Highway Intersection Safety

An Online Continuing Education Course for Engineers

Course Number: T-1008

Credit: 1 Hour / 1 PDH / 1 CPD

Highway Intersection Safety

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Purpose

The purpose of this course is to assist highway engineers, traffic engineers, and engineers involved in maintenance and public works in making at-grade intersections safe and safer for the traveling public. It will also assist forensic engineers in the investigation and analysis of intersection accidents and assessment of liability. Technical requirements for traffic control devices and sight distance are covered, along with measures to address safety problems at existing intersections.

The Federal Highway Administration has reported that more than 50% of Fatal and Injury highway accidents occur at or near highway intersections. By far, “angle” and “rear-end” accidents, which occur mainly at intersections at-grade, are the largest contributors to the number of Fatal and Injury accidents nationwide.

At-grade intersections are a major source of traffic conflicts and require more attention and judgment from motorists than any other highway feature. Entering or crossing a highway from an intersection requires motorists to make difficult assessments of the speed, time, and distance away from approaching vehicles. It also calls into play the capability (acceleration) of one’s own vehicle. Many motorists are very poor judges of these important measures.

The major parameters affecting safety at intersections are geometric design and layout, traffic speed, sight distance, signing, and signalization. Geometric design and intersection layout are well-covered in readily available publications, such as *A Policy on Geometric Design of Highways and Streets* (AASHTO), and not the subject of this course. Signalization is addressed only as a possible safety measure.

To be safe, every intersection must provide adequate sight distance for motorists turning, crossing, and entering. The kinematic principles involved in calculating sight distance needs will be provided, along with past and current AASHTO policies adopted

for intersection design. The kinematic principles are then applied for forensic analysis of an intersection accident for which sight distance was an important issue.

Safely operating an intersection also requires the proper selection and use of traffic control devices, as well as an understanding of their limitations. Appropriate warning signs need to be utilized and then suitably located to ensure adequate visibility. This course will direct the student to the signs called for under the *Manual on Uniform Traffic Control Devices* (MUTCD) and also will cover their effectiveness. For new intersections and those experiencing accident problems, this course provides tools to address possible contributing factors and measures to enhance safety using a range of recommended treatments.

Outline

1. Definitions and Primary Elements of Safe Intersections

2. Sight Distance, Requirements and Measurement

3. Traffic Control Devices, the MUTCD

4. Maintenance Issues

5. Crash Investigation Example

1. Definitions and Primary Elements of Safe Intersections

The intersections addressed are limited to intersections-at-grade, as opposed to interchanges, although the terminals of ramps at crossroads are covered. The latter are usually simpler and more like T-type intersections, but still, need proper traffic control devices and adequate sight distance (unless signalized).

Sight Distance - Intersection Sight Distance (ISD) will be the primary focus, as opposed to Stopping Sight Distance (SSD), Passing Sight Distance, or Decision Sight Distance.

When dealing with SSD, sight distance is defined by AASHTO as the length of the roadway ahead visible to the driver. Sufficient SSD must be provided at all points along the roadway for a motorist to recognize a hazard and stop within the distance available. That element can come into play approaching an intersection with a STOP sign, but SSD is not usually relevant for mainline vehicles except for uncontrolled and YIELD intersections.

ISD is a measure of the ability of a motorist waiting at or approaching from a crossroad to see oncoming traffic in either direction. That distance must be sufficient for a waiting vehicle to perceive, react, accelerate, and travel far enough to clear or stay ahead of an oncoming vehicle. The most common cases are with STOP control as opposed to no control or YIELD control since few intersections have enough sight distance to allow NO or YIELD control. This course will focus on the STOP control cases.

For all cases, it is the distance or length along the observed roadway that is measured, not the straight distance along the line of sight. When checking if there is enough time to clear an oncoming vehicle, we need to use the distance the vehicle would travel along the road. The hypotenuse of the sight triangle at an intersection is used to see if there are obstructions, but the distance of importance is how far the oncoming vehicle would actually travel.

Traffic Control Devices – The traffic control devices covered at intersections will mainly include intersection warning signs, STO signs, STOP AHEAD signs, Intersection Control Beacons, Warning Beacons, and Traffic Control Signals. All of these, including

conditions for their use, are described in the Manual on Uniform Traffic Control Devices (MUTCD) issued by the Federal Highway Administration (FHWA). Many states used their own manual for years, but as of December 22, 2005, all states are required to adopt the National Manual or develop a state supplement that substantially conforms to the National Manual, i.e., the MUTCD. In December 2009, the 2009 edition of the MUTCD was adopted, and all states were required to adopt the National MUTCD as their legal standard by January 15, 2012. Supplements are still permitted. For this course, we will be using the 2009 edition of the MUTCD with Revisions 1 and 2 dated May 2012, but students should check for updates. The MUTCD is available online.

2. Sight Distance Requirements and Measurement

For ISD, the current standard adopted by AASHTO calls for using an observer's eye height of 3.50' and the object 3.50' above the pavement for checking clearance over an obstruction. Previously, the model used for calculating the time needed to enter an intersection and clear an oncoming vehicle was based upon kinematics. That is no longer the practice, but it is informative to go over this theory because it becomes useful in the investigation and analysis of real-world crash events.

Kinematic Model - Previous to the 2001 edition of the AASHTO Policy on Geometric Design of Highways and Streets (the Policy), the analysis started with the placement of a vehicle on the crossroad with its front set back 10' from the edge of the travel-way. (Later editions used a setback of 6.5' based upon extensive field studies. The driver's eye position became 14.5' back.) The 1994 AASHTO Policy set a Perception/Reaction (P/R) time of 2.0 seconds for the operator to start accelerating to enter the intersection. For passenger cars, acceleration curves were provided that gave the travel time needed to go the necessary distance to clear oncoming traffic. For the simple crossing case, the formula is:

$$\boldsymbol{d = 1.47 \times V \times (J + T)}$$

d is the distance along the major highway, V is the design speed of the major highway in MPH, J is the P/R time, and T is the time required to accelerate and

travel the distance needed to clear the major highway travel way, including the length of the vehicle (19' for passenger cars).

For example, on a highway with a design speed of 50 MPH, starting 10' back, a vehicle would have to travel **10' + 24' + 19' = 53'** to clear the far lane of a 2- lane highway. Using time/distance curves provided by AASHTO (1994), it would take 4.5" to travel this distance. The required ISD looking to the right would be:

$$\boldsymbol{d = 1.47 \times 50 \times (2.0 + 4.5) = 478'}$$

As an exercise, let's see what the equivalent acceleration rate was for the combination of 4.5" to travel 53' **(S)**. From $\boldsymbol{S = \frac{1}{2} a \times T^2}$ we get the acceleration rate:

$$\boldsymbol{a = (2 \times S) \div T^2}$$

$$\boldsymbol{a = (2 \times 53) \div 4.5^2 = 5.2\ fps^2}$$

Later we will see how this can be used to analyze and reconstruct an accident and determine if the sight distance available at the site was sufficient for accident avoidance.

It gets more complicated for a vehicle making a left turn out of a crossroad. Here we have two cases to deal with. Looking left at oncoming traffic is the only one needed for this exercise.

Turning left to clear vehicle from the left - For the vehicle turning left and motorist looking left, the principles are the same as the crossing maneuver, except that the travel path involves a turning radius. For example, AASHTO uses a radius of 28' (at the center of the vehicle) for a vehicle turning left into a two-lane highway. This will bring a passenger car fully into the far lane, traveling ¼ of an arc distance of $\boldsymbol{(\pi \times 28) \div 2 = 44'}$. Adding the length of the vehicle of 19', we get the travel distance**, S = 63'.**

Referring to the AASHTO curves, for **S = 63', T = 5.0"**, the new acceleration rate would be $\boldsymbol{(2 \times 63) \div 5.0^2 = 5.0\ fps^2}$ **,** which is a lower acceleration rate because rates drop as vehicles reach higher speeds. (Note that median acceleration rates for turning

vehicles have been observed in field studies and found to be lower, typically about $\mathbf{4.5\ fps^2}$.) The required ISD would now be:

$$\boldsymbol{d = 1.47 \times 50\ \times (2.0 + 5.0) =\ 514'}$$

Looking right and being able to turn left and accelerate to some percentage of the highway speed without being overtaken is a case covered by AASHTO using a series of curves. The 1994 edition would have required about 840', assuming the approaching vehicle reduces its speed to 85% of the design speed.

This kinematic approach, although mathematically sound, was later recognized as highly conservative in some cases. For one thing, it assumes the oncoming vehicle will reduce its speed to 85% of Design Speed through the intersection, even when observing a vehicle attempting to cross or enter.

An extensive field study by the Midwest Research Institute and the Pennsylvania Transportation Institute led to a new approach, which was later published in NCHRP Report 383: Intersection Sight Distance. Observations of actual behavior showed that most vehicles will reduce their speed below 85% of Design Speed approaching an intersection, and adjust further when need[illegible]tering or crossing vehicles.

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Gap Acceptance Model[illegible]ap Acceptance model for the determinat[illegible]tions. The new driver's eye position was[illegible] object height became 3.5'. The Gap model is based [illegible] concept that, if motorists routinely enter an