Traffic Analysis at Signalized Intersections

David Levinson
(based on notes by Henry Liu
University of Minnesota)
History of Signalized Intersections

1868 - London, UK
- Manually operated semaphores (flags)
History of Signalized Intersections

1914 – Cleveland, OH
- 1st Electric Signal
History of Signalized Intersections

1917 - Detroit, MI
- Amber color introduced

Hanging Traffic Light
Detroit, Michigan, was the location for the world’s first three-color, four-direction traffic signal in 1920.
Gift of Police Department, City of Detroit
Designed by William L. Potts
History of Signalized Intersections

1922 - 1st Progression System, New York City

Space-time diagram

Image based on [Banks, 2002]
History of Signalized Intersections

1926 - 1st Actuated Signals

Horn actuated signal
Purposes:

1. Orderly assigned Right-of-Way
2. Safety
3. “Not” a panacea!
Advantages and Disadvantages

- Why do we use traffic signals? []
- What are the advantages and disadvantages?
Advantages and Disadvantages

1. Orderly Movement
2. Reduce right angle accidents
3. Increase Capacity
4. Allow Crossing
5. Coordination
6. Driver Confidence
7. Cost Effective

1. Increase Delay
2. Increase Rear End Accidents
3. Promote Disrespect when unwarranted or misapplied
4. Driver Irritation - improperly timed
Definitions & Related Terminology

- **Approach** - Lane or group of lanes through which traffic enters an intersection.

- **Cycle** - One complete signal sequence (all approaches).

- **Cycle Length (C)** - Total time (sec.) to complete a cycle for all approaches.

- **Traffic Signal Phase (φ)** - part of a cycle allocated to specific movement(s) that receive the right of way simultaneously.
NEMA Phasing Convention

Left Turn Movements: Odd numbers one less than opposing through movement designation

Through Movements: Even numbers clockwise starting with heaviest movement

What about right turns?
Definitions & Related Terminology

**Indication** – Illumination of one or more signal lenses permitting or prohibiting traffic movement.

**Interval** – Period of time during which all signal indications remain the same for all approaches.

**Change Interval** – Yellow time plus all-red time that provides for clearance of the intersection (Yellow + All-Red Time)

**Traffic Signal Controller** – controls sequence, duration and logic.
Movement

- **Protected movement**: A movement that has the right-of-way and does not need to yield to conflicting movements, such as opposing vehicle traffic or pedestrians.

- **Permitted movement**: A movement that must yield to opposing traffic flow or conflicting pedestrian movements.
Definitions & Related Terminology

- **Green Time (GT)** - time within cycle in which an approach has green indication.
- **Red Time (RT)** - time within cycle in which an approach has red indication.
- **Yellow Time (YT)** - time within cycle in which an approach has yellow indication.
- **All-Red Time (AR)** - time within cycle in which all approaches have red indication.
Definitions & Related Terminology

Lost Time (LT) – Time (sec) during which intersection not effectively used by any approach, including start-up lost time and clearance lost time.

Effective Green (g) – Time (sec) effectively used by an approach for traffic movement (g = GT + Y + AR - LT)

Effective Red (r) – Time (sec) not effectively used by an approach for traffic movement (cycle time - g)
Discharge Headways

The discharge headway is based upon expected highway after the point at which headways stabilize. This headway stabilizes at 2.14 seconds for the sixth and subsequent vehicles.

<table>
<thead>
<tr>
<th>Vehicle in Queue</th>
<th>Departure Headway</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>h = t_1</td>
</tr>
<tr>
<td>2</td>
<td>h = t_2</td>
</tr>
<tr>
<td>3</td>
<td>h = t_3</td>
</tr>
<tr>
<td>N + 1</td>
<td>h = h</td>
</tr>
<tr>
<td>N + 2</td>
<td>h = h</td>
</tr>
<tr>
<td>n</td>
<td>h = h</td>
</tr>
</tbody>
</table>

Figure 4–3  Conditions of Traffic Interruption in an Approach Lane of a Signalized Intersection


\[ l_1 = \sum e(i) = \sum (h_i - h) \]
Saturation Flow Rate

The saturation flow rate is computed as:

\[ s = \frac{3600}{h} \]

where \( s \) = saturation flow rate (vphgpl),
\( h \) = discharge headway (sec/veh)
Lost Time

The start-up lost time is estimated by the sum of the differences between the observed headway for each of the vehicles before the headway stabilizes.
Lost Time

Start-up lost time

\[ l_1 = \sum e(i) = \sum (h_i - h) \]

Time req’d to clear \( N \) veh.

\[ T = l_1 + h(N) \]

Greenshields (1947)

\[ T = 3.7 + 2.1(N) \]

Updated Greenshields (1978)

\[ T = 3.1 + 2.1(N) \]

Saturation Flow

\[ s = \frac{3600}{h} = \frac{3600}{2.1} = 1714 \text{ vphpl} \]
Effective Green

- Saturation flow
- Effective green time $g$
- Rate of discharge
- Lost time
- Time
Definitions & Related Terminology

- **Saturation Flow (s)** - Maximum flow that can pass through an intersection from a given approach, if that approach is allocated all of the cycle time as effective green with no lost time.

- **Approach Capacity (c)** - Maximum flow that can pass through an intersection under prevailing highway and traffic conditions, given the effective green time allocated to the approach \( c = s \times \frac{g}{C} \)
Types of Control

- Pretimed Signal
- Semi-Actuated Signal
- Fully-Actuated Signal
Pre-timed Signal

- Pre-determined schedule
- Fixed cycle lengths
- Need traffic history
- Several timing options possible
- Good at predictable locations or downtown CBD
Pre-timed Signal – Advantages and Disadvantages

- Simple
- Can be coordinated
- Easy to field adjust
- Can handle peak and off peak conditions

- Cannot react to short-term demand changes
- Can cause excessive Delays
- Sometimes results in disrespect ==> Liability
Semi-Actuated Signal

- Major Rd = High Volumes; Minor Rd = Low Volumes
- Detectors on Minor Approaches
- Minor phase (\( \varphi \)) = Min. Green Interval
- Major phase (\( \varphi \)) = Extends Indefinitely
- Minor Rd gets served upon actuation
  {and major roadway change interval after time out}
Fully-Actuated Signal

- Varying traffic demand; not homogeneous or probable FLOW
- Detectors on all approaches
- Phases have an initial interval which provides time for starting / standing vehicles
- Green interval extended by preset unit extension.... up to maximum limit of allocated time
- Yellow and red intervals preset for phases
Max Out/Gap Out

Green is terminated by one of two mechanisms

- Gap Out (GO)
- Max Out (MO)

The length of a phase is constrained to a range of the minimum green to the maximum green

See next page
Operations of an Actuated Phase

1st actuation on a conflicting phase

Max Out operation

Figure 19-2 Operation of an actuated phase. [Used with permission of Institute of Transportation Engineers, from Traffic Detector Handbook, 2nd Ed., JHK & Associates, p. 66. Copyright © Institute of Transportation Engineers.]
Signal Detectors and Controllers

- Most common controllers – NEMA controllers
- Advanced controllers
  - Type 170
  - Type 2070
- Advanced Transportation Controllers (ATC)
NEMA Controller
Econolite NEMA Controller
170 Controller
Transit Signal Priority System Components

Tag Interface Unit for Dynamic Data

Tag

Antenna

Interface Unit
Questions

- Questions?
Abbreviations
Key Terms
Variables