Lecture 5.40

5.2 Accident Recording and Analysis

Overview of Graphical Diagnostic Tools

Statistical crash tables alone cannot reveal how road geometry and traffic operations interact to produce crashes at a specific location.

Traffic engineers rely on two complementary graphic tools: 1. Condition Diagrams (which illustrate the physical geometry, environmental features, and traffic controls of a site) and 2. Collision Diagrams (which plot individual crash events using standardized directional symbols).

- Condition Diagram: Scale drawing of physical roadway layout, obstacles, and control devices
- Collision Diagram: Schematic drawing showing direction, type, and severity of all crashes
- Combined Diagnostic Utility: Correlating physical features with repeating crash patterns
- Time Horizon: Typically compiled using 1 to 3 years of recorded crash data

Condition Diagrams: Purpose and Key Features

A Condition Diagram is a scaled engineering drawing showing all physical and environmental conditions present at a high-accident location or intersection.

Key elements mapped include lane widths, pavement markings, curb radii, gradient, traffic signs and signals, street lighting poles, vision obstructions (buildings, hedges, billboards), surface conditions, and roadside hazards.

- Physical Geometry: Carriageway width, medians, shoulders, curb lines, and radii
- Traffic Control Devices: Signal pole locations, stop lines, regulatory/warning signs
- Sight Obstructions: Walls, trees, parked vehicles, or structures blocking sight lines
- Pavement & Environment: Surface texture, drainage slopes, lighting installations

Collision Diagrams: Purpose and Symbol Conventions

A Collision Diagram is a schematic drawing (not necessarily drawn to scale) that illustrates the path, direction, collision type, and severity of every accident recorded at a site over a specified period.

Standardized symbols and directional arrows depict vehicle movements prior to impact. Solid arrows show vehicle paths, dashed lines show pedestrian paths, cross-marks denote point of impact, and specific symbols indicate fatal, injury, or PDO outcomes.

Element	**Description**
Vehicle Movement Arrows	Indicating approach direction and path prior to collision
Impact Symbols	Distinct symbols for head-on, rear-end, right-angle, and side-swipe impacts
Severity Markers	Solid filled circles for fatal crashes, open circles for injuries, crosses for PDO
Temporal Annotations	Adding date, time of day, and weather conditions beside each crash arrow

Interpreting Collision Patterns for Safety Countermeasures

The primary power of a Collision Diagram lies in pattern recognition. Clusters of similar crash types point directly to specific engineering defects.

For example, a cluster of Rear-End crashes suggests inadequate signal amber time or poor skid resistance; a cluster of Right-Angle crashes indicates poor sight distance or signal phase deficiencies; and Night-time crashes suggest inadequate street lighting.

- Rear-End Clusters: Indicates sudden stopping, inadequate signal yellow time, or slick pavement
- Right-Angle Clusters: Indicates running red lights, obscured stop signs, or sight obstructions
- Head-on Clusters: Indicates lack of median separation or improper overtaking clearance
- Single-Vehicle Run-Off-Road: Indicates sharp unbanked curve, slippery surface, or poor delineation

Black Spot Identification Methodologies

Road networks span thousands of kilometers. Engineers must use objective mathematical methods to identify and prioritize hazardous locations ('black spots') for remedial funding.

Common identification methods include the Crash Frequency Method (ranking locations by total crash count), Crash Rate Method (ranking by crashes per million vehicle kilometers), and Severity Weighted Index methods.

- Crash Frequency Method: Simple ranking based on total crash count per section per year
- Crash Rate Method: Adjusts crash count by traffic volume exposure (MVkm or MEV)
- Rate-Quality Control Method: Combines statistical probability with volume rates to flag spots exceeding critical crash rate threshold (R_c)
- Weighted Severity Method: Assigns higher mathematical weights to fatal and grievous crashes

Weighted Severity Index (WSI) Calculation

The Weighted Severity Index (WSI) is the standard metric recommended by the Ministry of Road Transport and Highways (MoRTH) in India for evaluating the relative hazard level of road stretches.

WSI assigns numerical weight factors reflecting the social and economic cost of crash outcomes: Fatalities ($K = 5$), Grievous Injuries ($GI = 3$), and Minor Injuries ($MI = 1$).

- WSI Formula: $WSI = (5 \times K) + (3 \times GI) + (1 \times MI)$
- Threshold Criterion: Stretches of ∼500m with WSI exceeding thresholds are classified as Black Spots
- Objective Prioritization: Prevents low-severity PDO crashes from skewing safety investment

Outcome	**Variable**	**Weight Factor**
Fatalities	K	5
Grievous Injuries	GI	3
Minor Injuries	MI	1

Priority Ranking and Economic Evaluation of Countermeasures

Once black spots are identified, proposed engineering countermeasures must be evaluated economically to ensure optimal allocation of limited public safety funds.

Engineers perform Benefit-Cost (B/C) Analysis, calculating expected monetary savings from prevented crashes against the capital cost of the engineering improvement.

- Crash Modification Factors (CMF): Quantitative ratio estimating expected crash reduction from an engineering treatment
- Monetary Benefit (B): Annual economic savings from prevented fatalities, injuries, and property damage
- Capital Cost (C): Construction and maintenance cost of countermeasure (e.g., roundabout, signal, realignment)
- Benefit-Cost Ratio (B/C): Projects with $B/C > 1.0$ are economically viable; higher ratios receive top priority

Before-and-After Safety Studies

Before-and-After studies are conducted to evaluate the real-world effectiveness of implemented engineering countermeasures over a multi-year post-construction period.

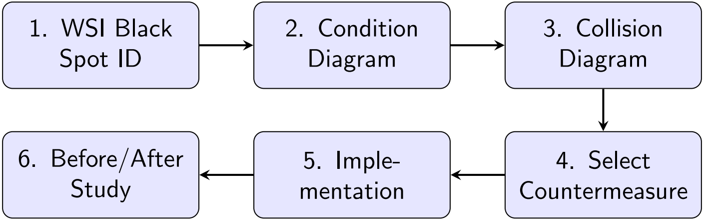
To prevent misleading conclusions, safety engineers must control for external confounding factors—such as general traffic growth, regional weather changes, and the statistical phenomenon known as 'Regression-to-the-Mean' (RTM).

- Study Window: Comparing 3 years of 'Before' crash data with 3 years of 'After' crash data
- Control Site Comparison: Using untreated control sites to isolate treatment effect from background trends
- Regression-to-the-Mean (RTM): Statistical tendency for extreme high-crash years to naturally return to average
- Empirical Bayes Adjustment: Accounting for RTM to measure true engineering impact

Step-by-Step Black Spot Remediation Workflow

Systematic black spot remediation follows a structured 6-step engineering workflow to ensure lasting safety improvements.

The workflow comprises: 1. Data screening and WSI identification, 2. Field site inspection and Condition Diagram drafting, 3. Collision Diagram analysis and pattern diagnosis, 4. Selecting tailored engineering countermeasures, 5. Project execution, and 6. Post-construction Before-and-After evaluation.



Case Study: Intersection Safety Diagnosis

Consider a high-crash un-signalized 4-leg intersection recorded 8 fatal crashes and 12 grievous injuries over 3 years. $WSI = (5 \times 8) + (3 \times 12) = 76$, far exceeding the black spot threshold.

The Collision Diagram revealed 70% of crashes were Right-Angle collisions. The Condition Diagram showed high boundary walls obscuring sight triangles. Remedial Action: Acquiring corner land to clear sight lines and converting the junction into a modern roundabout.

- Problem Site: Un-signalized 4-leg intersection with WSI = 76 (Severe Black Spot)
- Collision Pattern: Dominance of right-angle broadside impacts
- Condition Diagnosis: Corner structures obscuring Stopping Sight Distance on approach legs
- Engineered Solution: Removal of sight obstructions and installation of a 40m diameter roundabout
- Post-Improvement Outcome: Zero fatal angle collisions recorded in 3-year follow-up study

Summary of Accident Recording and Analysis

This lecture detailed Condition Diagrams, Collision Diagrams, Black Spot identification via Weighted Severity Index (WSI), and Before-and-After safety evaluation.

Mastering these diagnostic tools empowers civil engineers to transform raw crash records into precise physical diagnoses and cost-effective engineering solutions, ultimately saving lives across highway networks.

- Condition Diagrams map physical roadway features and sight line obstructions
- Collision Diagrams map directional crash paths and collision patterns using standardized symbols
- Overlaying diagrams reveals root causes of recurring crash clusters
- Weighted Severity Index $WSI = 5K + 3GI + 1MI$ objectively prioritizes black spot funding
- Before-and-After studies with control sites evaluate countermeasure success accurately