UNIT-V Traffic Signals & Highway Appurtenances

Necessity of Traffic Signals

Traffic signals are essential devices used to **control and manage traffic flow** at intersections, pedestrian crossings, and other road junctions. They are vital for ensuring **road safety**, **efficiency**, and **order** in transportation systems.

⬙ Why Traffic Signals Are Necessary

1. Regulate Traffic Flow

- Prevent **chaos and confusion** at busy intersections.
- Maintain a smooth, **predictable movement** of vehicles and pedestrians.

2. Ensure Safety

- Reduce the risk of **collisions** by assigning **right-of-way**.
- Protect **pedestrians** crossing roads by providing **designated** time intervals.

3. Control Congestion

- Manage traffic at **peak hours** by coordinating flow from multiple directions.
- Minimize **bottlenecks** and reduce delays through signal timing.

4. Support Law Enforcement

- Clearly define **rules of movement**, making traffic violations easier to identify and penalize.

5. Aid Vulnerable Road Users

- Assist **children, elderly, and persons with disabilities** in crossing roads safely.
- Provide **visual and auditory cues** for better accessibility.

6. Improve Efficiency at Intersections

- Alternate green lights help reduce waiting times by providing **organized access** to the junction.
- Adaptive traffic signals can adjust timing based on **real-time traffic volume**.

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Benefits Summary:

Purpose	How It Helps
Safety	Reduces crashes and protects pedestrians
Order	Assigns clear right-of-way
Flow Control	Manages heavy traffic at busy intersections
Time Efficiency	Minimizes delays with proper signal timing
Accessibility	Aids disabled and vulnerable road users

Types of Traffic Signals

Traffic signals are categorized based on their function and the type of traffic they control. They help in organizing vehicle and pedestrian movement safely and efficiently.

1. Fixed-Time Signals

- Operate on a **pre-set cycle** (e.g. 60 seconds green, 30 seconds red).
- **Does not change** based on actual traffic conditions?
- Ideal for intersections with **predictable and consistent** traffic flow.

Example: Small urban junctions with equal traffic volumes from all directions.

2. Traffic-Actuated Signals

- **Sensors or cameras** detect vehicle presence and adjust signal timing accordingly.
- More **responsive and efficient** than fixed-time signals.
- Helps **reduce delays** and improve flow during varying traffic conditions.

Example: Intersections near shopping centers or variable-volume roads.

3. Manual Signals

- Operated **by traffic police** using hand signals or control switches.
- Used in **emergency situations**, road repairs, or areas with **signal failure**.

Example: Events, VIP movement, or temporary diversions.

4. Pedestrian Signals

- Allow **safe crossing** for pedestrians by stopping vehicle traffic.
- Often include **visual (walk/don't walk)** and **auditory** cues.
- May operate independently or in coordination with vehicle signals.

Example: Crosswalks near schools, markets, or hospitals.

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5. Flashing Signals

- Used to **alert** or **warn** in special situations.
- **Flashing Red**: Stop and proceed when safe.
- **Flashing Yellow**: Proceed with caution.

Example: Railway crossings, accident-prone zones, or nighttime low-traffic intersections.

6. Special Signals

- Include signals for **buses, trams, bicycles**, or **emergency vehicles**.
- May show arrows, letters, or symbols.

Example: Bus-only lanes or tram intersections.

Summary Table:

Type	Function	Common Use Cases
Fixed-Time	Regular cycle, unchanging	Uniform traffic flow
Traffic-Actuated	Varies with detected traffic	Busy or variable intersections
Manual	Operated by authorities	Emergencies, VIP movement
Pedestrian	Ensures safe walking crossings	Schools, hospitals, busy markets
Flashing	Warns or cautions in special conditions	Railway crossings, night-time operation
Special	Used for specific vehicles or road users	Bus/tram priority, bike lanes

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Factors Affecting Traffic Signal Design

Designing an effective traffic signal system involves careful consideration of various **technical, environmental, and human factors** to ensure **safe and efficient** movement at intersections.

1. Traffic Volume

- One of the **most critical factors**.
- Includes **vehicular count** (by type) and **pedestrian flow** during different times of day.
- Helps determine the **number of phases**, **cycle length**, and **green time**.

2. Road Geometry

- Refers to the **layout and dimensions** of the intersection.
- Includes:
  - Number and width of lanes
  - Turning radii
  - Sight distances
  - Presence of medians or dividers
- Affects **signal placement**, **visibility**, and **timing**.

3. Type of Intersection

- T-junction, crossroad, roundabout, or multi-leg intersection.
- More complex intersections require **multi-phase signals** and **longer cycles**.

4. Pedestrian Movement

- Areas with high foot traffic (e.g., near schools, malls, or transit hubs) must account for **safe pedestrian crossing time**.
- May require **exclusive pedestrian phases** or **pedestrian push buttons**.

5. Traffic Composition

- Mix of **cars, trucks, buses, two-wheelers, and non-motorized traffic**.
- Heavier or slower vehicles may require **longer clearance times** or **dedicated lanes**.

6. Peak and Off-Peak Variations

- Design must consider **hourly or seasonal variations** in traffic demand.
- Adaptive signals may be needed to adjust based on **real-time traffic flow**.

7. Accident History

- Intersections with a history of frequent accidents may require **special signal timing**, **flashing signals**, or **dedicated turning phases**.

8. Environmental Conditions

- Includes **weather**, **lighting**, and **topography**.
- Poor visibility or fog-prone areas may need **brighter signals** or **longer amber phases**.

9. Legal and Policy Guidelines

- Must comply with national or local traffic control standards (e.g., IRC in India, MUTCD in the US).
- May influence **signal height, color, timing**, and **pedestrian rights**.

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Summary Table:

Factor	Impact on Signal Design
Traffic Volume	Cycle length, number of phases
Road Geometry	Signal placement, visibility, lane configuration
Intersection Type	Phase complexity, timing needs
Pedestrian Movement	Crossing time, separate signal phase
Traffic Composition	Clearance intervals, lane needs
Peak Hour Variability	Adaptive or dynamic timing
Accident Records	Safety-driven design changes
Environmental Conditions	Signal brightness, timing under poor visibility
Legal Standards	Compliance with design norms and policies

Merits and Demerits of Traffic Signals

Traffic signals play a key role in managing urban traffic. However, while they improve control and coordination, they also come with certain limitations.

Merits of Traffic Signals

Merits	Description
1. Improved Safety	Reduces chances of collisions, especially at busy intersections.
2. Efficient Traffic Flow	Regulates traffic movement systematically, minimizing confusion.
3. Right-of-Way Assignment	Clearly defines who moves when, improving fairness at junctions.
4. Pedestrian Protection	Provides dedicated crossing phases for pedestrians and vulnerable users.
5. Handles Heavy Traffic	Controls traffic in high volume areas more effectively than stop signs.
6. Adaptability	Smart signals adjust timing based on real-time traffic data.
7. Visual Enforcement	Helps enforce traffic rules; violations are easier to detect.

Demerits of Traffic Signals

Demerits	Description
1. Increased Delay	May cause unnecessary stops, especially during low-traffic hours.
2. Cost of Installation	Expensive to install and maintain, especially adaptive systems.
3. Risk of Rear-End Collisions	Sudden braking at red lights may lead to rear-end accidents.
4. Non-compliance Issues	Drivers may run red lights, especially when visibility is poor.
5. Power Dependency	Traffic signals stop functioning during power outages unless backed up.
6. Over-Control	Signals at low-volume intersections can frustrate drivers.
7. Pedestrian Delay	Pedestrians may have to wait longer during vehicle-priority phases.

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Signalized Intersections

A **signalized intersection** is a road junction controlled by **traffic signals** (lights) that assign **right-of-way** to different streams of vehicles and pedestrians in a **cyclical manner**. These intersections are widely used in urban traffic systems to manage complex vehicle and pedestrian movements safely and efficiently.

Key Features of Signalized Intersections

1. **Traffic Signals**
   - Mounted on poles or overhead structures.
   - Operate in cycles with **green**, **amber**, and **red** phases.
2. **Phases and Cycles**
   - Each movement (straight, left turn, etc.) gets a **time slot (phase)**.
   - A **cycle** is the total time to complete all phases once.
3. **Lane Markings and Directional Arrows**
   - Help guide vehicles into the proper lane for each movement.
4. **Pedestrian Crosswalks and Signals**
   - Timed signals to allow safe pedestrian movement across the road.
5. **Detectors or Sensors (Optional)**
   - In traffic-actuated signals, detect the presence or absence of vehicles.

Advantages of Signalized Intersections

- Provide **orderly movement** of traffic.
- Reduce **conflicts** between opposing traffic streams.
- Allow **safe pedestrian crossings**.
- Can be **coordinated** with nearby signals to smooth traffic flow.
- **Adaptive signals** can adjust timings in real time to reduce delays.

Disadvantages of Signalized Intersections

- May lead to **long delays** if poorly timed.
- **Increased rear-end collisions** due to sudden stopping.
- **Higher cost** of installation and maintenance.
- **Complex** design and operation, especially in high-volume intersections.

Common Layout Components:

Component	Purpose
Signal heads	Display light signals to control traffic
Stop lines	Mark where vehicles must stop for red signals
Crosswalks	Define pedestrian crossing paths
Lane markings	Guide turning and through movements
Detection systems	Trigger light changes based on vehicle presence
Signboards	Provide instructions or restrictions (e.g. no U-turn)

Example: A 4-Way Signalized Intersection

Phases might include:

1. North-South through traffic
2. North-South left turns
3. East-West through traffic
4. East-West left turns
5. Pedestrian crossing phase

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Signal Coordination (Traffic Signal Synchronization)

Signal coordination is the technique of timing a series of traffic signals along a corridor or network so that vehicles can move through **multiple intersections with minimal stops**. It's commonly used on **urban arterial roads** to enhance **traffic flow efficiency** and **reduce delays**.

Objectives of Signal Coordination

- 🚗 **Smooth traffic progression** along major routes
- **Minimize travel time** and delays
- 💨 **Reduce fuel consumption** and emissions
- 🚦 **Avoid frequent stops and restarts** at consecutive signals
- **Optimize intersection performance** in a network

Key Concepts

1. Cycle Length

- Total time to complete all phases at a signal
- Coordination requires consistent or compatible cycle lengths across intersections.

2. Offset

- The **time difference** between the start of green at one intersection and the next.
- Critical for **creating green waves**, where vehicles hit green lights in succession.

3. Split Time

- The portion of the cycle allocated to each phase (e.g., green for northbound, left turn, etc.).

4. Bandwidth

- The **time window** during which vehicles can travel through the corridor without stopping.

Types of Coordination Systems

Type	Description
Time-Based	Uses pre-set timing plans; often used where traffic is predictable.
Traffic-Responsive	Adjusts signal timing based on real-time sensor data.
Centralized	Managed from a traffic control center; allows coordinated city-wide control.
Adaptive	Uses AI or algorithms to predict and respond dynamically to traffic flows.

Benefits of Signal Coordination

- ✓ Reduces **stopping and idling**
- ✓ Improves **average travel speed**
- ✓ Decreases **fuel use** and **air pollution**
- ✓ Enhances **road user satisfaction**
- ✓ Eases **public transport and emergency vehicle movement**

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Limitations

- ✕ Less effective if **side street volumes** are high.
- ✕ Requires **regular retiming** as traffic patterns evolve.
- ✕ Cost of installing **sensors and communication systems**.
- ✕ May not work well during **incidents or unexpected congestion**.

Delineators and Attenuators

These are essential **roadside safety devices** used to improve visibility, guide drivers, and reduce the severity of crashes in hazardous areas.

1. Delineators

Definition:
Delineators are **reflective markers or devices** placed along roadways to **indicate road alignment**, especially during night or low-visibility conditions.

Purpose:

- Guide drivers along **curves, ramps, lane edges**.
- Enhance visibility during **fog, rain, or nighttime**.
- Prevent vehicles from **veering off the roadway**.

Types of Delineators:

Type	Location/Use Case
Post Delineators	Placed on roadside or medians
Guardrail Delineators	Mounted on safety barriers
Chevron Delineators	Used on sharp curves or turns
Barrier-Mounted Delineators	Installed on concrete barriers

Features:

- Retro-reflective surfaces (yellow, white, red)
- Mounted at **regular intervals** (e.g., every 50–100 meters)
- Not meant to stop vehicles—purely visual guidance

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2. Attenuators (Crash Cushions)

Definition:
Attenuators are **energy-absorbing devices** installed in front of fixed objects or barriers to **reduce the impact force** during a vehicle collision.

Purpose:

- Minimize injury or vehicle damage by **absorbing crash energy**.
- Protect structures like **toll booths, bridge piers, signposts**, etc.
- Redirect errant vehicles away from hazards.

Types of Attenuators:

Type	Description/Use Case
Sand Barrel Arrays	Simple and low-cost, filled with sand to absorb impact
Hydraulic/Mechanical	Use pistons, springs, or fluid to slow down the vehicle
Crashworthy End Terminals	Installed at guardrail ends to reduce severity
Truck-Mounted Attenuators (TMA)	Attached to work-zone vehicles to protect crews

Key Characteristics:

- Designed to crumple or deform safely on impact
- Reusable or sacrificial depending on type
- Must meet **safety standards** like NCHRP 350 or MASH

Comparison Summary

Feature	Delineators	Attenuators
Function	Guide drivers visually	Absorb crash energy
Location	Road edges, curves, medians	Fixed hazards, work zones, terminals
Contact	No physical contact expected	Designed for crash impact
Material	Reflective plastic or metal	Steel, plastic, rubber, or sand
Usefulness	Improves night/low-visibility driving	Reduces crash severity

Traffic Safety Barriers

Traffic safety barriers are physical structures installed on or along roads to **protect vehicles and road users** by preventing crashes or reducing their severity. They are especially critical in **high-risk zones** like highways, bridges, sharp curves, and medians.

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Objectives of Safety Barriers

- Prevent vehicles from leaving the roadway
- Shield hazards like poles, drop-offs, or bridge piers
- Reduce crash severity through **energy absorption or redirection**
- Separate **opposing lanes** of traffic to avoid head-on collisions
- Protect pedestrians, cyclists, and work zones

Types of Traffic Safety Barriers

1. Rigid Barriers

- **Material**: Concrete (e.g. Jersey or New Jersey barriers)
- **Function**: Redirect vehicles without deformation
- **Best Use**: High-speed roads, bridges, medians
- **Pros**: Strong, low maintenance
- **Cons**: High impact force, can injure occupants

2. Semi-Rigid Barriers (Guardrails)

- **Material**: Steel beams (e.g. W-beam or Thrie-beam)
- **Function**: Flexes on impact and absorbs energy while redirecting vehicle
- **Best Use**: Highway edges, curves, embankments
- **Pros**: Moderately absorbs energy, relatively easy to install
- **Cons**: Still causes moderate deceleration forces on vehicles

3. Flexible Barriers (Cable Barriers)

- **Material**: Steel wire ropes mounted on posts
- **Function**: Absorbs impact and deflects vehicle gradually
- **Best Use**: Median, wide shoulders, areas needing high energy absorption
- **Pros**: High energy absorption, low severity crashes
- **Cons**: Requires more space (deflection area), higher maintenance

4. Crash Cushions (Impact Attenuators)

- Installed at the **ends of barriers or in front of hazards**
- Absorb and dissipate energy upon impact
- May use **sand barrels, hydraulic pistons**, or deformable materials

5. Bridge Barriers

- Specially designed to prevent vehicles from falling off bridges
- Often **rigid** due to limited space and high protection needs

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Comparison Table

Type	Energy Absorption	Deflection	Maintenance	Cost
Rigid Barrier	Low	Very low	Low	Moderate
Semi-Rigid Barrier	Medium	Medium	Moderate	Moderate
Flexible Barrier	High	High	High	Lower initial cost
Crash Cushion	Very High	Variable	High	High

Benefits of Traffic Safety Barriers

- Saves lives by **containing or redirecting** errant vehicles
- Minimizes vehicle damage and injury severity
- Protects road infrastructure and **non-motorized users**
- Essential in **high-speed** and **hazard-prone** areas

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