Lecture 4.29

4.4 Traffic Geometrics

Role of Geometrics in Traffic Operations and Safety

Geometric design serves as the physical interface between the driver, vehicle, and roadway environment.

Proper geometrics accommodate vehicle operating characteristics, provide forgiving roadside clear zones, and minimize driver workload at critical decision points.

- Capacity Maximization: Providing adequate lane widths, shoulders, and turning radii
- Safety Enhancement: Eliminating sharp blind curves, abrupt lane drops, and short sight distances
- Driver Comfort: Designing smooth transition curves and balanced super-elevation rates
- IRC Compliance: Adherence to IRC:73 (Urban Roads) and IRC:37 / IRC:86 guidelines

Intersection Classification (At-Grade vs Grade-Separated)

Intersections are critical nodes in road networks where two or more traffic streams cross, diverge, or merge.

Engineers classify junctions into At-Grade Intersections (uncontrolled, priority, signalized, or rotary) and Grade-Separated Intersections (interchanges and overpasses).

- Unsignalized At-Grade: Stop-controlled, Yield-controlled, and priority junctions
- Signalized At-Grade: Time-sharing junctions controlled by traffic signal phases
- Rotary Intersections: Self-regulating circular junctions operating on weaving flow
- Grade Separations: Flyovers, underpasses, trumpet, cloverleaf, and diamond interchanges

Conflict Points at Intersections (3-Leg and 4-Leg Junctions)

A conflict point is any location within an intersection where traffic paths cross, merge, or diverge, presenting potential collision risks.

The number of conflict points increases exponentially with the number of intersecting legs and travel lanes.

Intersection Type	Crossing	Merging	Diverging	Total
4-Leg Uncontrolled	16	8	8	32
3-Leg (T-Junction)	3	3	3	9

- **Crossing Conflicts**: Most severe type, causing right-angle T-bone collisions.
- **Conflict Mitigation**: Channelization, signalization, or roundabouts.

Principles of Intersection Channelization

Channelization involves using raised islands, curb radii, and pavement markings to direct traffic into defined travel paths.

Channelized intersections eliminate broad unguided pavement areas, force turning vehicles to cross opposing streams at near-right angles (75°-90°), and separate conflicting movements.

- Path Confinement: Preventing drivers from taking erratic or dangerous shortcut paths
- Crossing Angle Optimization: Ensuring intersecting streams meet at 75° to 90° for optimal visibility
- Refuge Provisions: Creating safe raised islands for crossing pedestrians and signal posts
- Speed Control: Using curved island radii to decelerate turning traffic to safe speeds

Rotary Intersections (Roundabouts) - Geometry and Weaving

A traffic rotary is a specialized channelized intersection where all entering traffic moves in a single direction around a central raised island.

Vehicular streams enter the rotary, weave into the circulating traffic stream, and exit at their desired leg without stopping.

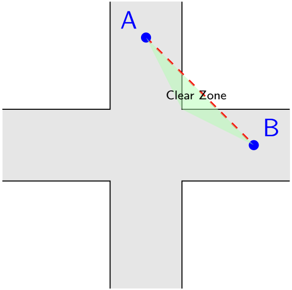
- Weaving Section: The length of rotary roadway where entering and exiting vehicles cross paths
- Entry Radius & Speed: Curved entry island design to limit entering speeds to 30-40 km/h
- Central Island Shape: Circular, elliptical, or elongated to fit traffic volume proportions
- IRC:65 Criteria: Recommended for total intersecting volumes between 500 and 3,000 veh/hr

Sight Distance Requirements at Intersections (ISD)

Intersection Sight Distance (ISD) provides drivers entering or crossing a major road with adequate line-of-sight to perceive oncoming vehicles and complete maneuvers safely.

Engineers construct clear 'Sight Triangles' at uncontrolled and yield-controlled intersection corners.

- **Sight Triangle**: Obstruction-free sight lines on approaches.
- **SSD**: Minimum stopping distance.
- **ISD Criteria**: 1.5 to 2.0× SSD.
- **Clearance**: Removing walls, vegetation, signs.



Horizontal Alignment Geometrics (Radius, Super-elevation, Transition Curves)

Horizontal alignment consists of straight tangents connected by circular horizontal curves and transition curves.

Super-elevation (e) is the transverse banking of the outer edge of pavement on curves to counteract centrifugal force.

- Centrifugal Force Equilibrium: $e + f = \frac{V^2}{127R}$, where f is side friction
- Transition Curves: Provide gradual curvature change

Terrain Type	**Max Super-elevation (e_{max})**	**Remarks**
Plain / Rolling	7% (0.07)	Standard limit
Hilly / Steep	10% (0.10)	Not bound by snow
Urban (Frequent Stops)	4% (0.04)	To prevent sliding

Vertical Alignment Geometrics (Gradients, Crest & Sag Curves)

Vertical alignment consists of longitudinal gradients connected by vertical parabolic crest and sag curves.

Vertical curves provide smooth transitions between changes in grade while preserving stopping sight distance over hill crests.

- Ruling Gradients: Maximum design gradient for normal terrain (3.3% to 5.0% per IRC:73)
- Crest Vertical Curves: Designed to guarantee Stopping Sight Distance (SSD) over the summit
- Sag Vertical Curves: Designed for headlight sight distance (HSD) and comfort criteria at night
- Grade Compensation: Reducing steep gradients on sharp horizontal curves to offset combined resistance

Median Openings and Right-Turn Lanes Design

Divided highways require properly spaced median openings and dedicated exclusive turning lanes to facilitate access without disrupting high-speed through traffic.

Exclusive right-turn (or left-turn in left-hand drive systems) lanes provide storage space for deceleration and queuing.

- Median Opening Spacing: Minimum 200m to 500m spacing along urban arterials to prevent friction
- Exclusive Turn Lanes: Consist of entry taper, deceleration length, and queue storage length
- Taper Ratios: 1:8 to 1:15 taper ratios for smooth vehicular entry into turn pockets
- Storage Length: Sized to accommodate 1.5 to 2.0 times the average peak period queue length

Speed-Change Lanes (Acceleration and Deceleration Lanes)

Speed-change lanes are auxiliary lanes provided adjacent to expressways and high-speed arterials to allow entering or exiting vehicles to adjust speed safely.

Deceleration lanes allow exiting drivers to slow down outside the through traffic lane; acceleration lanes allow entering drivers to speed up and merge smoothly.

- Deceleration Lane Length: Computed based on initial highway speed and safe turn-off ramp speed
- Acceleration Lane Length: Sized for vehicles to accelerate from ramp speed to highway cruising speed
- Taper Design: Providing gradual lateral transition for merging and diverging maneuvers
- Operational Benefit: Prevents rear-end collisions caused by sudden braking on mainline freeways

Summary of Traffic Geometrics Principles

Traffic geometrics translates vehicular dynamics and human factors into physical roadway dimensions, optimizing capacity, safety, and operational efficiency.

Engineers apply IRC design standards to intersections, sight triangles, super-elevation, vertical curves, and auxiliary lanes.

- Intersections are engineered to minimize crossing conflict points through channelization and roundabouts
- Sight triangles guarantee adequate Stopping Sight Distance (SSD) and Intersection Sight Distance (ISD)
- Super-elevation ($e + f = V^2/127R$) counteracts centrifugal forces on horizontal curves
- Speed-change lanes and median turn pockets isolate decelerating/accelerating vehicles from through traffic