

ATME College of Engineering

13th K M Stone, Bannur Road, Mysore – 570028



A T M E

College of Engineering

DEPARTMENT OF CIVIL ENGINEERING

(ACADEMIC YEAR 2026 - 27)

SUBJECT NAME: ROAD SAFETY ENGINEERING

SUBJECT CODE: BCV755A

SEMESTER: 7

INSTITUTIONAL MISSION AND VISION

Vision of the Institute

Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

Mission of the Institute

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torch bearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence

DEPARTMENT VISION AND MISSION

Vision of the Department

To develop globally competent civil engineers who excel in academics, research and are ethically responsible for the development of the society.

Mission of the Department

- To provide quality education through faculty and state of art infrastructure
- To identify the current problems in society pertaining to Civil Engineering disciplines and to address them effectively and efficiently
- To inculcate the habit of research and entrepreneurship in our graduates to address current infrastructure needs of society

Program outcomes (POs)

Engineering Graduates will be able to:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. The Engineer and The World: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO8. Individual and Collaborative Team Work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings

PO9. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO10. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO11. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Program Specific Outcomes (PSOs)

PSO1: Provide necessary solutions to build infrastructure for all situations through competitive plans, maps and designs with the aid of a thorough Engineering Survey and Quantity Estimation.

PSO 2: Assess the impact of anthropogenic activities leading to environmental imbalance on land, in water & in air and provide necessary viable solutions revamping water resources and transportation for a sustainable development

Program Educational Objectives (PEOs)

PEO 1- Engaged in professional practices, such as construction, environmental, geotechnical, structural, transportation, water resource engineering by using technical, communication and management skills.

PEO 2- Engaged in higher studies and research activities in various civil engineering fields and life time commitment to learn ever changing technologies to satisfy increasing demand of sustainable infrastructural facilities.

PEO 3- Serve in a leadership position in any professional or community organization or local or state engineering board

PEO 4- Registered as professional engineer or developed a strong ability leading to professional licensure being an entrepreneur.

VII Semester

ROAD SAFETY ENGINEERING			
Course Code	BCV755A	CIE Marks	50
Teaching Hours/Week(L:T:P:S)	3:0:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03
Course Learning objectives: This course will enable students to - To provide students with a comprehensive understanding of the principles, strategies, and techniques related to ensuring safety on roadways. - To equip students with the knowledge and skills necessary to analyse road safety issues - To design effective road safety measures, and contribute to the improvement of road safety practices.			
Teaching-Learning Process (General Instructions) - Blackboard teaching/PowerPoint presentations (if needed) - Regular review of students by asking questions based on topics covered in the class.			
Module -1			
Accident Investigations and Risk Management: Collection of Accident Data, Assessment of Road Safety, Methods to Identify and Prioritize Hazardous Locations and Elements, Determine Possible Causes of Crashes, Crash Reduction Capabilities and Countermeasures, Effectiveness of Safety Design Features, Accident Reconstruction, Condition and Collision Diagram.			
Module -2			
Traffic Engineering Studies: Statistical Methods in Traffic Safety Analysis – Regression Methods, Poisson Distribution, Chi- Squared Distribution, Statistical Comparisons- Traffic Management Measures and Their Influence on Accident Prevention.			
Module -3			
Road Safety in Transport Planning and Geometric Design: Vehicle and Human Characteristics, Road Design and Safety Elements, Redesigning Junctions, Cross Section Improvements, Traffic Control, Traffic Calming Measures, Road Safety Furniture			
Module -4			
Role Of Signs and Markings in Safety: Types of Signs – Design Specifications – Guidelines for Installation – Role of Signs in Safety; Types of Road Markings – Design Specifications – Role of Road Markings in Safety.			
Module -5			
Traffic Management Systems for Safety: Road Safety Audits and Tools for Safety Management Systems, Road Safety Audit Process, Road Safety Improvement Strategies, ITS And Safety.			
Course outcomes:			
Course outcome (Course Skill Set) At the end of the course the student will be able to: - Analyse road safety data, identify hazardous locations, and assess safety risks on roadways - Evaluate the effectiveness of road safety interventions and conduct post-implementation analysis. - Utilize modelling and simulation techniques to predict and assess the impact of road safety measures. - Demonstrate knowledge of traffic control devices, traffic management strategies, and their role in enhancing road safety			

- Comprehend the legal and policy framework related to road safety engineering and contribute to policy development.

Assessment Details (both CIE and SEE) The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 35% (18 Marks out of 50)in the semester-end examination(SEE), and a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together

Continuous Internal Evaluation:

Three Unit Tests each of **20 Marks (duration 01 hour)**

1. First test at the end of 5th week of the semester
2. Second test at the end of the 10th week of the semester
3. Third test at the end of the 15th week of the semester

Two assignments each of **10 Marks**

4. First assignment at the end of 4th week of the semester
5. Second assignment at the end of 9th week of the semester

Group discussion/Seminar/quiz any one of three suitably planned to attain the COs and POs for **20 Marks (duration 01 hours)**

6. At the end of the 13th week of the semester

The sum of three tests, two assignments, and quiz/seminar/group discussion will be out of 100 marks and will be **scaled down to 50 marks**

(to have less stressed CIE, the portion of the syllabus should not be common /repeated for any of the methods of the CIE. Each method of CIE should have a different syllabus portion of the course).

CIE methods /question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the subject (**duration 03 hours**)

1. The question paper will have ten questions. Each question is set for 20 marks.
2. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.

The students have to answer 5 full questions, selecting one full question from each module

Suggested Learning Resources:

Books

1. Choudury M A and Sadek A, "Fundamentals of Intelligent Transportation Systems Planning" Artech House.
2. Pradip Kumar Sarkar, Amit Kumar Jain, "Intelligent Transport Systems", PHI Learning Publishers
3. Kan Paul Chen, John Miles, "Recommendations for World Road Association (PIARC)" ITS Hand Book 2000.
4. Sussman, J. M., "Perspective on ITS", Artech House Publishers, 2005.
5. US Department of Transportation, "National ITS Architecture Documentation", 2007

(CDROM).

6. Turban. E and Aronson. J. E, “Decision Support Systems and Intelligent Systems”

Web links and Video Lectures (e-Resources):

<https://nptel.ac.in/courses/105107210>

https://www.civil.iitb.ac.in/tvm/nptel/591_ITS_1/web/web.html

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Seminars/Quiz (To assist in GATE Preparations)
- Self-Study on simple topics
- Simple problems solving using Excel
- Discussion of case studies
- ☐ Virtual Lab experiments

Module – 1
Accident Investigations and Risk Management

Structure

- 1.0 Introduction
- 1.1 Objectives
- 1.2 Collection of Accident Data
- 1.3 Assessment of Road Safety
- 1.4 Methods to Identify and Prioritize Hazardous Locations and Elements
- 1.5 Determine Possible Causes of Crashes
- 1.6 Crash Reduction Capabilities and Countermeasures
- 1.7 Effectiveness of Safety Design Features
- 1.8 Accident Reconstruction
- 1.9 Condition and Collision Diagram
- 1.10 Recommended questions
- 1.11 Outcomes
- 1.12 Further Reading

1.0 Introduction

The accident studies pertain to the road accidents that occur from time to time on an existing road system, though road accidents cannot be totally prevented, the rate can be decreased substantially by suitable traffic engineering and management measures.

Objectives of Accident studies

The various objectives of the accident studies may be listed as:

- To study the causes of accidents and to suggest corrective treatment at potential locations
- To evaluate existing design, regulation and control measures
- To support proposed changes in design, regulation and control measures in the selected zone
- To carry out 'before and after studies' after implementing changes and to demonstrate the improvement in the accident problem
- To make computations of financial loss due to accidents and
- To provide economic justification for the improvement measures suggested by the traffic engineer

1.1 Objectives

To provide students with a comprehensive understanding of the principles, strategies, and techniques related to ensuring safety on roadways.

1.2 Collection of Accident Data

- a) General - Date, time, persons involved in the accident and their particulars, classification of accident like fatal, serious, minor, property damage only, etc

- b) Location - Description and details of the location of accident supported by diagrams
- c) Details of vehicles involved - Registration number, make and description of the vehicles, loading details, vehicular defects
- d) Nature of accident - Condition of vehicles involved, details of collision, and pedestrians or objects involved, damages, injuries, casualty, etc
- e) Road condition - Details of road geometrics, whether the road stretch is straight or curved, surface characteristics such as dry, wet or slippery, etc
- f) Traffic condition - Type vehicles in the traffic flow, traffic volume and density, etc
- g) Primary causes of accident - various possible causes and the primary cause of the accident
- h) Other probable causes/secondary and contributing causes for the accident
- i) Accident cost - The total cost of the accident, such as property damages, personal injuries and casualties, computed in terms of Rupees

Methods for collection of accident data

Collecting accident data is crucial for analyzing road safety, designing improvements, and forming policies. Below are the main methods for collection of accident data:

Police Records:

- Description: Accidents reported to and recorded by local police departments.
- Details Captured: Time, location, vehicle type, driver info, road condition, cause, injuries, fatalities.
- Advantages: Official, standardized, and legally recognized.
- Limitations: Underreporting of minor accidents.

Hospital & Medical Records

- Description: Data from emergency rooms and trauma centers.
- Details Captured: Nature and severity of injuries, treatment, patient demographics.
- Advantages: Captures unreported accidents; useful for injury severity analysis.
- Limitations: May lack accident location and context.

Insurance Company Reports

- Description: Claims submitted for damages or medical treatment.
- Details Captured: Vehicle damage, cost, nature of impact.
- Advantages: Includes both minor and major accidents.
- Limitations: Data access is often private/confidential.

On-site Investigations

- Description: Detailed examination at the accident location by traffic engineers or researchers.
- Details Captured: Road geometry, skid marks, vehicle final positions, environmental conditions.

- Advantages: Accurate and comprehensive.
- Limitations: Time-sensitive; resource-intensive.

Surveys & Interviews

- Description: Questionnaires or verbal interviews with drivers, victims, or witnesses.
- Details Captured: Human factors, perception, pre-accident behavior.
- Advantages: Provides subjective insights.
- Limitations: Recall bias; limited sample size.

CCTV / Video Surveillance

- Description: Traffic camera or surveillance footage from accident-prone areas.
- Details Captured: Real-time visuals of accident sequence.
- Advantages: Verifiable evidence; helps analyze crash dynamics.
- Limitations: Limited coverage; privacy concerns.

Automatic Traffic Recorders (ATRs) & IoT Sensors

- Description: Smart sensors embedded in road infrastructure or vehicles.
- Details Captured: Speed, traffic volume, impact forces.
- Advantages: Continuous monitoring; no human bias.
- Limitations: High cost; data integration challenges.

GPS & Telematics Data

- Description: From fleet management systems, apps, or black boxes.
- Details Captured: Vehicle speed, location, sudden stops, crash detection.
- Advantages: Precise and real-time.
- Limitations: Privacy and data ownership issues.

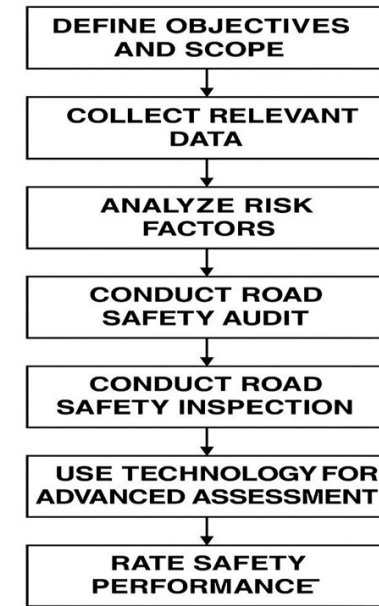
Academic and Government Research Databases

Examples:

- India: MoRTH (Ministry of Road Transport and Highways) accident database, IRAD (Integrated Road Accident Database)
- US: NHTSA's (National Highway Traffic Safety Administration) FARS (Fatality Analysis Reporting System)

1.3 Assessment of Road Safety

Road safety refers to the measures, practices, and strategies designed to prevent road users such as drivers, passengers, pedestrians, and cyclists—from being killed or seriously injured in traffic accidents. It involves the safe design and operation of roads, vehicles, and traffic systems, as well as the enforcement of laws and promotion of responsible user behaviour. The following flow chart depicts how to conduct Road Safety Assessment.



Step-by-step procedure to assess

Step 1: Define Objectives and Scope

Objective: Determine why and where the road safety assessment is being done.

- **Scope:** Is it a full corridor, a junction, a rural road, or an urban street?
- **Purpose:**
 - Reduce fatalities and serious injuries.
 - Evaluate post-construction performance.
 - Improve pedestrian or cyclist safety.
 - Conduct feasibility for road widening or signal changes.

Example: Assess the safety of a national highway stretch between two towns due to rising crash rates.

Step 2: Collect Relevant Data

Collect accurate and recent data related to road use, crash occurrences, and road environment.

1. Crash/Accident Data

- Source: Police, hospitals, insurance, Integrated Road Accident Database (IRAD – India).
- Fields: Date, time, type of accident, location (GPS or chainage), weather, fatalities, injuries.

2. Traffic Data

- Volume (AADT – Annual Average Daily Traffic).
- Speed studies (average speed, 85th percentile speed).
- Vehicle mix (2W, 4W, buses, trucks).

3. Road Inventory

- Road width, number of lanes, shoulder condition, pavement condition.

- Signage, markings, lighting, intersections, curves, visibility.
- Nearby land use (schools, shops, bus stops).

4. Human Factors

- Driver behaviour: speeding, drunk driving, distraction.
- Pedestrian movements.
- Helmet/seatbelt usage rates.

Tools: Traffic counters, GPS mapping, drone surveys, field notes.

Step 3: Analyze Risk Factors

Goal: Identify hazardous conditions or risky behaviors contributing to accidents.

- **Blackspot Identification:** Locations with high crash density or crash severity index.
 - **Crash Pattern Analysis:**
 - Repeated types (e.g., rear-end, side-impact, pedestrian hits).
 - Time pattern (e.g., night crashes due to poor lighting).
- **Design Deficiencies:** Poor horizontal alignment, steep slopes, inadequate shoulder width, wrong signage.

Tools: GIS, crash plotting software, Excel heat maps, iRAP ViDA.

Step 4: Conduct Road Safety Audit (RSA)

A **systematic and formal safety review** done by an independent, qualified team at different stages:

- **Planning/Design Stage:** Ensure safety is built into drawings.
- **Construction Stage:** Check temporary traffic control and safety during work zones.
- **Pre-opening Stage:** Evaluate final road conditions before opening.
- **Post-opening Stage:** Assess real-world performance.

Checklist Items:

- Are signs visible at night?
- Is the road shoulder stable?
- Are pedestrian crossings adequate?

Standard: IRC SP 88-2019 (Road Safety Audit Manual – India)

Step 5: Conduct Road Safety Inspection (RSI)

An **on-site field visit** to visually assess the condition of an existing road from a safety perspective.

- **Visual checks** (no need for crash data).
- Focuses on:
 - Pavement defects
 - Faded signs/markings
 - Obstructions near the carriageway (trees, poles)
 - Wrongly placed bus stops
 - Poor drainage causing waterlogging

Frequency: Can be done periodically (monthly/quarterly).

Step 6: Use Technology for Advanced Assessment

Technology helps in **quantifying risks** and **predicting** unsafe conditions.

Tools:

- **CCTV & Drone Video Analytics:**
 - Study near misses, red-light violations, pedestrian behaviour.
- **Crash Simulation Models:**
 - Software like VISSIM, SIDRA, PTV for dynamic modelling.
- **GIS Mapping:**
 - Visualizing crash hotspots and traffic patterns.
- **iRAP Star Rating System:**
 - Roads are rated from 1 to 5 stars based on risk exposure.

Use Case: Use drone footage to observe pedestrian conflict zones at a busy junction.

Step 7: Rate Safety Performance

Based on collected data, audits, and observations, assign a **safety score or rating**.

Common Performance Indicators:

- Crash rate per million vehicle-km
- Fatality and injury rate
- Helmet/seatbelt usage rate
- Response time to accidents
- iRAP star rating (1 star = very dangerous, 5 stars = very safe)

Outcome: Helps compare safety levels of different roads or the effect of implemented measures.

Step 8: Recommend Improvements

Based on identified risks and safety rating:

A. Engineering Measures

- Speed calming: rumble strips, speed humps, roundabouts.
- Signage upgrades, pedestrian footpaths, lighting.
- Guardrails, medians, shoulder strengthening.

B. Enforcement

- Install speed/red-light cameras.
- Conduct regular drunk driving checks.
- Deploy traffic police at blackspots.

C. Education

- Campaigns for helmet/seatbelt use.
- School zone awareness programs.

D. Emergency Response

- Improve ambulance access routes.
- GPS tracking for emergency services.

1.4 Methods to Identify and Prioritize Hazardous Locations and Elements

1. Crash Frequency Method

- **What it does:** Identifies locations based on the number of crashes in a given period (typically 3–5 years).
- **Identification Criteria:** Locations with crash counts above a predefined threshold are considered hazardous.
- **Limitation:** Doesn't consider exposure (traffic volume) or crash severity.
- **Prioritization:** Sites with the highest number of crashes are given priority.

2. Crash Rate Method (Exposure-Based)

- **What it does:** Normalizes crash frequency by traffic volume and road length.
 - **Formula:**

$$\text{Crash Rate} = \frac{\text{Crashes} \times 10^6}{\text{AADT} \times \text{Road Length} \times 365}$$

- **Benefit:** Allows fair comparison between roads with different traffic volumes.
- **Prioritization:** Locations with unusually high crash rates are prioritized even if total crashes are low.

3. Crash Severity Index Method

- **What it does:** Assigns weights to crashes based on severity (e.g., fatal = 5, serious = 3, minor = 1).
 - **Formula:**

$$\text{Severity Index} = \frac{\text{Weighted Sum of Crashes}}{\text{Total Number of Crashes}}$$

- **Benefit:** Highlights locations with more serious crashes.
- **Prioritization:** Sites with higher severity index scores are ranked higher.

4. Crash Cost Analysis

- **What it does:** Calculates economic losses associated with crashes (injuries, fatalities, property damage).
- **Application:** Helps in cost-benefit analysis for proposed safety improvements.
- **Prioritization:** Locations causing higher societal costs are treated with urgency.

5. Statistical Models (Poisson, Negative Binomial, Empirical Bayes)

- **What they do:**
 - Use mathematical models to predict expected crashes based on road characteristics.
 - Compare observed vs. expected crash values.
- **Empirical Bayes:** Combines historical data with predictions for better accuracy.
- **Prioritization:** Locations with the largest positive difference (Observed >

Expected) are critical.

6. Road Safety Audits (RSA)

- **What it does:** Independent safety review of existing/planned roads by a multidisciplinary team.
- **Focus:** Not just crash data, but also geometric design, visibility, signage, etc.
- **Prioritization:** Based on identified safety concerns and expert judgment.

7. Traffic Conflict Technique (TCT)

- **What it does:** Observes near-miss situations as a proxy for potential crashes.
- **Use:** Proactive method where crash data is unavailable or outdated.
- **Prioritization:** Sites with the most frequent or severe conflicts are prioritized.

8. GIS-Based Spatial Analysis

- **What it does:** Uses GIS tools to map crash locations and identify clusters/hotspots.
- **Methods:** Heat maps, kernel density estimation, spatial autocorrelation.
- **Prioritization:** High-density crash zones are prioritized based on spatial intensity.

9. Public Input and Community Reports

- **What it does:** Collects reports from road users about dangerous or confusing road segments.
- **Use:** Supplements analytical methods.
- **Prioritization:** Based on frequency and seriousness of complaints.

10. Composite Index or Scoring System

- **What it does:** Combines multiple factors (crash frequency, rate, severity, volume) into one composite score.
 - **Example Scoring:**
 - Crash Frequency: 40%
 - Crash Rate: 30%
 - Severity Index: 20%
 - Public Complaints: 10%
- **Prioritization:** Rank based on total weighted score.

1.5 Determine Possible Causes of Crashes

There are five basic elements in a traffic accident, namely:

- (a) Road user
- (b) Vehicle
- (c) Road and its condition
- (d) Traffic
- (e) Environmental factors such as weather, visibility, etc.

Various causes of accidents may be listed as given below:

(a) Drivers: Excessive speed and rash driving, carelessness, violation of rules and regulations, failure to see or understand the traffic situation, sign or signal, temporary effects due to fatigue, sleep or effect of consuming alcohol

(b) Pedestrians: Violating regulations, carelessness while using the carriageway meant for vehicular traffic

(c) Passengers: Alighting from or getting into moving vehicles

(d) Vehicle defects: Failure of brakes, steering system, or lighting system, tyre burst and any other defect in the vehicles

(e) Road condition: Slippery or skidding road surface, pot holes, ruts and other damaged conditions of the road surface, temporary obstruction to line of sight (caused by branch of tree or disabled vehicle) resulting in reduction in normal sight distance

(f) Road design: Defective geometric design like inadequate sight distance at horizontal or vertical curves, improper curve design, inadequate width of shoulders, improper lighting and improper traffic control devices

(g) Traffic condition: Other vehicles of the traffic stream, such as a vehicle moving ahead getting involved in accident, presence of disabled vehicle on the roadway

(h) Weather: Unfavourable weather condition like mist, fog, snow, dust, smoke or heavy rainfall which restrict normal visibility and render driving unsafe

(i) Animals: Stray animals on the road

(j) Other causes: Incorrect signs or signals, gate of level crossing not closed when required, ribbon development, badly located advertisement boards or service station, etc.

1.6 Crash Reduction Capabilities and Countermeasures

Crash reduction capability refers to the estimated percentage decrease in crashes (or crash severity) expected after applying a specific safety countermeasure.

Example: Installing a roundabout at an intersection may reduce fatal and injury crashes by 60% compared to a stop-controlled intersection.

Crash Reduction Countermeasures

1. Roundabouts

- Replace traditional intersections to eliminate angle and head-on collisions.
- Reduce conflict points and force lower vehicle speeds, improving safety.

2. Rumble Strips (Edge/Center Line)

- Alert inattentive or drowsy drivers when they leave their lane.
- Reduce run-off-road and head-on crashes significantly.
- 3. **Improved Street Lighting**
 - Enhances nighttime visibility for drivers and pedestrians.
 - Reduces crashes in poorly lit areas, especially at intersections.
- 4. **Pedestrian Crosswalk Enhancements**
 - Includes markings, raised tables, and flashing beacons at crossings.
 - Improves pedestrian visibility and driver compliance.
- 5. **Speed Humps and Calming Measures**
 - Physically reduce vehicle speeds in residential or high-pedestrian areas.
 - Lower speed leads to fewer and less severe crashes.
- 6. **Dedicated Turn Lanes (Islands)**
 - Separate turning traffic from through lanes at intersections.
 - Reduce rear-end and angle-type collisions by improving traffic flow.
- 7. **Median Barriers (e.g., cable or concrete)**
 - Prevent vehicles from crossing into oncoming traffic lanes.
 - Reduce fatal head-on collisions on divided highways.
- 8. **Traffic Signal Upgrades**
 - Includes signal timing, phasing, and visibility improvements.
 - Reduces intersection-related crashes and improves traffic efficiency.
- 9. **High Friction Surface Treatment (HFST)**
 - Applies specialized pavement to high-risk curves or intersections.
 - Improves traction, especially in wet conditions, reducing skidding crashes.
- 10. **Guardrails and Crash Cushions**
 - Protect vehicles from steep drops, obstacles, or fixed objects.
 - Absorb impact energy and reduce crash severity.
- 11. **Better Signage and Pavement Markings**
 - Improve driver awareness with clearer visual guidance.
 - Especially effective in curves, work zones, and merging areas.
- 12. **Road Safety Audits (RSA)**
 - In-depth safety assessments by expert teams on existing or planned roads.
 - Helps detect risks proactively and recommend targeted solutions.
- 13. **Access Management**
 - Control's location and number of driveways/intersections on a corridor.
 - Reduces conflict points and crash frequency on arterial roads.
- 14. **Pedestrian Overpasses and Underpasses**
 - Completely separate pedestrian movement from vehicle traffic.
 - Eliminate pedestrian-vehicle conflict and enhance safety.
- 15. **Speed Cameras and Automated Enforcement**
 - Detect and penalize speeding or red-light violations automatically.
 - Discourages risky behavior and reduces speed-related crashes.

Methods to Estimate Crash Reduction Capabilities of Countermeasures

1. Before-and-After Studies

Description: Compares the number of crashes at a location before and after implementing a countermeasure.

$$\text{Crash Reduction}(\%) = \frac{C_{\text{before}} - C_{\text{after}}}{C_{\text{before}}} \times 100$$

2. Empirical Bayes (EB) Method

Description: Adjusts before-and-after studies by factoring in expected crash frequency using reference (similar) sites.

Approach: Combines actual crash data with predicted crashes from statistical models.

3. Crash Modification Factors (CMF)

Description: Uses known CMFs from prior research to estimate crash changes.

Formula: $\text{Expected Crashes After} = \text{Current Crashes} \times \text{CMF}$

Example: $\text{CMF} = 0.6 \rightarrow 40\%$ expected crash reduction

4. Predictive Crash Modeling (Statistical Regression)

Description: Uses models (e.g., Poisson or Negative Binomial regression) to predict crashes based on road features, volume, and control type.

5. Cross-sectional Studies

Description: Compares crash rates across multiple sites, some with and some without a specific countermeasure.

6. Meta-Analysis / Literature Review

Description: Uses published research studies to derive average crash reduction values.

7. Expert Judgment and Engineering Evaluation

Description: Based on experience, crash diagrams, and field investigations.

Common Road Safety Countermeasures and Their Crash Reduction Capabilities

Countermeasure	Crash Type Targeted	Typical Crash Reduction (%)
Roundabout Installation	Angle, Head-on	60–80%
Rumble Strips (Center/Edge Line)	Run-off-road, Head-on	20–40%
Improved Street Lighting	Night-time crashes	20–40%
Installing Guardrails	Run-off-road	25–45%
Speed Humps / Calming Measures	Speed-related, Pedestrian	40–70%
Signalizing Intersections	Right-angle, Rear-end	10–30%

Converting Signals to Roundabouts	Angle, Fatal crashes	60–90%
Adding Turn Lanes at Intersections	Left-turn/Rear-end	15–55%
Improved Signage and Markings	All crash types	10–20%
Pedestrian Crosswalk Enhancements	Pedestrian crashes	20–50%
Median Barriers (e.g., cable barriers)	Cross-median, Head-on crashes	50–90%
High Friction Surface Treatment (HFST)	Wet surface crashes, Skidding	30–70%
Access Management (e.g., driveway limits)	Rear-end, Angle crashes	15–30%

1.7 Effectiveness of Safety Design Features

Roadway Geometry Improvements: Improving road geometry such as alignment, lane width, and shoulder space helps enhance driver control and visibility. These adjustments reduce sharp curves and blind spots, minimizing crash potential. Smoother transitions between road sections improve traffic flow. Roads designed with proper curvature and grade reduce speeding and skidding. Overall, this can reduce crashes by 30–40%.

Median Barriers: Median barriers are installed on divided highways to prevent vehicles from crossing into oncoming traffic. They are especially effective in reducing head-on collisions, which are often fatal. Types include concrete, steel, or cable barriers. These barriers are low-maintenance and highly durable. Studies show they can reduce cross-median crashes by up to 90%.

Rumble Strips: Rumble strips are grooved patterns on the road that create noise and vibration when driven over. They alert distracted or drowsy drivers who unintentionally drift from their lane. Typically placed on the shoulder or centerline of highways, they prevent run-off-road and head-on crashes. These strips are cost-effective and require minimal maintenance. Crash reductions of 20–80% have been observed.

Roadside Safety Treatments: Improving the roadside environment involves removing or shielding fixed objects like trees, poles, or steep slopes. Guardrails and crash cushions absorb impact energy and prevent rollovers. Providing a clear recovery zone allows vehicles to regain control safely. These measures reduce the severity of run-off-road crashes. Crash reductions range between 30% and 45%.

Traffic Calming Measures: Traffic calming involves physical design strategies to reduce vehicle speed in sensitive zones. Common features include speed bumps, raised pedestrian crossings, and road narrowings. These are vital in residential, school, and urban areas to enhance pedestrian safety. Slower speeds result in fewer and less severe crashes. Effectiveness shows crash reduction rates of up to 60%.

Pedestrian and Bicycle Facilities: Dedicated paths, sidewalks, and crossings ensure the safety of non-motorized road users. These features separate pedestrians and cyclists from vehicular traffic, reducing conflict points. Signalized crossings, overpasses, and warning signage further enhance safety. Proper lighting and markings also play a role. Such facilities can reduce crashes involving pedestrians/cyclists by up to 50%.

Roundabouts: Roundabouts are circular intersections that replace traditional traffic signals or stop signs. They reduce the number and severity of conflict points, especially right-angle and head-on collisions. Traffic moves continuously, which lowers speed and delays. Roundabouts are especially effective in reducing fatal and injury crashes. Crash reductions up to 90% have been reported for severe cases.

Access Control: Controlling access to highways and arterial roads minimizes interruptions and conflict points. This includes limiting driveways, merging lanes, and using frontage roads. Reducing uncontrolled access points lowers the risk of rear-end and side-impact crashes. Access control also improves traffic flow efficiency. Studies show a 25–40% reduction in crash frequency.

Signage and Road Markings: Proper signage and clear lane markings are crucial for communicating road rules to drivers. Signs warn about curves, speed limits, pedestrian zones, and upcoming intersections. Road markings guide vehicle movement and improve night time visibility. Well-maintained signs and paint reduce driver confusion and reaction time. These can lead to crash reductions of 10–30%.

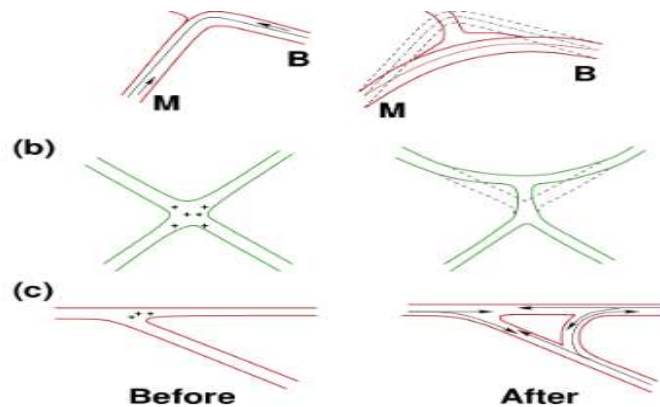
Street Lighting: Good lighting enhances visibility for drivers, especially at intersections, curves, and pedestrian crossings. It helps detect obstacles, road users, and signage during night time or adverse weather. Lighting reduces accidents caused by low visibility or surprise hazards. It is especially effective in urban areas with high pedestrian traffic. Night-time crash reduction rates range from 20% to 50%.

1.8 Accident Reconstruction

Accident reconstruction is a scientific and systematic process used to determine how and why a road traffic accident occurred. It involves the collection, analysis, and interpretation of physical evidence from the crash scene to reconstruct the events leading up to, during, and following the incident. The goal is to establish the sequence of actions and contributing factors such as speed, direction, vehicle positions, driver behaviour, and environmental conditions.

Accident reconstruction is commonly used in legal investigations, insurance claims, and safety analysis. It plays a critical role in identifying fault, understanding crash causation, and developing strategies to prevent similar accidents in the future.

Diagram of accidents before and after reconstruction



Steps Involved in Accident Reconstruction:

1. Data Collection: The first step involves collecting all available evidence from the crash site. This includes:

- Photographs and videos of the scene
- Skid marks, debris, and gouge marks
- Measurements of road features and vehicle positions
- Weather and lighting conditions
- Statements from witnesses and involved parties

2. Vehicle Inspection: The involved vehicles are examined to assess damage patterns, mechanical failures, and safety system deployment (e.g., airbag activation). Tire conditions, brake systems, and steering mechanisms are also inspected.

3. Scene Documentation: Investigators create detailed diagrams of the accident scene using manual measurements or digital mapping tools. This includes road geometry, lane markings, traffic signs, and the location of physical evidence.

4. Event Analysis and Timeline Construction: Analysts determine the sequence of events, such as the point of perception, reaction, braking, and impact. They assess driver actions, traffic flow, and potential avoidance maneuvers.

5. Speed and Motion Calculations: Using principles of physics, investigators estimate vehicle speeds, angles of collision, and forces involved. Calculations are based on skid mark lengths, crush damage, and time-distance analysis.

6. Simulation and Modelling: Advanced software is used to recreate the accident in a virtual environment. This helps visualize the crash dynamics and test various scenarios to identify the most probable cause.

7. Report Preparation and Conclusion: The findings are compiled into a formal report, often including diagrams, simulation images, and expert opinions. This report is used by law enforcement, legal teams, or insurers.

Tools and Technologies Used in Accident Reconstruction:

1. Total Stations and 3D Laser Scanners: These are used to accurately map the accident scene and produce detailed diagrams.

2. Crash Simulation Software: Programs like PC-Crash, HVE (Human Vehicle Environment), and Virtual CRASH simulate the physics of vehicle movement and collision to test reconstruction hypotheses.

3. EDR (Event Data Recorder) Downloads: Many modern vehicles are equipped with “black box” recorders that store critical crash data such as speed, brake usage, and steering input before and during the crash.

4. Drones: Aerial drones provide overhead images and videos of the scene, helping document evidence quickly and safely.

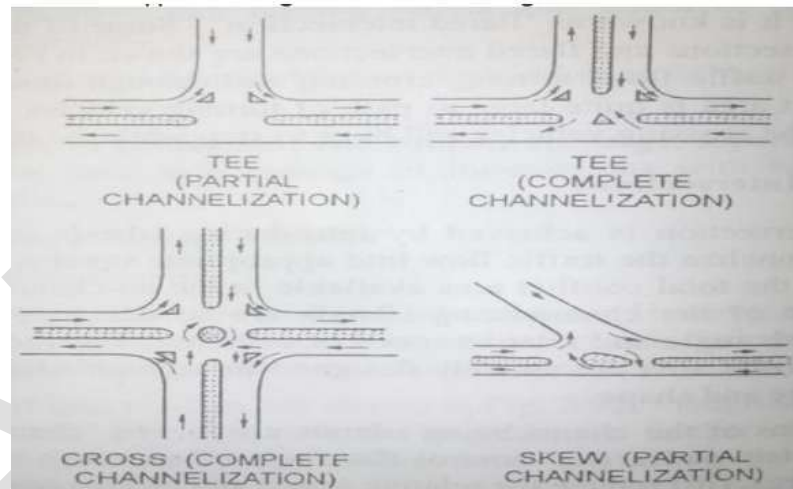
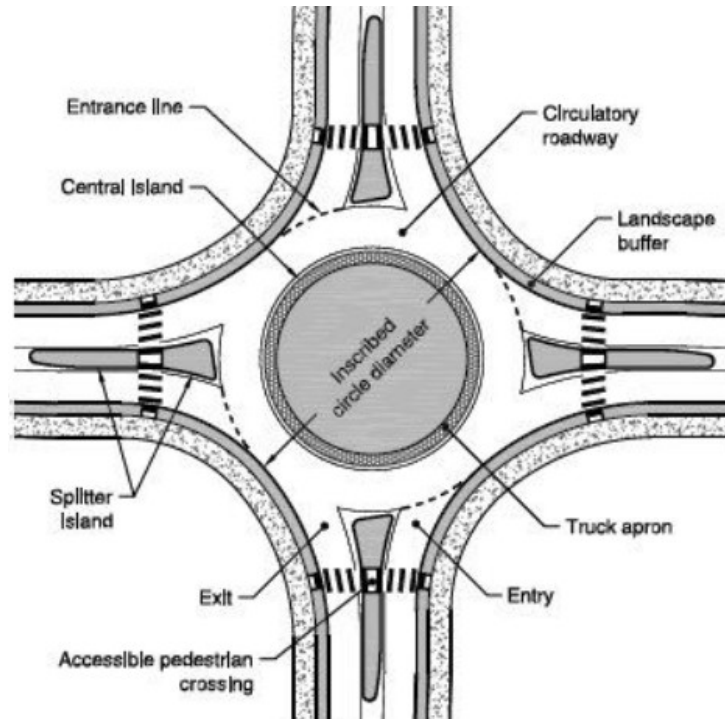
5. Photogrammetry: This technique uses photographs to generate 3D models of the crash site for analysis and visualization.

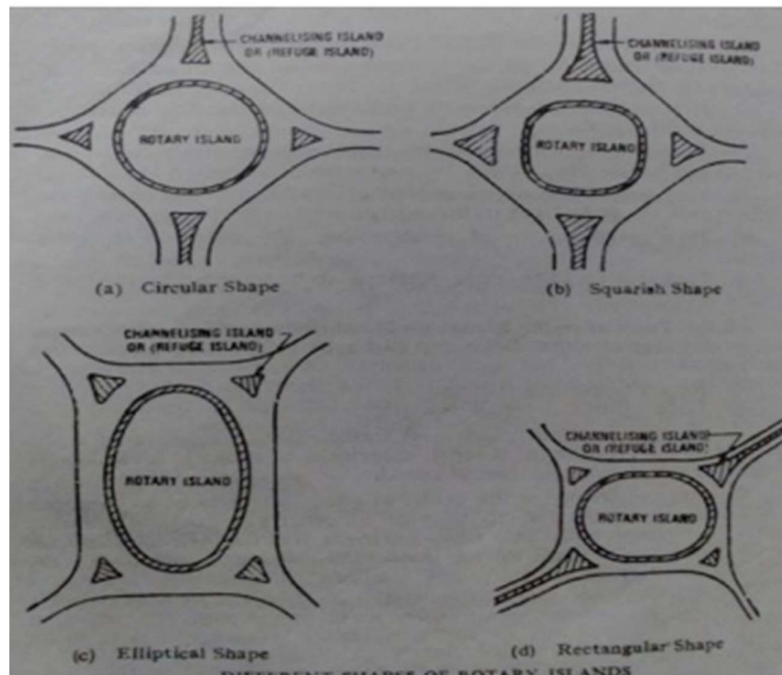
Accident reconstruction is a vital investigative tool that combines science, engineering, and technology to uncover the truth behind road traffic accidents. By following a structured process and using modern tools, investigators can provide accurate, objective insights that support legal proceedings, policy development, and road safety improvements.

Condition and Collision Diagram.

Condition Diagram

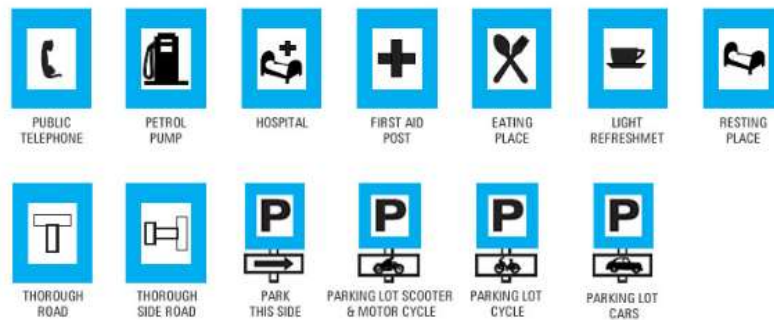
- The condition diagram is a drawing of the accident location showing the important physical conditions drawn to scale
- A Condition Diagram is generally drawn to scale showing roadway limits, curves, kerb lines, bridges, culverts, trees, obstruction to vision, signs, signals markings etc
- These Condition Diagram are drawn using certain symbols each representing a different condition.
- Condition Diagram also should indicate traffic control devices, road side amenities, presence of median, shoulder type, type of land use, location of potholes, ruts, ponding etc

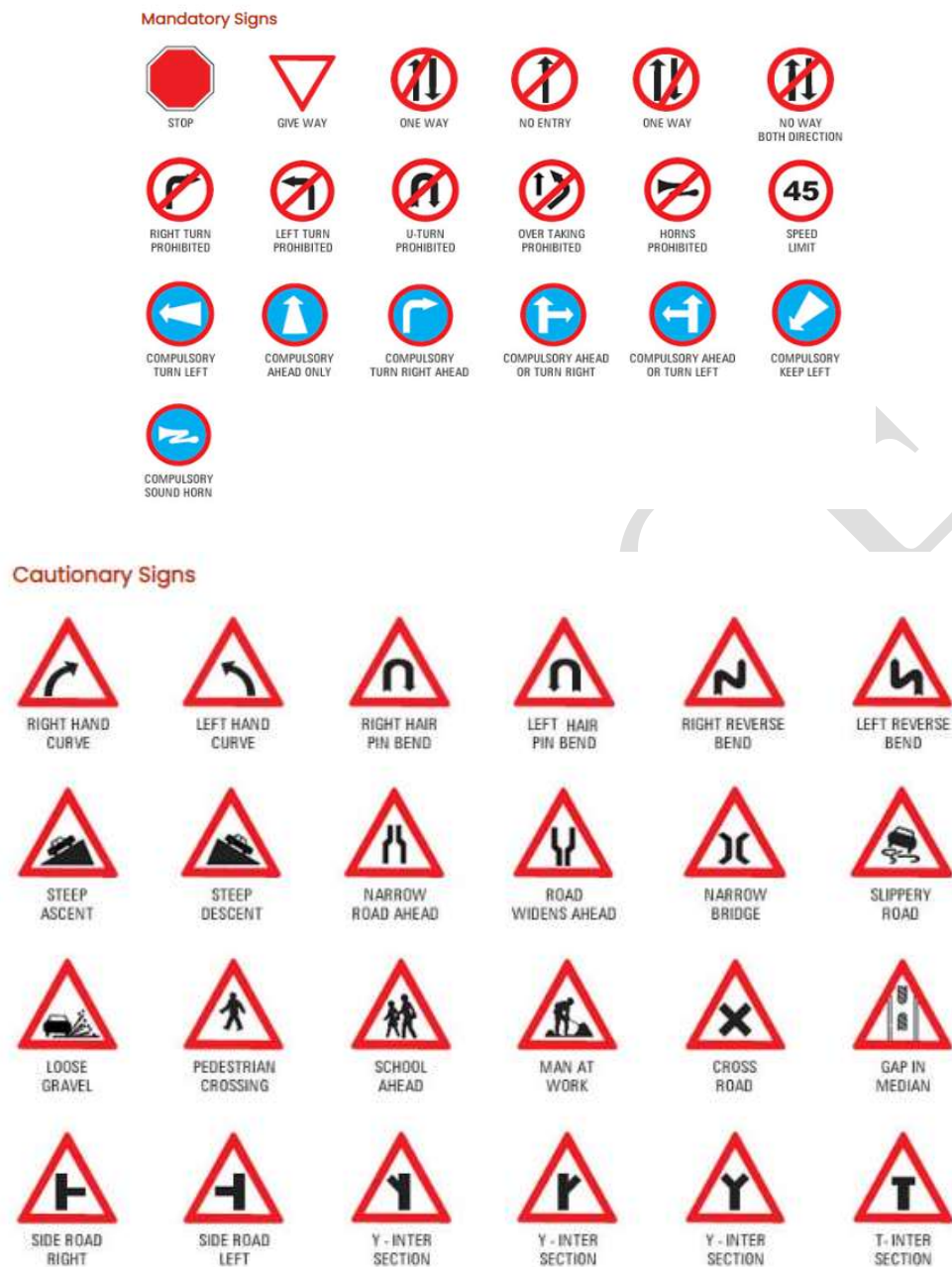




Condition Diagram Symbols

Informatory Signs





Purpose of Condition Diagrams: A condition diagram is a simplified plan view drawing of a roadway segment or intersection, providing detailed information about the physical and operational characteristics of the site. It typically includes:

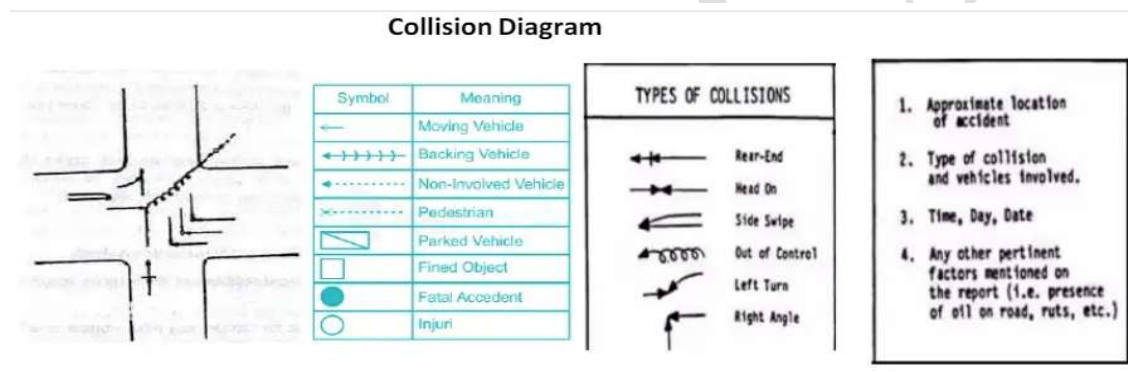
- Road geometry and lane configurations
- Traffic control devices (e.g., signs, signals, markings)
- Sidewalks, medians, and pedestrian crossings
- Nearby land uses or access points
- Lighting, visibility conditions, and obstructions

Purpose:

- To establish a clear and accurate understanding of the existing road environment.
- To provide a base map for plotting crash data (used in conjunction with collision diagrams).
- To identify design or operational deficiencies that may contribute to crashes, such as poor sight distance, complex signal phasing, or inadequate signage.

Collision Diagram

- Collision Diagram is a drawing showing the approximate path of vehicles and pedestrians involved in the accident
- Collision diagram is most important to compare the accident pattern before and after the remedial measures have been taken
- They provide information on the type and number of accident including information such as time of day, climatic conditions, pavement conditions, cause of accidents

**Procedure to draw Collision Diagram**

1. Sketch the location which need not be to scale
2. Show the path of each vehicle involved in the accident
3. Place the north arrow for orientation
4. Mention the type of collision , accident severity, time, day, date etc

Purpose of Collision Diagrams: A collision diagram is a graphical representation of traffic accidents that have occurred at a particular location over a defined period. These diagrams use standardized symbols to indicate:

- Type of collision (e.g., rear-end, angle, head-on, pedestrian-related)
- Direction of travel of involved vehicles
- Exact location of impact
- Sequence of events in multi-vehicle crashes
- Time, date, and crash severity (in some cases)

Purpose:

- To detect crash patterns or trends by visualizing where and how crashes occur.
- To determine common causes of accidents, such as signal violations, turning conflicts, or inadequate gaps in traffic.

- To prioritize locations and types of countermeasures based on recurring crash types.

Support for Decision-Making in Road Safety Improvements: By combining condition and collision diagrams, analysts can connect physical road characteristics with crash patterns, offering a comprehensive perspective on the problem. Here's how these tools support effective decision-making:

1. Problem Identification: Collision diagrams reveal recurring crash types (e.g., multiple left-turn collisions), while condition diagrams help pinpoint contributing roadway features, such as unclear signal phasing or obstructed views.

2. Selection of Countermeasures: Once patterns are identified, engineers can select targeted solutions. For instance, if rear-end collisions are frequent on an approach, adding advance warning signs or adjusting signal timing may be recommended.

3. Cost-Effective Planning: Diagrams help prioritize improvements based on risk and frequency. Limited budgets can be directed toward interventions that address the most critical safety issues.

4. Stakeholder Communication: Visual diagrams make it easier to explain complex issues to stakeholders, including decision-makers, community members, and law enforcement.

5. Before-and-After Analysis: Post-implementation, new collision diagrams can be compared with older ones to evaluate the effectiveness of safety interventions.

Condition and collision diagrams are essential tools in the field of traffic safety analysis. By visually presenting both the environment and the crash history of a site, they support data-driven decision-making, enabling road safety professionals to design and implement targeted improvements that reduce crashes and enhance overall roadway safety.

1.10 Recommended questions

1. Explain the various methods used to collect road accident data
2. Discuss the different techniques used to identify and prioritize hazardous road locations
3. List and explain the major contributing factors to road traffic crashes
4. What is an accident reconstruction? Discuss the steps involved in reconstructing a road traffic accident and the tools or technologies commonly used
5. Explain the purpose of condition and collision diagrams in accident analysis

1.11 Outcomes

- Analyze road safety data, identify hazardous locations, and assess safety risks on roadways

1.12 Further Reading

https://www.civil.iitb.ac.in/tvm/nptel/582_Accident/web/web.html

<https://www.slideshare.net/slideshow/drmakendran-chapter-ii-accident-studies-collision-diagram-pdf/254407832>