Roadway Geometric Design III - Intersections & Interchanges

An Online Continuing Education Course for Engineers

Course Number: T-4021

Credit: 4 Hours / 4 PDH / 4 CPD

Roadway Geometric Design III Intersections & Interchanges

Gregory J. Taylor, P.E.

INTRODUCTION

This course is the **last** in a series of three volumes that summarizes and highlights the geometric design process for modern roads and highways. Subjects covered include: *intersections (types/examples, alignment, profile, sight distance, roundabouts); grade separations and interchanges (types, warrants, safety, economic factors).* 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 design guidelines for intersections and interchanges. The course objective is to give engineers and designers an in-depth look at the principles to be considered when selecting and designing roads.

The *American Association of State Highway and Transportation Officials (AASHTO)* publishes and approves information on geometric roadway design for use by individual state transportation agencies. Most today's geometric design research is sponsored and directed by AASHTO and the Federal Highway Administration (FHWA) through the National Cooperative Highway Research Program (NCHRP).

For this course, AASHTO's **A Policy on Geometric Design of Highways and Streets** (also known as the "Green Book") will be used primarily for fundamental geometric design principles. This text is 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.

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,* and *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 is 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.

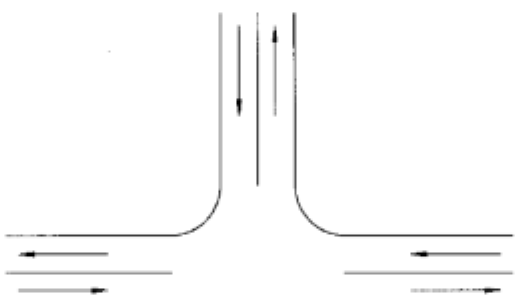
Level of service analysis and roadway capacity are critical considerations in intersection design. Capacity is determined by constraints at intersections. Vehicle turns at intersections interrupt traffic flow and reduce levels of service.

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.

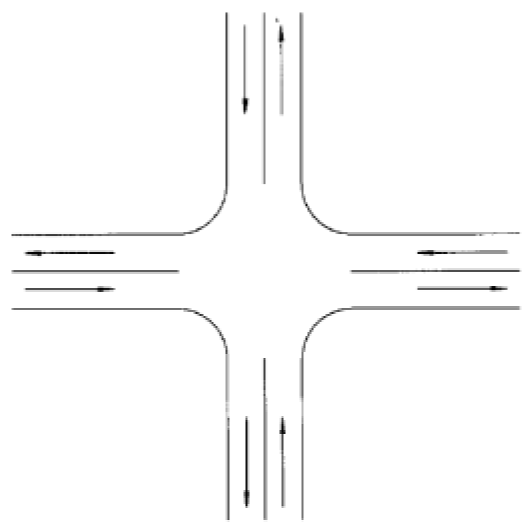
A well-designed intersection is clear to the driver with design dimensions supporting operational requirements, traffic control devices functioning as intended, and non-motorized vehicle users operating safely through the intersection.

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 using an island.

Four-leg

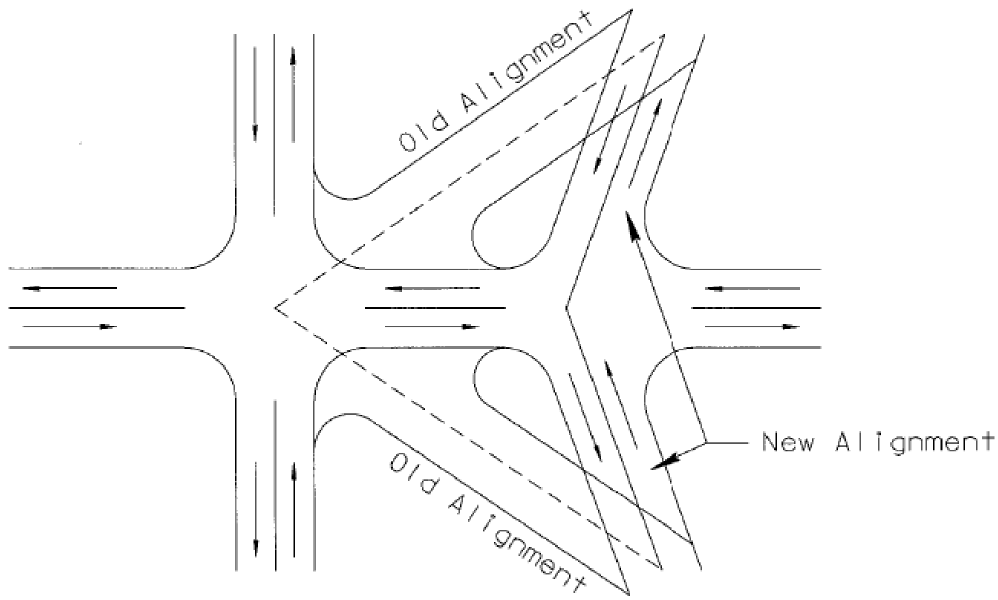
Many of the three-leg intersection design considerations (islands, auxiliary lanes, channelization, etc.) may also be applied to four-leg intersections.

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.

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 and design (CADD) 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 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 more than 3 percent within intersection areas** unless cost prohibitive – then a maximum limit of 6 percent may be permissible.

AASHTO provides the following general design guidelines regarding horizontal and vertical alignment combinations:

- Vertical and horizontal elements should be bal… …gn which optimizes safety, capacity, operation… …'s topography is desirable.
- Horizontal an… …provide a pleasing facility for roa…
- Avoid sharp ho… …urve or near the low point of a sag v… …expectations. Using higher design v… …d can produce suitable designs…
- Horizontal and v… …rsections with sight distance concern…
- For divided road… …h or use independent hori… …y roads.
- Roadway alignme… …residential areas. Measures may inc… …ility and noise), or horizontal adju… …and neighborhoods).