SUBJECT NAME: ROAD SAFETY ENGINEERING (BCV755A)

MODULE:5- Traffic Management Systems For Safety:

Syllabus 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.

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Road safety audits:

A **Road Safety Audit (RSA)** is a formal, systematic, and independent examination of a road or traffic project by a qualified team, aimed at identifying potential safety issues and opportunities for improvement for all road users.

Objectives and need of Road safety audits:

- To minimize the risk of road accidents.
- To ensure safety for all road users (drivers, pedestrians, cyclists, etc.).
- To identify potential safety problems at all project stages.
- To enhance the cost-effectiveness of road safety improvements.
- To improve overall traffic operation and user satisfaction.
- Detects design and operational deficiencies early.
- Reduces accident frequency and severity.
- Saves costs related to accidents and maintenance.
- Promotes a safety-first culture in highway design and management.
- Helps achieve Vision Zero (zero fatalities) targets

Process/Procedure of Road Safety Audit:

The procedure of Road Safety Audit (RSA) as recommended by the **Indian Roads Congress (IRC:SP:88–2019)** involves a **systematic and step-by-step approach** to identify potential safety issues and recommend improvements throughout the project life cycle.

1. Selection of Project / Road Section

- The **road project or existing road section** to be audited is selected.
- Selection is based on criteria such as accident-prone locations, high traffic volume, or new project stages.

2. Formation of Audit Team

- A **qualified and independent audit team** is appointed by the client (road agency).
- The team should include road safety experts, traffic engineers, and experienced highway professionals **not involved in the project design**.

3. Collection and Review of Data

- The team collects all **relevant background information**, such as:
  - Traffic volume and composition
  - Speed data
  - Crash history and black spot details
  - Design drawings, layout plans, and geometric details
- This helps understand the existing safety issues or design intentions.

4. Site Inspection

- The audit team conducts **field visits**—both **daytime and nighttime**—to examine actual road and traffic conditions.
- The inspection focuses on visibility, signage, road markings, pedestrian facilities, junction layouts, and roadside conditions.

5. Identification of Safety Issues

- The team identifies potential **safety hazards or deficiencies** that could lead to accidents.
- Issues are analyzed from the perspective of all road users—drivers, cyclists, pedestrians, and vulnerable users.

6. Preparation of Audit Report

- The team prepares a **formal audit report** containing:
  - Description of identified safety issues
  - Possible causes
  - Specific recommendations for corrective actions
- Each issue is prioritized based on severity and likelihood of occurrence.

7. Client's Response Report

- The **project owner or client** reviews the audit findings and prepares a **response report**, stating:
  - Actions accepted and implemented
  - Reasons for non-acceptance (if any)
  - Time frame for implementation

8. Implementation of Recommendations

- The **accepted safety measures** are incorporated into the design, construction, or operation phase.
- Implementation may include physical improvements, signage changes, or traffic management interventions.

9. Follow-Up Audit / Monitoring

- After implementation, a **follow-up inspection** is carried out to verify the effectiveness of the recommended safety improvements.
- Monitoring ensures that the identified risks have been adequately addressed.

10. Documentation

- All records of the audit process, including reports, responses, and follow-up actions, are properly documented for future reference and accountability.

Road safety audit - Tools For Safety Management Systems,

1. Accident Data Analysis Tool: Uses crash records to identify accident-prone (black spot) locations and recurring crash patterns. Helps prioritize interventions.

2. Conflict Technique / Traffic Conflict Studies: Observes near-miss events at intersections or stretches to assess potential risks even before accidents occur.

3. Speed Studies: Measures operating and design speeds using radar or sensors to check consistency and identify unsafe speed zones.

4. Road Inventory and Condition Surveys: Collects data on road geometry, signs, markings, lighting, and surface conditions using manual or automated tools (e.g., video logging).

5. Sight Distance Measurement Tools: Ensures adequate stopping, overtaking, and intersection sight distance; tools include measuring wheels or digital mapping.

6. Black Spot Analysis / GIS Mapping: Uses GIS-based mapping of accident locations to visualize and analyze high-risk zones.

7. Checklist and Rating Forms: Standardized audit checklists for different project stages — feasibility, design, construction, and operation.

8. Road Safety Inspection (RSI): Field-based tool for systematic visual assessment of existing roads to identify deficiencies in safety features.

9. Video Survey and Photographic: Documentation Used to record field conditions for review, documentation, and presentation of findings.

10. Simulation and Modelling Tools Traffic simulation: (e.g., VISSIM, SIDRA) to evaluate safety and operational performance of intersections or corridors.

11. Intelligent Transport System (ITS): Data Real-time traffic data used for analyzing speed violations, congestion, and incident patterns.

12. Pedestrian and Cyclist Safety Assessment Tools: Used to evaluate crosswalks, sidewalks, and non-motorized traffic facilities.

13. Stakeholder Consultation and night visibility

Road Safety Improvement Strategies

Road safety improvement strategies are **systematic measures** adopted to **reduce road accidents, injuries, and fatalities**, and to improve safety for all categories of road users — drivers, pedestrians, cyclists, and passengers. They combine engineering, education, enforcement, and emergency response approaches, often called the **"4 E's of Road Safety."**

Objectives

- To minimize the number and severity of road crashes.
- To identify hazardous locations and improve their safety performance.
- To promote safe road design and responsible road-user behaviour.
- To achieve sustainable and safe transport as part of **Vision Zero**.

Major Road Safety Improvement Strategies

A. Engineering Measures (Infrastructure-based)

1. **Improvement of Road Geometry** – Adequate sight distance, smooth curves, proper gradients, and lane width.
2. **Junction and Intersection Improvements** – Signalization, roundabouts, channelization, and grade separation.
3. **Roadside Safety** – Removal of fixed objects, provision of guardrails and crash barriers.
4. **Pedestrian and Cyclist Facilities** – Footpaths, subways, zebra crossings, and cycle tracks.
5. **Proper Signage and Road Markings** – As per **IRC:67-2022** and **IRC:35-2015** for clear driver guidance.
6. **Street Lighting and Visibility** – Better night visibility and retro-reflective devices.
7. **Pavement Maintenance** – Regular upkeep to prevent skidding and potholes.

B. Education and Awareness

1. **Driver and Pedestrian Education** – Training in defensive driving and safe walking/cycling.
2. **Public Awareness Campaigns** – Mass media campaigns on helmet use, seatbelts, and dangers of drunk driving.
3. **School and College Programs** – Introducing road safety education in curricula.
4. **Community Participation** – NGOs and local bodies promoting safety culture.

C. Enforcement Measures

1. **Implementation of Traffic Laws** – Enforcing speed limits, helmet, and seat-belt rules.
2. **Use of Technology** – Speed cameras, red-light violation detection, and e-challans.
3. **Strict Penalties** – Fines and license suspension for repeated violations.
4. **Monitoring Commercial Vehicles** – Ensuring rest periods, overloading checks, and fitness certification.

D. Emergency / Post-Crash Management

1. **Quick Response Systems (Dial 108/112)** – To provide rapid medical help.
2. **Trauma Care Centres** – Establishment near highways for critical care.
3. **First-Aid Training for Police and Volunteers** – Immediate life-saving actions at accident sites.
4. **Accident Data Analysis** – Identify black spots and evaluate safety interventions.

E. Policy and Institutional Measures

1. **National and State Road Safety Policies** – Framing coordinated safety action plans.

2. **Road Safety Audit (as per IRC:SP:88–2019)** – Systematic safety assessment during design and operation.
3. **Black Spot Improvement Programmes** – Engineering corrections and signage at high-risk sites.
4. **Intelligent Transport Systems (ITS)** – Real-time traffic monitoring, driver alerts, and automated control.

F. Modern Technological Strategies

- **ITS-based Traffic Management Systems** – Adaptive signals, variable message signs.
- **Vehicle Safety Technologies** – ABS, airbags, lane-keeping assist.
- **Smartphone-based Safety Apps** – For reporting crashes and unsafe conditions.

ITS And Safety:

Intelligent Transport Systems (ITS) refer to the **application of advanced information, communication, and sensor technologies** in road transport to enhance the **safety, efficiency, and sustainability** of transportation networks. ITS integrates **vehicles, infrastructure, and users** to reduce human errors the main cause of most road accidents.

Objectives/Role / Functions of ITS in Improving Road Safety

A. Accident Prevention (Pre-Crash Phase)

1. **Intelligent Traffic Signal Systems**
   - Adaptive signal control adjusts timings based on real-time traffic flow, reducing red-light jumping and intersection crashes.
2. **Speed Management Systems**
   - Automatic speed detection cameras and variable speed limit signs help control overspeeding — a major cause of accidents.
3. **Driver Assistance Systems**
   - In-vehicle technologies such as Anti-lock Braking System (ABS), Lane Departure Warning, and Adaptive Cruise Control assist drivers in maintaining safe behavior.
4. **Weather and Road Condition Monitoring**
   - Sensors provide warnings about fog, rain, or slippery roads through variable message signs (VMS).
5. **Collision Avoidance Systems**
   - Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication warn drivers about obstacles or sudden braking ahead.

B. Accident Management (During Crash Phase)

1. **Incident Detection and Response**
   - CCTV and Automatic Incident Detection (AID) systems alert traffic control centers immediately after an accident.
   - Enables faster clearance and minimizes secondary crashes.
2. **Emergency Call Systems (e-Call)**
   - Automatic crash notification to emergency services with GPS coordinates for quick response.

C. Post-Crash Phase (Emergency Management)

1. **Integrated Emergency Response Systems**
    - Coordination between ambulances, police, and hospitals through ITS platforms (e.g., Dial 108/112) reduces response time.
2. **Traffic Diversion and Information Systems**
    - Real-time updates to drivers about road closures or diversions after a crash help maintain flow and safety.

D. Enforcement and Monitoring

1. **Automatic Number Plate Recognition (ANPR)** – Detects red-light or speed violations automatically.
2. **Electronic Toll Collection (ETC)** – Reduces congestion and rear-end crashes at toll plazas.
3. **Surveillance and Monitoring** – CCTV cameras monitor driver behavior, lane discipline, and pedestrian safety.

E. Information and Awareness Systems

1. **Variable Message Signs (VMS)** – Display real-time safety messages (e.g., "Accident Ahead – Slow Down").
2. **Travel Information Systems** – Mobile apps and GPS devices provide safe route guidance and hazard alerts.

Examples of ITS implementation in India

1. Delhi Traffic Police – Smart Traffic Management System

Adaptive traffic signal control, CCTV-based surveillance, and real-time traffic monitoring. Reduces congestion and improves enforcement of traffic rules.

- **Technology Used:** AI-based camera analytics, GPS tracking, and dynamic traffic light timing.

2. FASTag – Electronic Toll Collection (ETC)

- **Implemented by:** National Highways Authority of India (NHAI).
- **Technology:** RFID (Radio Frequency Identification).
- **Function:** Enables automatic toll deduction without stopping at plazas, reducing travel time and fuel consumption.

3. Bengaluru Metropolitan Transport Corporation (BMTC) – Vehicle Tracking and Passenger Information System

GPS-based real-time bus tracking, estimated arrival display at bus stops, and mobile app updates.

4. Indian Railways – Train Tracking and Control Systems

5. Mumbai Traffic Management – Area Traffic Control (ATC) System

Synchronizes 253 traffic signals based on real-time traffic flow. Reduced waiting time and fuel consumption at junctions.

6. Integrated Traffic Management System (ITMS) – Hyderabad

- **Components:**
  - Automatic Number Plate Recognition (ANPR)
  - Red light violation detection
  - Speed enforcement
  - Centralized Command and Control Centre
- **Outcome:** Improved law enforcement and traffic violation tracking.

7. National Highway Traffic Management System (NHTMS)

- **Implemented by:** NHAI.
- **Functions:**
  - Variable Message Signs (VMS) for driver information
  - CCTV surveillance
  - Automatic incident detection
  - Emergency call boxes
- **Purpose:** Enhance safety and response time on highways.

8. Smart Parking Management – Chandigarh, Delhi, Pune

- **Features:** Sensor-based parking availability detection and mobile app guidance.
- **Goal:** Reduce on-street parking chaos and congestion.

9. E-Challan System

- **Cities:** Delhi, Bengaluru, Hyderabad, Chennai, etc.
- **Technology:** Integration of handheld enforcement devices and central databases.
- **Function:** Digital issuance and payment of traffic violation fines.

10. GPS-Based Fleet Management Systems

- **Users:** State transport buses, logistics companies, and taxi aggregators (e.g., Ola, Uber).
- **Functions:** Route optimization, driver behavior monitoring, and fuel efficiency management.

Common challenges faced during the implementation of road safety audits and ITS-based safety interventions in developing countries:

Road Safety Audits (RSAs) and Intelligent Transportation Systems (ITS)-based safety interventions are globally recognized strategies for reducing road traffic injuries and fatalities. RSAs offer proactive evaluation of road design from a safety perspective, while ITS applications—such as real-time traffic monitoring, speed enforcement cameras, and automated incident detection—leverage technology to improve road user behaviour and response to hazards. However, in many developing countries, the implementation of these strategies faces several challenges that hinder their effectiveness. These challenges can be grouped into institutional, technical, financial, and socio-cultural categories. Addressing them requires a coordinated, multi-dimensional approach.

1. Institutional and Policy Challenges: Many developing countries lack formal policies or frameworks that mandate the use of RSAs or integrate ITS into national transport strategies. There is often no legislative requirement for safety audits during planning, design, or post-construction phases of road projects.
Solution: Governments must establish clear legal mandates for road safety audits at all stages of road development and integrate ITS into national transport safety policies. Creating dedicated road safety agencies or units within ministries can ensure consistent oversight and accountability.
2. Technical Capacity and Expertise: There is often a shortage of trained road safety auditors and ITS professionals. Additionally, awareness of the audit process or the operational requirements of ITS is limited among engineers and planners. Many professionals lack training in interpreting crash data or applying technology-based interventions appropriately.
Solution: Capacity-building programs are essential. Governments, in collaboration with international organizations, should invest in the training of local engineers, planners, and enforcement officers in road safety engineering, audit methodologies, and ITS operations. Establishing partnerships with universities and professional bodies can support continuous learning and certification.
3. Financial Constraints: Implementing RSAs and deploying ITS technologies require initial investment in equipment, software, data systems, and human resources. Budget limitations often lead to prioritizing infrastructure expansion over safety upgrades, especially in low-income settings.
Solution: Safety should be treated as an integral part of infrastructure investment rather than an optional add-on. Governments can allocate a fixed percentage of road project budgets for safety audits and ITS integration. Exploring public-private partnerships (PPPs) and international funding sources (e.g., World Bank, UN Road Safety Trust Fund) can also help bridge the financial gap.
4. Data Availability and Reliability: Effective RSAs and ITS require reliable data on traffic volumes, crash locations, and road user behaviour. In many developing countries, crash reporting is incomplete or inconsistent, and digital databases are lacking.
Solution: Investment in data collection systems is critical. This includes digitizing crash records, implementing geospatial data systems (GIS), and using low-cost sensors or mobile technology for traffic monitoring. A centralized national road safety database should be developed and maintained.
5. Cultural and Public Acceptance Issues: Resistance to change, low public awareness of road safety benefits, and lack of trust in technology can hinder ITS deployment or acceptance of audit recommendations.
Solution: Public education campaigns highlighting the benefits of road safety technologies and audits can build support. Community involvement in safety planning can also foster ownership and acceptance of interventions.

While developing countries face significant challenges in implementing RSAs and ITS-based safety interventions, these are not insurmountable. With strong political will, strategic investment, capacity-building, and stakeholder engagement, it is possible to overcome barriers and move toward safer, smarter, and more sustainable road networks.

Road Safety Audit team Composition, qualifications and responsibilities during the safety audit process:

A Road Safety Audit (RSA) is a structured, formal review of a road project's safety performance, conducted by an independent and qualified team. The effectiveness of an RSA greatly depends on the skills, experience, and objectivity of the audit team. As such, selecting

the right individuals and clearly defining their roles is essential to ensure comprehensive and reliable safety evaluations.

Who Should Be Involved in a Road Safety Audit Team: A standard RSA team typically includes three to five members, depending on the size and complexity of the project. The team should be multidisciplinary and independent from the road design or construction teams. Core members often include:

1. Team Leader (Road Safety Engineer):

- Leads the audit process and is responsible for coordination, reporting, and ensuring quality.
- Should have significant experience in road safety engineering and RSAs.

2. Traffic/Transportation Engineer:

- Specializes in traffic flow, intersections, signal control, and capacity analysis.
- Brings insight into the behavior of various road users under different traffic conditions.

3. Highway Design Engineer:

- Offers expertise on road geometry, alignment, signage, drainage, and cross-sectional elements.
- Evaluates whether design features meet standards and safety principles.

4. Human Factors Specialist (Optional):

- Focuses on driver behavior, perception-reaction time, and decision-making processes.
- Helps assess how design decisions align with real-world human limitations.

5**. Local Enforcement or Road Maintenance Personnel (Advisory Role):** May provide practical insights into recurring issues like speeding, poor signage visibility, or maintenance lapses.

Qualifications of Road Safety Auditors

Road safety auditors must possess a blend of formal education, relevant experience, and training:

Education: A degree in civil engineering, traffic engineering, transportation planning, or a related field is typically required.

Experience: Auditors should have hands-on experience in road design, traffic operations, or crash investigation.

Certification/Training: Many jurisdictions require formal RSA training or certification from recognized institutions.

Independence: Auditors must not be involved in the design or implementation of the project under audit to ensure objectivity.

Knowledge of Standards: Auditors should be well-versed in national and international road design standards, safety guidelines, and audit methodologies.

Responsibilities of Auditors During the RSA Process:

1. Preparation and Familiarization:

- Review project documents, plans, and previous audits.
- Understand the project context, including land use, traffic volumes, and vulnerable road users.

2. Site Visit (if applicable):

- Observe real-world conditions including traffic behavior, lighting, and visibility.
- Identify risks that may not be evident from drawings alone.

3. Safety Issue Identification:

- Assess potential safety problems objectively.
- Consider all road users, including pedestrians, cyclists, public transport users, and drivers.

4. Reporting:

- Prepare a structured audit report detailing identified issues and providing practical, prioritized recommendations.
- Ensure the report is clear, evidence-based, and constructive.

5. Collaboration and Communication:

- Work collaboratively within the audit team and communicate findings to the project owner or design team.
- Maintain professionalism and neutrality throughout the process.

A successful Road Safety Audit relies on a skilled and independent team with diverse expertise in road design, traffic operations, and user behavior. The auditors' qualifications and their commitment to identifying safety issues impartially are critical to ensuring that road projects are developed with the highest possible level of safety for all users.

Questions for Exam - Module 5

1. What is road safety audit and Explain objectives/Needs of Road safety audit.
2. Briefly Enumerate the Road safety Audit Process.
3. Explain the tools considered in road safety audit for Safety management.
4. Explain in detail Major Road safety Improvement strategies. Otherwise same question can be asked as Explain 4 E’s in road safety improvement strategies.
5. Define ITS. Explain the Role/objectives/Functions of ITS in improving Road safety.
6. Give the examples of ITS implementation in India.
7. What are the common challenges faced during the implementation of road safety audits and ITS-based safety interventions in developing countries? Suggest possible solutions.
8. Who should be involved in a Road Safety Audit team? What are the qualifications and responsibilities of auditors during the safety audit process?