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Intersection Sight Distance Parameters for Horse-Drawn Vehicles

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ABSTRACT

Current intersection sight distance design parameters may not adequately accommodate horse-drawn vehicles which are present in significant numbers in some rural areas of the United States. This study examined the intersection sight distance case for two-way, stop-controlled intersections (stop on the minor road) for horse-drawn vehicles. The eye height of a horse-drawn vehicle driver was found to average 5.8 feet, noticeably higher than the standard value used for passenger cars, but less than that used for trucks. The stopping position of horse-drawn vehicle drivers was found to be further from the edge of travelled way of the major road than for motorized traffic, at an average distance of 27.2 feet. Analysis of accepted and rejected gaps for left turns, right turns and crossing maneuvers suggests that the critical gaps for horse-drawn vehicles are noticeably longer than for either passenger cars or trucks and range from 12 to 14 seconds.

Keywords: roads & highways, safety, intersection sight distance, non-motorized, horse-drawn vehicles, Amish

1. INTRODUCTION

Horse-drawn vehicles are common road users in a number of locations throughout the United States where there is a significant population of Amish and other religious communities that do not own or operate motorized vehicles.

According to Manns [1], three states have more than 45,000 Amish adherents each and 14 states have at least 1,000 adherents. Within Indiana, seven counties have more than 1,000 Amish adherents with LaGrange County having the most with more than 14,000 (approximately 38% of the total population) [1].

Elkhart County, where the data for this study was collected, has more than 6,000 Amish adherents and more than 5000 registered horse-drawn vehicles.

To date, intersection sight distance parameters used for roadway design by Elkhart County are found in the American Association of State Highway and Transportation Official's (AASHTO's) Policy on Geometric Design of Highways and Streets (the Green Book) [2]. These parameters were developed for motorized traffic by Harwood et. al, in 1996 [3] as an NCHRP study that was later incorporated in the AASHTO Policy on Geometric Design of Highways and Streets. Elkhart County was interested in assessing the adequacy of their design standards as they relate to horse-drawn vehicles, which led to this study. As most Elkhart County intersections are two-way stop controlled (stop control on the minor road), this study focuses on that condition exclusively (AASHTO Case B).

The three main elements of intersection sight distance for this type of intersection control are: acceptable gap for the minor road vehicle's planned maneuver, the distance from the driver position when stopped to the edge of the mainline, and the height of the driver's eye above the road. This study examines each of these elements for horse-drawn vehicles.

2. DATA COLLECTION

Two intersections in Elkhart County, Indiana were selected for the study: CR 34 at CR 37 and CR 40 at SR 13. The intersections were chosen based on the prevalence of horse-drawn vehicles at these locations.

Both intersections have approach slopes of less than 3%, and no obstructions to sight distance at the corners. CR 34 has a posted speed limit of 55 mph (88 kph). Both CR 34 and CR 37 have nominal 11 foot (3.35 m) wide lanes and asphalt surfaces with aggregate shoulders.

SR 13 has a posted speed limit of 55 mph, 12 foot (3.66 m) wide asphalt lanes and aggregate shoulders. CR 40 has 11 foot (3.35 m) wide asphalt lanes, aggregate shoulders, and a 55 mph (88 kph) speed limit.

Data was collected at both sites using small, battery powered action cameras mounted on poles and braced against power poles (Figure 1). Data from both of the minor road approaches were collected and analyzed. Markings on the pavement (Figure 2) were used to indicate the distance on each approach from the edge of the major road travelled way. These markings were used to determine the position of horse-drawn vehicle drivers when stopped. Gap times, and accept/reject decisions, were determined by analysis of the video files.

Driver eye heights were measured in parking lots of commercial areas with a known presence of horse-drawn vehicles (indicated by dedicated parking for such vehicles). The drivers were asked to sit in their horse-drawn vehicles in their normal position when driving, and the height of their eye was measured to the pavement directly below them. The measured driver population included both men and women. A total of 14 measurements of driver eye height were recorded.

Figure 1. Typical camera placement at intersection corner

Figure 2. Intersection of CR 34 and CR 37 showing pavement markings used for determination of vehicle stopping position

The distance of a buggy driver stopped on the minor road approach from the edge of the major road was measured from the captured video of the intersection approaches. It was noted that horse-drawn vehicles tend to not come to a complete stop in light traffic situations. Data from these situations was excluded from the study. A total of 118 horse-drawn vehicle data points for stopping location were able to be collected.

The horse-drawn vehicles observed in this study included single seat row buggies, double seat row buggies, open buggies and wagons. For stopping locations, all the horse-drawn vehicles have fairly standard dimensions from the horse's nose to the driver location. The dimensions of the vehicles vary the most in length, which occurs behind the driver position.

The gap analysis of both intersections resulted in a total of 427 measured gaps. Of these, 197 were for left-turn movements, 70 for right-turn movements and 160 were for crossing movements.

3. RESULTS AND ANALYSIS

3.1 Stopping Position

The stopping position of horse-drawn vehicle drivers was estimated from the collected video data for 118 horse-drawn vehicles. This position was measured on the minor approach from the edge of travelled way of the major road to the position of the driver in the vehicle. The average distance was 27.2 ft (8.3 m), the standard deviation was 4.6 ft (1.4 m), the minimum value was 16 ft (4.9 m) and the maximum was 37 ft (11.3 m).

Compared to the value given for motor vehicles in the AASHTO Green Book, 14.5 ft (4.4 m) (up to 18 ft (5.5 m) recommended), the values observed for horse-drawn vehicles are significantly larger. Speaking with horse-drawn vehicle drivers, and observing the video data, horses vary greatly in temperament with some being very nervous near motor vehicle traffic, and others being calmer. Given the uncertainty, horse-drawn vehicle drivers generally keep their horses a greater distance from the major road. Figure 3 shows a typical stopping location on the minor road approach.

Figure 3. Typical stopping location of a horse-drawn vehicle on minor road approach

A histogram of the observed horse-drawn vehicle drivers' positions when stopped, measured from the edge of the major road travelled way, can be seen in Figure 4. As can be seen, the distribution is roughly normal. Based on a normal distribution, the sight distance point from the major road that would cover 85% of the stopping positions is 32.0 ft (9.8 m).

3.2 Driver Eye Height

Fourteen measurements of driver's eye heights above the pavement were made. These measurements ranged from 68 to 72 inches (173 to 183 cm) with an average of 70 inches (178 cm) and a standard deviation of 1.25 inches (3.2 cm). Despite the measured population including a diverse grouping of various types of buggies, drivers of various heights and including both men and women, the observed eye heights were fairly uniform. The average of 70 inches (5.8 ft or 178 cm) is considerably higher than the values used for passenger cars (3.5 ft, 107 cm), but less than the value used for trucks (7.6 ft, 233 cm). Additional data collection to expand the population size for eye height will be required to draw stronger conclusions, but it can generally be noted that horse-drawn vehicle drivers will have extended sight distances over those of passenger car drivers given the same vertical road geometry.

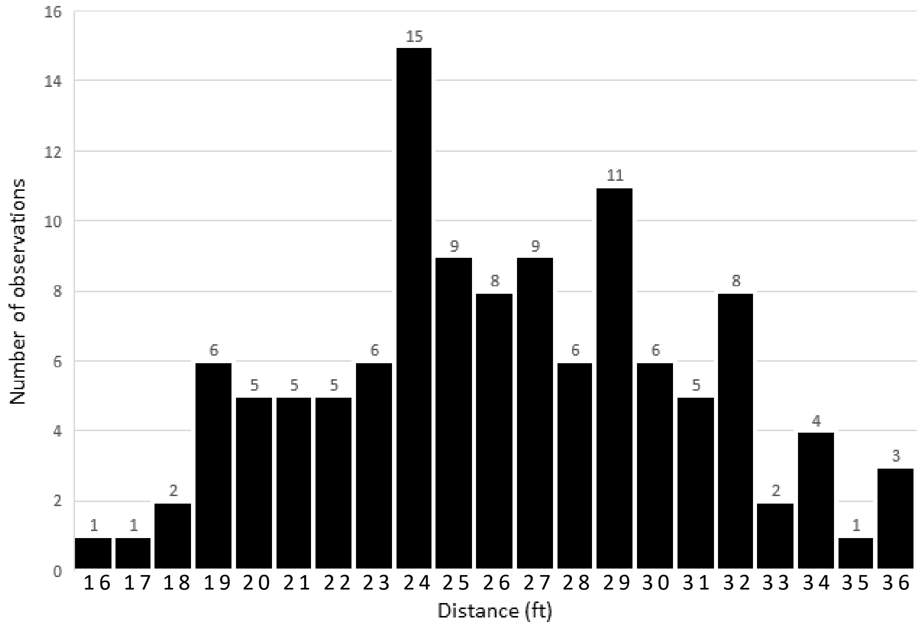

Figure 4: Histogram of measured driver stopping distances from the major road

3.3 Gap Acceptance

A total of 427 measurements of accepted and rejected gaps for horse-drawn vehicles were collected. These gaps were measured on the minor road approaches at both intersections, and for all three movements: left, crossing and right.

To analyze the gap data the Raff method [4], as used by Harwood in the NCHRP report [3], was employed. In this method the cumulative distributions of rejected and accepted gaps are plotted, and the point at which the distributions cross is the critical gap.

There were 20 observed rejected gaps for right turns ranging from one to 23 seconds, and 50 observed accepted gaps ranging from nine seconds to 6 minutes and 55 seconds. At 55 mph, a gap of one minute equates to approximately 4,850 feet (1478 m). This is beyond a reasonable sight distance even for the flat topography in this region, so only gaps equal to or less than one minute were used for subsequent analysis on all movements. For right turns, there were 36 accepted gaps equal to or less than one minute. The apparent critical gap for right turns was 13 seconds.

Left turn gap data included 111 rejected gaps ranging from one to 19 seconds, and 73 accepted gaps less than one minute in length with a minimum of 10 seconds. Both cumulative distributions are shown in Figure 6. The apparent critical gap for left turns was12 seconds.

Crossing gap data included 63 rejected gaps ranging from one to 26 seconds and 70 accepted gaps less than one minute long, with a minimum of nine seconds. The cumulative accepted and rejected distributions can be seen in Figure 7. The apparent critical gap for crossing movements was 14 seconds.

Based on the apparent critical gaps for each movement noted above, horse-drawn vehicles require longer gaps than those of passenger cars or trucks (as provided in the current AASHTO Green Book). The comparison of these time gap values can be seen in Table 1.

Table 1. Comparison of current time gap values for intersection sight distance based on the AASHTO Green Book, and estimated values for horse-drawn vehicles, in seconds

	Minor Road Vehicle Movement		
	Left Turn	**Cross-ing**	**Right Turn**
Passenger Cars	7.5	6.5	6.5
Single Unit Trucks	9.5	8.5	8.5
Combination Trucks	11.5	10.5	10.5
Horse-Drawn Vehicles	12	14	13

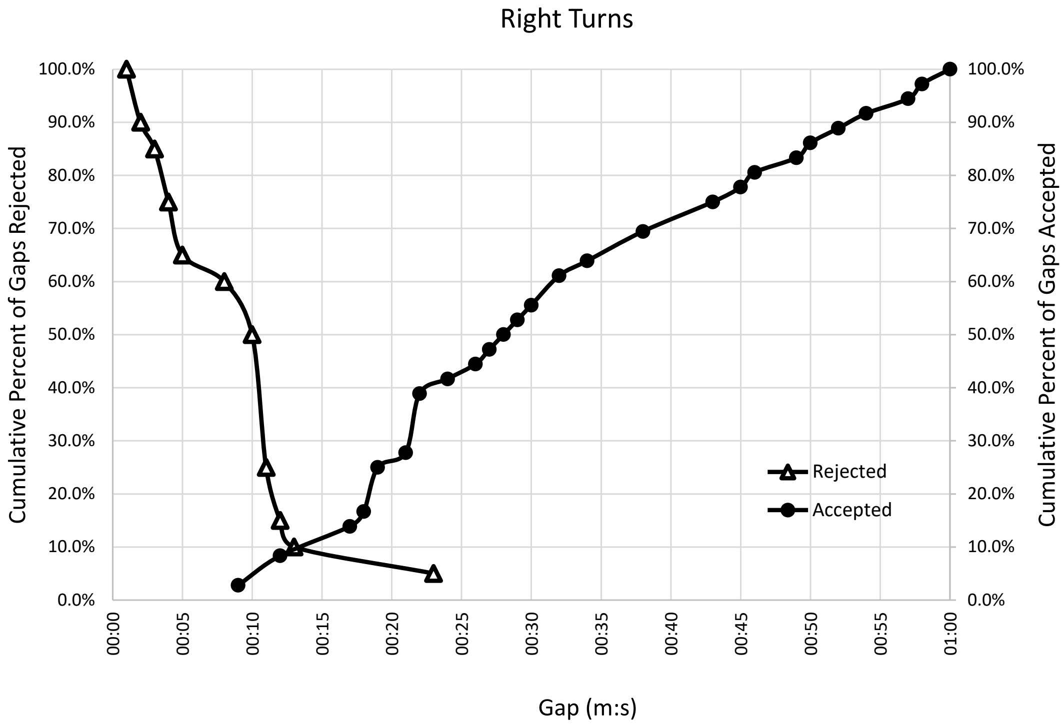

FIGURE 5: Cumulative distribution of gaps for right turn movements

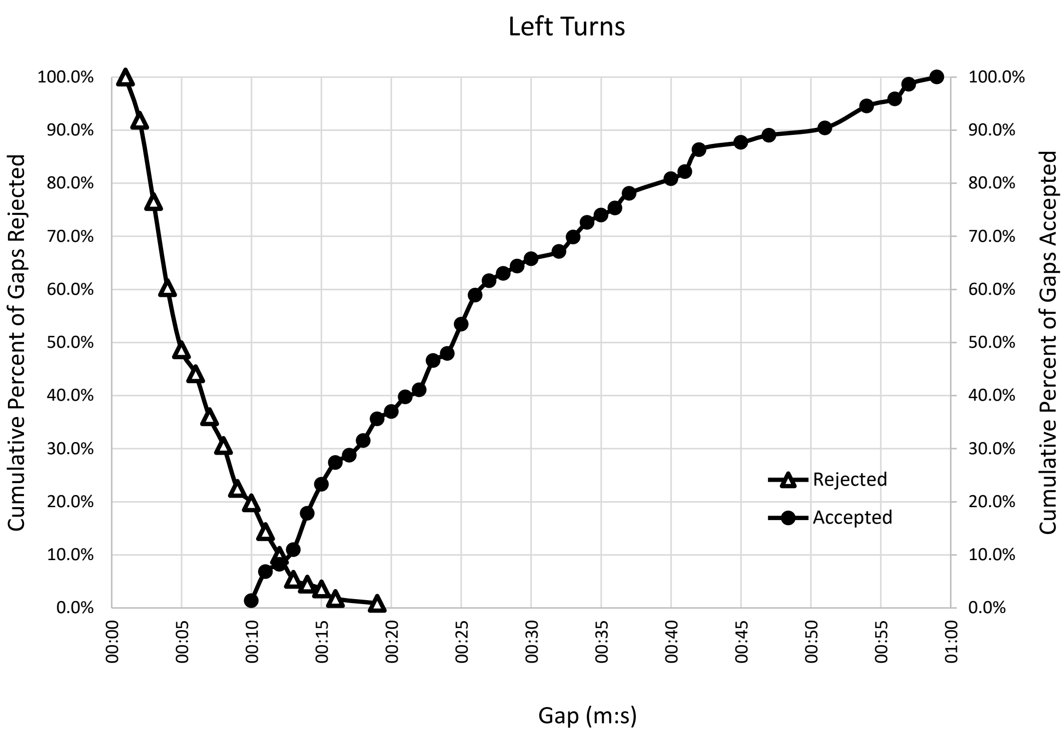

FIGURE 6: Cumulative distribution of rejected and accepted gaps for left turn movements

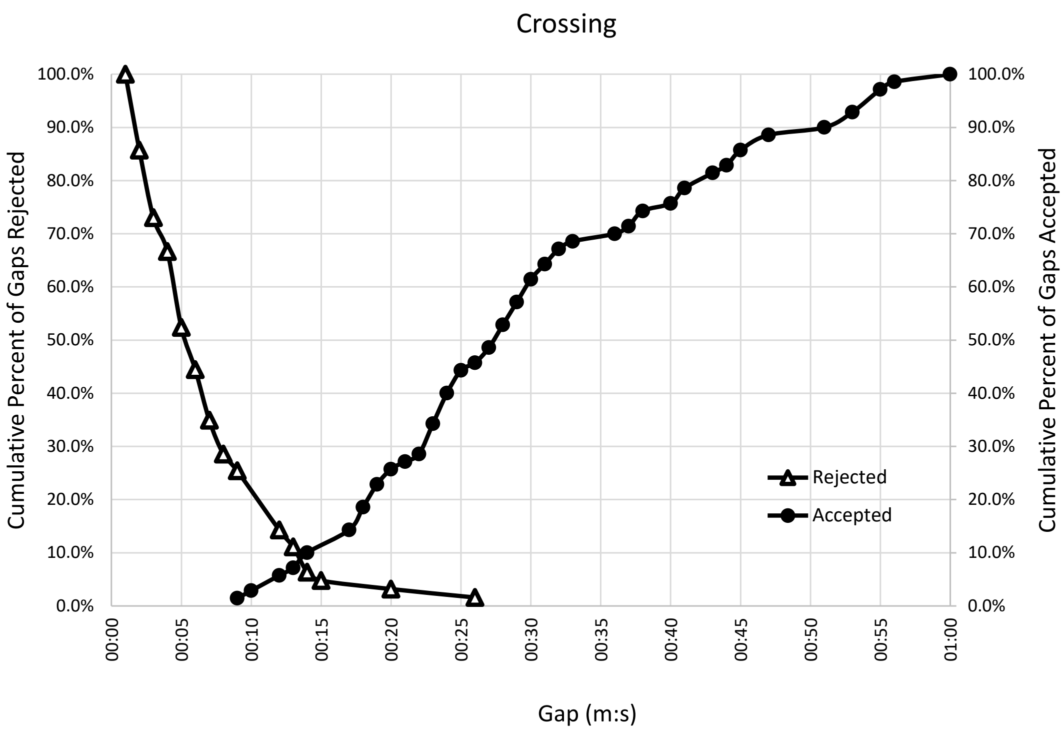

FIGURE 7: Cumulative distribution of rejected and accepted gaps for crossing movements

4. CONCLUSIONS

The three parameters used to determine the clear intersection sight triangle for the stop on minor road condition are likely to need adjustment for horse-drawn vehicles. A horse-drawn vehicle driver's eye height is approximately 5.8 feet above the pavement.

The stopping position of the driver is also further from the major road's edge of travelled way than that assumed for motor vehicles. Horse-drawn vehicles stopped an average distance of 27.2 ft (8.3 m) from the major road. To cover 85 percent of the observed stopping positions, a design value of up to 32 ft (9.8 m) might be considered.

Critical time gaps for left turns, right turns and crossing maneuvers were estimated using the Raff method. The estimated critical time gaps were longer than those used currently by the AASHTO Green Book for passenger cars and trucks, with values of 12, 14 and 13 seconds for left turns, crossing maneuvers and right turns, respectively.

5. ACKNOWLEDGMENTS

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The authors confirm contribution to the paper as follows: study conception and design: Grossman, McKenzie; data collection: Veloz, Grossman; analysis and interpretation of results: Grossman, McKenzie; draft manuscript preparation: Grossman. All authors reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Manns, M., Indiana's Amish Population. IN Context: Vol 13, No. 6. Indiana Business Research Center, Indiana University Kelley School of Business, Bloomington, IN. 2012.
2. AASHTO. Policy on Geometric Design of Highways and Streets, Seventh Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2018.
3. Harwood, D. W., J. M. Mason, R. E. Brydia, M. T. Pietrucha, and G. L. Gittings. National Cooperative Highway Research Program Report 383: Intersection Sight Distance. NCHRP, Transportation Research Board, National Research Council, Washington, DC, 1996.
4. Raff, M. S., and Hart, J. W., A Volume Warrant for Stop Signs, Eno Foundation for Highway Traffic Control, 1950.