from the traffic lane edge was taken over from the German [5] and Austrian [11] guidelines for the situation when the vehicle stops on the minor leg before entering the intersection.

Table 2 Table 2. The driver's eye position in the vehicle and the vehicle dimensions

Vehicle type	Driver's eye position in vehicle (x, y), vehicle width (b) and length (l) [m]					
	x	y_{SB}	y_{CP}	y_{LF}	b	l
Passenger car	0,54	2,24	2,15	1,92	1,78	4,20
Van (≤ 3,5 t)	0,55	2,00	1,90	1,69	1,90	4,89
Semi-trailer truck (≤ 40 t)	0,52	1,12	1,03	0,78	2,50	16,50

On the basis of the data on visibility angles, the position of the driver's eye and the intersection geometry the available sight distance was calculated using following formula:

$$ASD = (o + 2w - w_{lt} - \frac{w-k}{2}) / tg(\alpha - VA) + (o + 2w + w_{lt} - \frac{w-k}{2}) \cdot tg(\alpha - 90°) - (\frac{b-x}{2\cos(\alpha - 90°)}) - k \cdot tg(\alpha - 90°) \quad (1)$$

where:
α – intersection angle (Figure 2): 90 - 120°,
b – vehicle width (minor road) (Table 2) [m],
ASD – available sight distance [m],
k – vehicle width (major road): 1,8 m,
o – driver's eye (head) distance from the traffic lane edge: 3,0 m,
w – major road through-lane width [m],
w_{lt} – left turn lane width [m],
VA – visibility angle (Table 1) [°],
x – driver's eye position in vehicle (Figure 2, Table 2) [m].

Since the minimum or maximum allowable intersection angle of crossing roads could not be determined only according to the data on available sight distance, stopping sight distance (SSD) had to be set so that the available sight distance could be compared to something. For determining the stopping sight distance it was necessary to calculate the path length (s) and the time (t) the vehicle needed to cross the major road. To calculate the path length depending on the intersection angle the following formula was used:

$$s = (o + 2w + w_{lt}) / \cos(\alpha - 90°) + l - y + x \cdot tg(\alpha - 90°) \tag{2}$$

where:
α – intersection angle [°],
l – vehicle length (minor road) [m],
o – driver's eye (head) distance from the traffic lane edge [m],
s – path [m],
w – major road through lane width [m],
w_{lt} – left turn lane width [m],
x, y – driver's eye position in vehicle (Figure 2, Table 2) [m].

The time (t) calculation was based on the hypothesis that vehicles move along the road (path) with constant acceleration from the moment the drivers estimate that the situation on the major road is favorable for performing the necessary traffic maneuver. For time calculation the following formula was used:

$$t = \sqrt{\frac{2s}{a} + t_r} \tag{3}$$

where:
a – acceleration 1,5 m/s2 → passenger car,
1,25 m/s2 → van (≤ 3,5 t),
0,7 m/s2 → semi-trailer truck (≤ 40,0 t),
s – path [m],
t – time needed for the vehicle to cross the major road [s],
t_r – reaction time: 2 s.
The obtained time data (t) were used to calculate stopping sight distance (SSD) for the different driving speed on the major road using following formula:

$$SSD = \frac{V \cdot t}{3{,}6} \tag{4}$$

where:
SSD – stopping sight distance [m],
t – time needed for the vehicle to cross the major road [s],
V – driving speed on the major road: 20 - 100 [km/h].

Following the example of the research [2] on the basis of the obtained data on the available (for the three driver's head positions – SB, CP, LF) and stopping sight distance (for different vehicle speed on the major road) for intersection angles from 90 to 120° nomographs were made (Figures 3, 4). Nomographs were used to determine the maximum allowable intersection angles (> 90°) separately for each vehicle based on the relevant speed of 40 and 80 km/h. The speed of 40 km/h was selected as legally [12] minimum speed limit on all roads, and the speed of 80 km/h as the highest vehicle speed on intersections at grade. Based on the selected speed criteria for driver's different head positions, minimum or maximum allowable intersection angles (> 90°) for all vehicles were determined (Table 3). The minimum allowable intersection angle of 97° was obtained for semi-trailer truck and the speed of 80 km/h, while the maximum angle of 120° was obtained for passenger vehicle and the speed of 40 km/h (Figure 3, 4, Table 3). The obtained results are logical with regard to the visibility from the vehicle as well as the vehicle performance and dimensions.

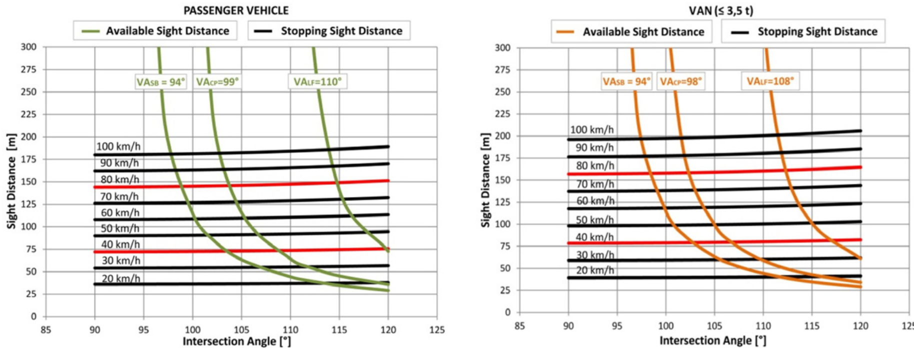

Figure 3 Sight distance nomographs for passenger car and van (≤ 3.5 t)

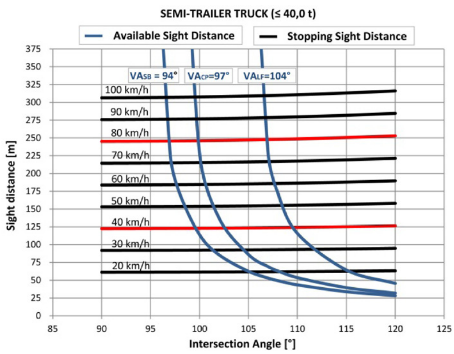

Figure 4 Sight distance nomograph for semi-trailer truck (≤ 40,0 t)

Table 3 Allowable intersection angles for relevant speed and different visibility angles

Vehicle type	Allowable intersection angles [°]					
	VA_{SB40}	VA_{CP40}	VA_{LF40}	VA_{SB80}	VA_{CP80}	VA_{LF80}
Passenger car	103	108	120	99	104	115
Van (≤ 3,5 t)	103	107	117	98	102	112
Semi-trailer truck (≤ 40,0 t)	99	102	109	97	100	107

2.2 Sight Distance Testing at Intersections with Intersection Angles Smaller than 90° o

Sight distance tests at intersections with intersection angles smaller than 90° started with determining the driver's field of view and the head rotation angle since these are the main parameters that influence the visibility from the vehicle. In addition to the fact that the mentioned parameters influence the visibility from the vehicle they also directly influence the available sight distance at intersections which is the basis for determining minimum or maximum allowable intersection angles of crossing roads.

Data on the driver's field of view (Figure 5) were taken over from the Directive 2009/113/EC [13] and the Croatian book of regulations [14], based on which the field of view width should be:

- minimum 120° for non-professional drivers: M, A1, A2, A, B, B+E and F category,
- minimum 160° for professional drivers: M, A1, A2, A, B, B+E, C1, C, C1+E, C+E, D, D+E, F, G and H category.

The data regarding the driver's head rotation angle were taken over from the research carried out by Isler et al. [15]. They showed that the minimum head rotation mean value in male and female drivers of all ages (from ‹ 30 to › 70 years) is approximately 60° (Figure 6). However, the sample on which the driver's head rotation testing was done can hardly be considered representative since the graph (Figure 6) shows a lot of illogicality. For example, in female drivers head rotation decreases as their age increases, while it is not the case in male drivers, so it turns out that male drivers aged 60-69 can turn their head more than those aged 40-59. Regardless of the fact that drivers' head rotation measurement was not conducted on the representative sample, driver's head rotation angle of 60° was selected as a relevant angle for available sight distance calculation as a kind of a guarantee that this selection takes into consideration capabilities of all drivers regardless of age or gender.

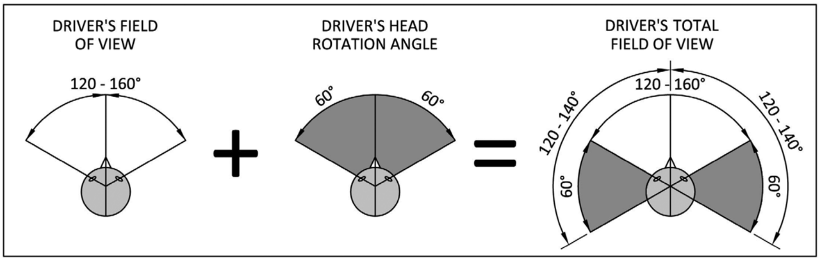

Figure 5 Figure 5. Driver's total field of view

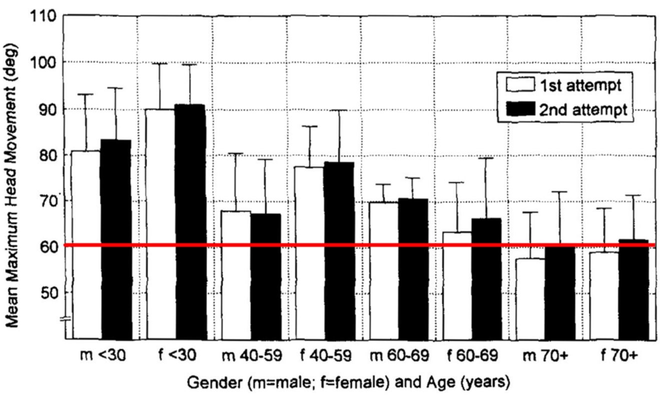

Figure 6 Figure 6. Mean values of the driver's maximum head rotation according to age and gender [15]

The total driver's field of view of 240° to 280° was obtained by adding input data of driver's field of view and head rotation angle (Figure 5). For the calculation of the available sight distance from the driver's total field of view only the part of 120 to 140°, which refers to the driver's look on the left, was taken into consideration. The determination procedure of the driver's left visibility angle (VA) came down to adding half of the field of view from the book of regulations [14] and the Directive [13] and one of the selected driver's head rotation angles (Table 4). Combinations of the driver's fields of view and head rotations were done for all three test vehicles (Figure 5, Table 4) and called driver's visibility angle (VA). Based on the data from Table 4 and the intersection scheme from Figure 7, it was concluded that the obtained combination of field of view and head rotation provides the driver of semi-trailer truck with enough visibility at intersections with intersection angles between 45 and 90°. Thus, semi-trailer truck was excluded from further procedure of determining minimum intersection angles.

Table 4 Driver's visibility angles when looking to the left (VA)

	Vehicle type	
	Passenger car and van (≤ 3,5 t)	Semi-trailer truck (≤ 40,0 t)
Head rotation angle [°]	60	60
Driver field of vision [°]	60	80
VA – visibility angle [°]	120	140

In order to calculate the available sight distance on the basis of visibility angles (VA) from Table 4, the scheme of four-leg intersection at grade (Figure 7) was drawn with three 3.25 m wide traffic lanes on the major road (two through-traffic lanes and one for the left turn). In addition to traffic lanes and islands the intersection scheme contains also the vehicles on the major and minor road, as well as the driver's visibility angle from the vehicle (VA), available sight distance (ASD) and path (s) which the vehicle needs to pass across one major road lane. The position of the vehicle on the major road was determined by the visibility angle from the vehicle on the minor road, and the position of the vehicle on the minor road by the distance of the driver's eye (head) (o) from the major road lane edge. In order to calculate the available sight distance relevant visibility angles from Table 4 were measured from the comfort position (CP) of the driver's head in the cab (Table 2, Figure 7).

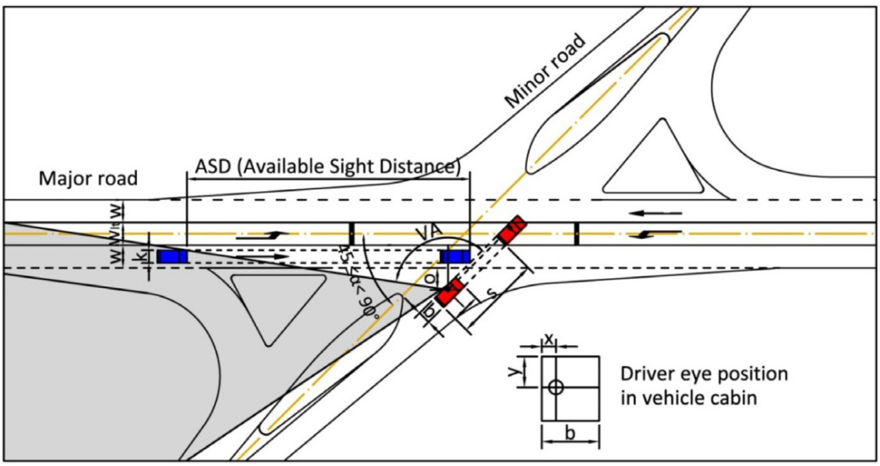

Figure 7 Figure 7. Intersection scheme for available sight distance calculation (ASD)

Available sight distance (ASD) is the distance between two positions of the car on the major road, the first determined by the visibility angle (VA) and the second on the spot where trajectories of the vehicles on the major and minor road cross (Figure 7). The distance of the driver's eye from the major road lane edge is 3.0 m (Section 2.1). The available sight distance was calculated on the basis of the data on visibility angles (Table 4), the driver's eye position and the intersection geometry (Figure 7) using the following formula:

$$ASD = (o + k + \frac{w-k}{2}) / tg(180° - \alpha - VA) + (o + \frac{w-k}{2}) \cdot tg\alpha - \frac{x}{\sin\alpha} \quad (5)$$

where:
α – intersection angle [°]
ASD – available sight distance [m]
k – major road vehicle width: 1,8 [m]
o – driver's head (eye) distance from the traffic lane edge [m]
w – major road through lane width [m]
VA – visibility angle (Table 4) [°]
x – driver's eye position in vehicle (CP) (Figure 7, Table 2) [m]

Since the minimum allowable intersection angle could not be determined on the basis of the available sight distance, it was also necessary to determine the stopping sight distance so that the available sight distance could be compared to something. To determine the stopping sight distance it was necessary to calculate the path length (s) and time (t), needed for the vehicle to cross one major road traffic-lane. For the calculation of the path length the following formula was used:

$$s = l - y + \frac{o + w}{\sin\alpha} + \frac{b - x}{tg\alpha} \tag{6}$$

where:
α – intersection angle [°]
b – vehicle width (minor road) (Table 2) [m]
l – vehicle length on the minor road (Table 2) [m]
o – driver's head (eye) distance from the traffic lane edge [m]
s – path [m]
w – major road through lane width [m]
x, y – driver's eye position in vehicle (CP) (Figure 7, Table 2) [m]

The obtained path data (s) were used to calculate the time (t). The calculation was based on the hypothesis that the cars move with constant acceleration starting from the moment when the drivers estimate that the situation on the major road is favorable for performing the necessary traffic action. Therefore, formula (3) was used for time (t) calculation for constant acceleration on the straight line. Input data on the acceleration and the time of reaction are the same as for the calculation of time (t) at intersections with intersection angles bigger than 90° (Section 2.1). Based on the calculated time (t) and available sight distance (ASD) using formula (4) the stopping sight distance (SSD) was calculated for different vehicle speed on the major road (from 20 to 100 km/h).
The data on the available and stopping sight distance for intersection angles of 45 to 90° were used for making nomographs (Figure 8). Based on the criteria of stopping sight distance for the speed of 40 and 80 km/h and the available sight distance for 120° visibility angle by means of nomographs minimum and maximum allowable intersection angles (< 90°) were determined separately for both test vehicles. For both test vehicles the same allowable intersection angles were obtained: for the speed of 40 km/h angle was 55°, and for the speed of 80 km/h angle was 57°.

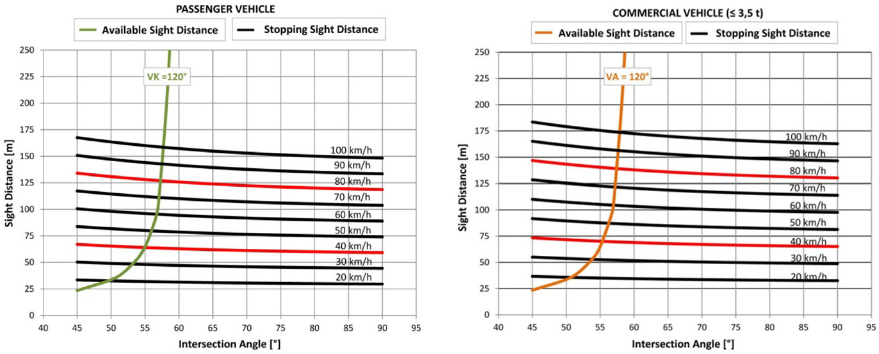

Figure 8 Sight distance nomographs for a passenger car and a van (≤ 3.5 t)

3 Conclusion

Sight distance tests carried out on different intersection schemes, respecting the parameters which influence the visibility from the vehicle, resulted in different minimum (<90°) and maximum (>90°) allowable intersection angles up to which it is possible to keep the minor road axis in the direction (Figures 3, 4, 8, Table 3). Research results shown on nomographs (Figures 3, 4) and in Table 3 demonstrated that for intersection angles bigger than 90° allowable intersection angles differ significantly depending on the position of the driver's head in the vehicle and the type of the vehicle. Due to their performances and dimensions passenger cars allow the application off bigger intersection angles (120°) than trucks (109 to 115°). In the process of testing sight distance and setting allowable intersection angles the least favorable driver's head position was also used which resulted in the smallest visibility angles (VA_{SB}) from the vehicle. If allowable intersection angle was determined even for those visibility angles for the speed of 40 and 80 km/h, in that case intersection angles for 3 to 10° (depending on the test vehicle) would be smaller than intersection angles for visibility angles VA_{CP} and VA_{LF}. Apart from that, for the smallest visibility angles (VA_{SB}) allowable intersection angles had to be limited to less than 100 or 105°, but such a restrictive limit was not present in any considered guideline [5, 6] or scientific papers so far [1, 2]. Based on these data it is recommended that the maximum allowable intersection angle should be 110° under the condition that intersections with intersection angles ≤ 105° can be applied when the speed limit on the major roads is 80 km/h or less, and intersections with angles between 105 and 110° can be applied only when speed limit on the major road is 40 km/h. This would completely fulfill the criteria for safe traffic flow at intersections.

For intersection angles smaller than 90° allowable intersection angles are the same for a passenger car and a van. Nomographs for intersection angles smaller than 90° (Figure 8) reveal that even small differences between intersection angles result in big differences in vehicle speed. For example, for the difference of only two degrees (from 55 to 57°) between intersection angles, the speed limit on the major road ranges from 40 to 80 km/h. Based on these data it is recommended that the minimum intersection angle of crossing roads should be 55° under the condition that intersection angles between 55 and 60° are exclusively applied at intersections with 40 km/h speed limit on the major road, while the intersections with intersection angles > 60° can be applied when the major road speed limit is 80 km/h or less. That would completely satisfy the criteria of safe intersection traffic flow.

Designers and researchers are left with a possibility to determine by themselves even some other (more or less severe) criteria of determining intersection angles on the basis of given nomographs.

References

[1] Gattis, J. L. and Low, S. T. Intersection Angle Geometry and the Driver´s Field of View. Transportation Research Record nº 1612, University of Arkansas, USA. Mack-Blackwell National Rural Transportation Study Center, 1997, pp. 10-16.

[2] Son, Y. et al. Methodology to Calculate Sight Distance Available to Drivers at Skewed Intersections. Transportation Research Record nº 1796, 02-3487, Myong Ji University, Kyunggido, South Korea, Department of Transportation Eng., 2002, pp. 41-47.

[3] Garcia, A. Lateral Vision Angles and Skewed Intersections Design. Proc., 3rd International Symposium on Highway Geometric Design, Chicago, June 29-July 1, 2005.

[4] Garcia, A., Belda-Esplugues, E. Lateral Vision Angles in Roadway Geometric Design. Journal of Transportation Engineering, Vol. 133, No. 12, December 2007, pp. 654-662.

[5] Richtlinien für die Anlage von Strassen Teil: Knotenpunkte, Abschnitt 1: Plangleiche Knotenpunkte, Forschungsgessellschaft für Straßenund Verkehrswesen (FGSV), Köln 1988.; Beiblatt 2001.

[6] A Policy on Geometric Design of Highways and Streets 2004. American Association of State Highway and Transportation Officials.

[7] JATO Dynamics: http://www.jato.com

[8] ACEA - European Automobile Manufacturers' association:

[9] http://www.acea.be/index.php/collection/statistics

[10] Volkswagen Croatia: http://www.volkswagen.com.hr/

[11] Mercedes-Benz Deutschland - LKW: http://www.mercedes-benz.de

[12] Plangleiche Knoten – Kreuzungen, T-Kreuzungen, Österreichische Forschungsgesellschaft Straße-Schiene-Verkehr (FSV), (RVS 03.05.12), Wien, 2007.

[13] The Road Traffic Safety Act (NN 67/08).

[14] Commission Directive 2009/113/EC of 25 August 2009 amending Directive 2006/126/EC of the European Parliament and of the Council on driving licences.

[15] Book of regulations on medical examinations for drivers and candidate drivers (NN, br. 1/11).

[16] Isler, R. B., Parsonson, B. S., and Hansson, G. J. 1997. Age-related effects of restricted head movements on the useful field of view of drivers. Accid. Anal Prev., 29(6), 793–801.