Instructor Notes
Traffic Signal Timing and Phasing

Module Overview
This module focuses on how traffic signals control intersections, emphasizing:

- Phasing (who moves when)
- Timing (how long they move)
- Analytical and practical approaches to signal timing design

Key Message for Instructors
Signals are not just lights—they are decision systems that manage conflict points and allocate time efficiently.

Learning Objectives
By the end of this lecture, students should be able to:

- Define and explain key traffic-signal terminology, phasing concepts, and intersection control principles.
- Differentiate between signal operation types and left-turn treatments.
- Interpret typical signal-head configurations and their implications for safety and operations.
- Apply formulas for yellow and all-red intervals to determine safe change and clearance times.
- Compute critical flow ratios and determine appropriate cycle lengths.
- Develop a basic signal timing plan including phase selection, cycle length, and green time allocation.

Teaching Flow / Suggested Lecture Structure

A. Role of Traffic Signals (10–15 min)
Key Concepts

- Intersections = **most complex part of network (≈32 conflict points)**

- Three control levels:
    1. Rules of the road
    2. Stop/Yield signs
    3. Traffic signals

Core Idea

Signals are used when:

- Conflicts cannot be safely managed otherwise
- Traffic volumes are high
- Visibility or driver judgment is insufficient

Instructor Prompt:

- "Why not signalize every intersection?"

B. Signal Terminology (10 min)

Essential Definitions

- **Cycle**: One full sequence of signal indications
- **Cycle Length**: Total time of one cycle
- **Interval**: Time period with no change
    - Green (G)
    - Yellow (Y)
    - All-red (AR)
    - Red (R)
- **Phase**: A set of intervals serving a movement

(*Highly testable content*)

C. Signal Operation Types (15 min)

1. Pre-timed

- Fixed schedule
- Based on time-of-day

2. Semi-actuated

- Detectors on minor roads

3. Fully-actuated

- Detectors everywhere

4. Demand-responsive

- Fully dynamic (adaptive systems)

Detection Technologies

- Loop detectors
- Cameras
- Radar
- Pedestrian push buttons

Instructor Tip:
Connect to **smart cities and AV systems**

D. Left-Turn Treatments & Phasing (20 min)
Types of Left Turns

- **Permitted** → yield to opposing traffic
- **Protected** → exclusive movement
- **Protected–Permitted (compound)**

When to Use Protected Left Turns

- High volume (> ~200 veh/hr)
- Safety concerns
- Limited sight distance

Phasing Design Principles

- Minimize number of phases → reduce lost time
- Each phase introduces **3–5 seconds of lost time**

Tools

- Ring and barrier diagrams
- Phase numbering systems

Discussion Prompt:

- Tradeoff: efficiency vs safety in left-turn design

E. Yellow and All-Red Intervals (20 min)
Yellow Interval

- Warns of change from green to red
- Typical: **3–6 seconds (MUTCD guidance)**
- Rule of thumb: ~10% of speed limit

Legal Context

- **Permissive states (e.g., CA)** → enter on yellow allowed
- **Restrictive states** → stricter interpretation

All-Red Interval

- Allows vehicles to clear intersection
- Typical ≈ **1 second**

Key Safety Function
Prevents **right-angle crashes**
Instructor Tip:
Students often underestimate importance—emphasize **crash prevention**

F. Signal Timing Fundamentals (25–30 min)
1. Critical Flow Ratio

- Flow ratio = volume / saturation flow rate

- Identify **critical movements**

2. Lost Time Components

- Startup delay
- Clearance time

3. Cycle Length Calculation

- Minimum cycle length based on:
    - Lost time
    - Flow ratios
    - Intersection utilization

4. Green Time Allocation

Goal:

- Balance demand across movements

Common strategy:

- Equalize **v/c ratios**

5. Pedestrian Considerations

- Must ensure **minimum crossing time**
- Often controls minimum green time

G. Signal Timing Plan Development (15 min)

Steps:

1. Select phasing scheme
2. Determine critical movements
3. Calculate:
    - Yellow + all-red
    - Cycle length
4. Allocate green time
5. Check pedestrian requirements

Key Insight:

There is **no strict national standard** → requires engineering judgment

---

Key Concepts to Reinforce

- Signals manage **conflicts through time allocation**
- Safety and efficiency are often **in tension**
- Timing decisions are **context-specific**
- Human behavior (reaction time, compliance) is critical
- Engineering judgment fills gaps where standards don't exist

---

Common Student Misconceptions

- Confusing **phase vs interval vs cycle**
- Assuming "one correct answer" for timing
- Underestimating pedestrian constraints
- Difficulty interpreting flow ratios

Suggested Examples / Activities

- Work through a **cycle length calculation example**
- Draw a **phasing diagram for an intersection**
- Compare:
  - Pre-timed vs actuated signals
- Case study:
  - "Should this intersection have protected left turns?"

Assessment Ideas

- Quiz on signal concepts
- Numerical problems:
  - Calculate yellow interval
  - Compute cycle length
- Conceptual:
  - Choose appropriate signal type
- Design problem:
  - Create a basic timing plan

Closing Summary for Instructors

Emphasize that:

- Signal timing is both **analytical and judgment-based**
- Small timing changes can have **large safety impacts**

References

- MUTCD (2023)
- Traffic Signal Timing Manual (NCHRP Report 812)
- Standard traffic engineering textbooks