Intersection Geometric Design

An Online Continuing Education Course for Engineers

Course Number: T-3023

Credit: 3 Hours / 3 PDH / 3 CPD

Intersection Geometric Design

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INTRODUCTION

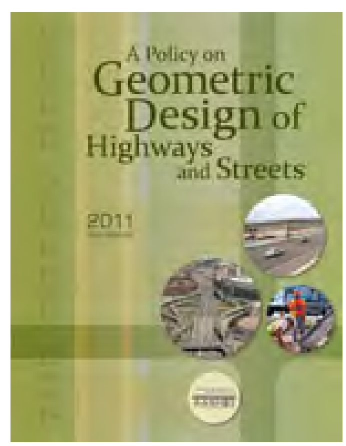
This course summarizes and highlights the geometric design process for modern roadway intersections. The contents of this document are intended to serve as guidance and not as an absolute standard or rule.

When you complete this course, you should be familiar with the general guidelines for at-grade intersection design. The course objective is to give engineers and designers an in-depth look at the principles to be considered when selecting and designing intersections.

Subjects include:

- General design considerations – function, objectives, capacity
- Alignment and profile
- Sight distance – sight triangles, skew
- Turning roadways – channelization, islands, superelevation
- Auxiliary lanes
- Median openings – control radii, lengths, skew
- Left turns and U-turns
- Roundabouts
- Miscellaneous considerations – pedestrians, traffic control, frontage roads
- Railroad crossings – alignments, sight distance

For this course, Chapter 9 of **A Policy on Geometric Design of Highways and Streets** (also known as the “Green Book”) published by the American Association of State Highway and Transportation Officials (AASHTO) will be used primarily for fundamental geometric design principles. This text is considered to be the primary guidance for U.S. roadway geometric design.



This document is intended to explain some principles of good roadway design and show the potential trade-offs that the designer may have to face in a variety of situations, including cost of construction, maintenance requirements, compatibility with adjacent land uses, operational and safety impacts, environmental sensitivity, and compatibility with infrastructure needs.

Geometric design is the assembly of the fundamental three-dimensional features of the highway that are related to its operational quality and safety. Its basic objective is to provide a smooth-flowing, crash-free facility. Geometric roadway design consists of three main parts: **cross section** (lanes and shoulders, curbs, medians, roadside slopes and ditches, sidewalks); **horizontal alignment** (tangents and curves); and **vertical alignment** (grades and vertical curves). Combined, these elements provide a three-dimensional layout for a roadway.

Effective geometric design transmits knowledge from research and operational experience to the user. It reflects both human and vehicular characteristics and capabilities.

The practice of geometric design will always be a dynamic process with a multitude of considerations: driver age and abilities, vehicle fleet variety and types, construction costs, maintenance requirements, environmental sensitivity, land use, aesthetics, and most importantly, societal values.

Despite this dynamic character, the primary objective of good design will remain as it has always been **– to provide a safe, efficient and cost-effective roadway that addresses conflicting needs or concerns.**

INTERSECTIONS

Intersections are unique roadway elements where conflicting vehicle streams (and sometimes non-motorized users) share the same space. This area encompasses all modes of travel -

pedestrian,
bicycle,
passenger vehicle,
truck,
transit,

as well as auxiliary lanes, medians, islands, sidewalks and pedestrian ramps. These may further heighten the accident potential and constrain the operational efficiency and network capacity of the urban street system. However, *the main objective of intersection design is to facilitate the roadway user and enhance efficient vehicle movement.* The need to provide extra time for drivers to perceive, decide, and navigate through the intersection is central to intersection design controls and practices.

Designing to accommodate the appropriate traffic control are critical to good intersection design. Warrants and guidelines for selection of appropriate intersection control (including stop, yield, all-stop, or signal control) may be found in the MUTCD.

Basic Elements of Intersection Design

Human Factors
Driver habits, decision ability, driver expectancy, decision/reaction time, paths of movement, pedestrian characteristics, bicyclists

Traffic Considerations
Roadway classifications, capacities, turning movements, vehicle characteristics, traffic movements, vehicle speeds, transit, crash history, bicycles, pedestrians

Physical Elements
Abutting properties, vertical alignments, sight distance, intersection angle, conflict area, speed-change lanes, geometric design, traffic control, lighting, roadside design, environmental factors, crosswalks, driveways, access management

Economic Factors
Improvement costs, energy consumption, right-of-way impacts

A range of design elements are available to achieve the functional objectives, including horizontal and vertical geometry, left- and right-turn lanes, channelization, etc.

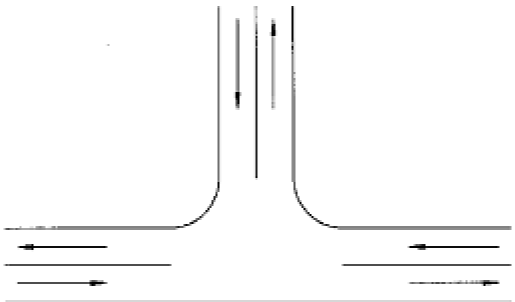
Levels of service analysis and roadway capacity are critical considerations in intersection design. Capacity is determined by constraints at intersections. Vehicle turns at intersections interrupt traffic flow and reduce levels of service.

AASHTO defines intersection capacity as "the maximum hourly rate at which vehicles can reasonably be expected to pass through the intersection under prevailing traffic, roadway, and signalization conditions". The Highway Capacity Manual (HCM) provides various analysis techniques for comparing different conditions at intersections.

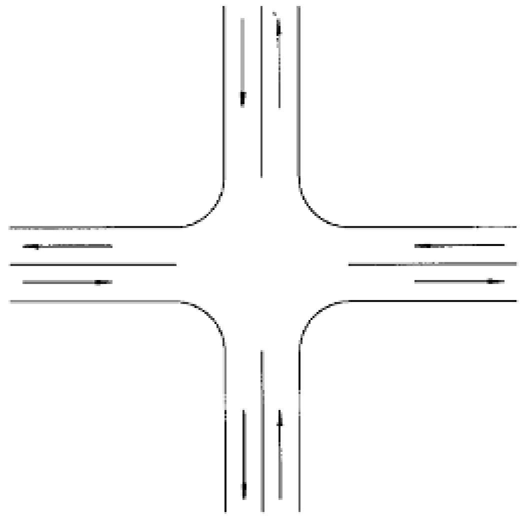
A well-designed intersection is clear to the driver with design dimensions supporting operational requirements, traffic control devices functioning as intended, and non-motorized vehicle users operating safely through the intersection.

Basic Types of Intersections

- Three-leg (T)
- Four-leg
- Multi-leg
- Roundabout



THREE-LEG INTERSECTION



FOUR-LEG INTERSECTION

These types may vary based on scope, shape, flaring (for auxiliary lanes), and channelization (separation/regulation of conflicting traffic).

Variables for determining the type of intersection to be used at a location include:

Topography
Traffic characteristics
Number of legs
Type of operation
Roadway character

Three-leg
The typical three-leg intersection configuration contains normal paving widths with paved corner radii for accommodating design vehicles. The angle of intersection typically ranges from 60 to 120 degrees.

Auxiliary lanes (left or right-turn lanes) may be used to increase roadway capacity and provide better operational conditions.

Channelization may be achieved by increasing corner radii to separate a turning roadway from the normal traveled ways by an island.

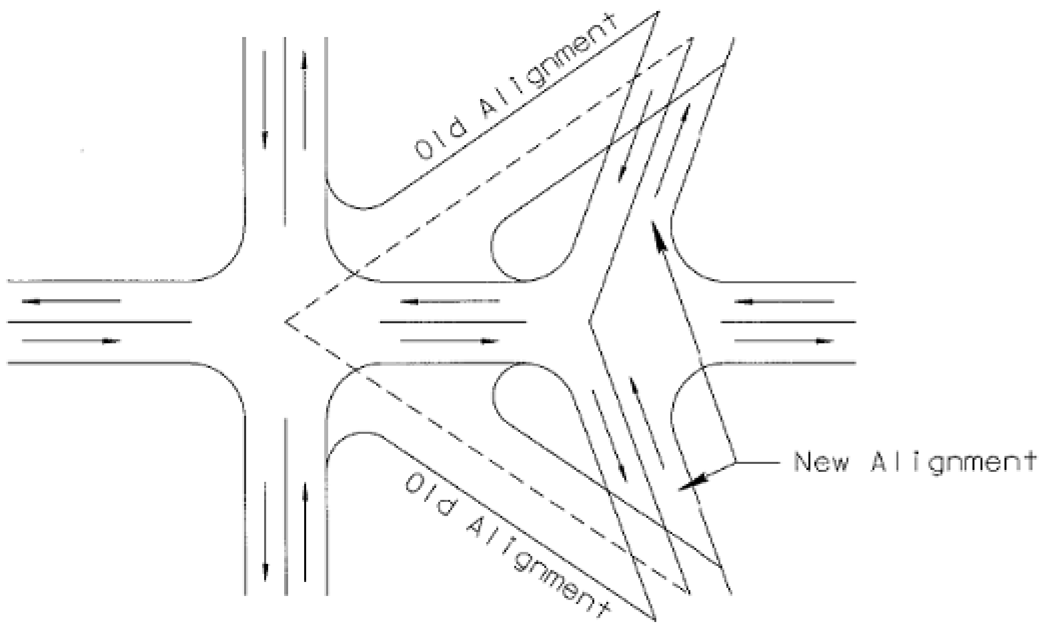
Four-leg
Many of the three-leg intersection design considerations (islands, auxiliary lanes, channelization, etc.) may also be applied to four-leg intersections.

Multi-leg
Intersection designs with multiple legs (5 or more) should not be used unless there is no other viable alternative. If multi-legs must be used, a common paved area where all legs intersect may be desirable for light traffic volumes and stop control.

Operational efficiency can also be increased by removing major conflicting movements.

Multi-leg Reconfiguration Options

- Realigning one or more legs
- Combining traffic movements at subsidiary intersections
- Redesigning as a roundabout
- Converting legs to one-way operation



MULTILEG INTERSECTION REALIGNMENT

Alignment and Profile
Roadway geometry influences its safety performance. This has been confirmed by research showing that roadway factors are the second most contributing factor to roadway crashes. In the U.S., the average crash rate for horizontal curves is about three times that of other highway segments.

Conflicts tend to occur more frequently on roadways with sudden changes in their character (i.e. sharp curves at the end of long tangent roadway sections). The concept of design consistency compares adjacent road segments and identifies sites with changes that might appear sudden or unexpected. Design consistency analysis can be used to show the decrease in operating speed at a curve.

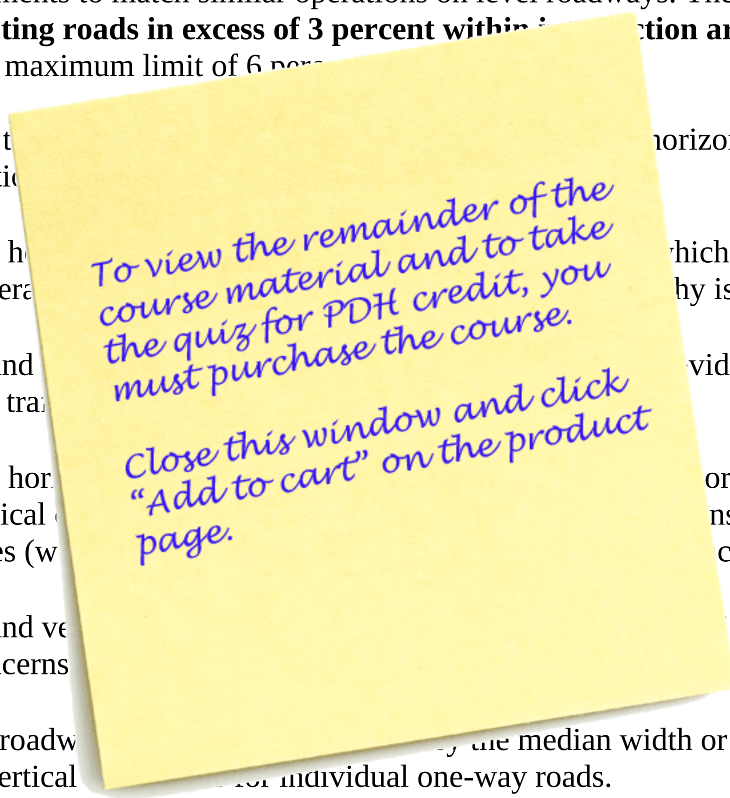
The **horizontal** and **vertical geometries** are the most critical design elements of any roadway. While most designers normally design the horizontal and then the vertical alignment, these should be coordinated to enhance vehicle operation, uniform speed, and facility appearance without additional costs (checking for additional sight distance prior to major changes in the horizontal alignment; revising design elements to eliminate potential drainage problems; etc.). Computer-aided design (CAD) is the most popular method used to facilitate the iterative three-dimensional design and coordinate the horizontal and vertical alignments.

The location of a roadway may be determined by traffic, topography, geotechnical concerns, culture, future development, and project limits. Design speed limits many design values (curves, sight distance) and influences others (width, clearance, maximum gradient).

Intersecting roads should be aligned at approximate right angles in order to reduce costs and potential crashes. Intersections with acute angles need larger turning areas, limit visibility, and increase vehicle exposure time. Although minor road intersections with major roads are desired to be as close to 90 degrees as practical, some deviation is allowable – angles of 60 degrees provide most of the benefits of right angle intersections (reduced right-of-way and construction costs).

Vertical grades that impact vehicle control should be avoided at intersections. Stopping and accelerating distances calculated for passenger vehicles on 3 percent maximum grades differ little from those on the level. Grades steeper than 3 percent may require modifications to different design elements to match similar operations on level roadways. Therefore, **avoid grades for intersecting roads in excess of 3 percent withi** ... **ction areas** unless cost prohibitive – then a maximum limit of 6 per...

AASHTO provides t... horizontal and vertical alignment combinati...



- Vertical and h... which optimizes safety, capacity, opera... hy is desirable.
- Horizontal and ... vide a pleasing facility for roadway tra...
- Avoid sharp hor... or near the low point of a sag vertical ... ns. Using higher design values (w... ce suitable designs.
- Horizontal and ve... ons with sight distance concerns...
- For divided roadw... the median width or use independent horizontal/vertical ... for individual one-way roads.