New Directions in Traffic Signal Timing
Second Edition

Tom Urbanik
Boise, Idaho
April 25, 2013
A Little Context and Perspective

• KAI is lead firm
• Tom Urbanik is lead author
• The Manual will include the New Directions I discuss today
• I will present the material within the structure of the new Manual

http://www.signaltiming.com/
Vision and Approach

• The Manual is a practical presentation of best practice
• Focus on a concise document that is easy to use
• Presented in four Parts
• Will not contain any “nice to know” material
• Will not repeat material in other references such as the MUTCD or Highway Capacity Manual
• Will focus on signal timing and only other issues that preclude good signal timing like detection design and controller/cabinet issues
• Will be based on best practice
Approved Outline

- PART I – Signal Timing Program
  - Chapter 1. Introduction
  - Chapter 2. Program Elements
- PART II – Concepts and Design
  - Chapter 3. Concepts
  - Chapter 4. Design
- PART III – Basic Signal Timing
  - Chapter 5. Developing Timing Plans
  - Chapter 6. Intersection/Uncoordinated
  - Chapter 7. System/Coordinated
  - Chapter 8. Operations and Monitoring
- PART IV – Advanced Applications and Systems
  - Chapter 9. Special Applications
  - Chapter 10. Preferential Treatment (Priority and Preemption)
  - Chapter 11. Advanced Systems
Outcome Process

1. Define Operating Environment
2. Identify Users
3. Establish User & Movement Priorities
4. Select Operational Objectives
5. Establish Performance Measures
6. Develop Timing Strategies and Timing Values
7. Implement & Observe
8. Monitor & Maintain
## Getting Started

<table>
<thead>
<tr>
<th>Outcome Process Step</th>
<th>Initial Signal Timing Considerations</th>
</tr>
</thead>
</table>
| **Multi-Jurisdictional Impacts** | □ Is the system of signals located in a single or multiple jurisdictions?  
     □ If multiple, is signal timing performance consistent across jurisdictional boundaries?  
     □ Is there an existing agreement in place that defines certain signal timing parameters?  
     □ Would an agreement between jurisdictions to establish consistent signal timing strategies be beneficial? |
| **STEP 1** Define the Operating Environment | □ Location and Associated Environment  
     □ Is the system of intersections located in a rural, suburban, or urban area?  
     □ How is the roadway classified where the signal system is located (e.g., freeway interchange, major arterial, minor arterial, major collector, minor collector, local street)?  
     □ Are there specific freight, pedestrian, bicycle, or transit route classifications?  
     □ How does the classification affect user expectations of the facility? |
| **Roadway Classification** | □ Transportation Network  
     □ How closely spaced are the signalized intersections?  
     □ Is there a reason to consider multiple intersections as a system when developing the signal timing?  
     □ What is the existing mix of users (e.g., light vehicles, pedestrians, bicyclists, heavy vehicles (including trucks and transit vehicles), priority vehicles)?  
     □ Does the mix change by time of day?  
     □ Are there unique travel patterns? |
| **STEP 2** Identify Users | □ Who are the critical users at the intersection?  
     □ Does the critical user change by time of day?  
     □ Does the jurisdiction have any policies related to user priorities?  
     □ What are the critical movements? |
| **STEP 3** Establish User and Movement Priorities |
Step 1: Operating Environment

- Urban
- Suburban
- Rural
Steps 3: Users

- Pedestrian
- Bikes
- Light Vehicles
  - Trucks
  - Cars
- Heavy Vehicles
  - Buses
  - Trucks
Step 3: User Priorities

- Local Policies
- Objectives
## Steps 4: Objectives

### Step 5: Performance Measures

<table>
<thead>
<tr>
<th>Operational Environment</th>
<th>Desired Operational Objective</th>
<th>Example Performance Measures</th>
</tr>
</thead>
</table>
| Suburban Arterial               | Maximize mobility for through vehicles                                                       | • Corridor travel time  
 • Speed  
 • Vehicle capacity  
 • Number of stops |
| Central Business District / Downtown | Walkable urban core; access to key destinations (auto, freight, etc.)                  | • Pedestrian delay  
 • Bike delay  
 • Vehicle capacity  
 • Speed (lower is better)  
 • Number of conflicts |
| Neighborhood Street             | Good access to local retail; safe pedestrian and bike mobility and crossings             | • Pedestrian delay  
 • Bike delay  
 • Speed (lower is better)  
 • Number of conflicts |
| Priority Transit Corridor       | Increase attractiveness of transit                                                           | • Transit travel time/speed  
 • Transit reliability |
| Priority Bike Corridor          | Increase attractiveness of cycling as a transportation option                             | • Bike delay  
 • Number of stops (cyclists)  
 • Number of conflicts |
## Tying Performance Measures to Timing Parameters

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Influential Signal Timing Parameter(s)</th>
<th>Typical Method of Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay</td>
<td>Cycle length, split, offset</td>
<td>• Queue estimation method&lt;br&gt;• Probe vehicle (experienced-free-flow travel time)&lt;br&gt;• Call to service controller logging</td>
</tr>
<tr>
<td>Number of Stops</td>
<td>Offset</td>
<td>• Probe vehicle (GPS floating car, GPS fleet data)</td>
</tr>
<tr>
<td>Travel Time</td>
<td>Cycle length, split, offset</td>
<td>• Probe vehicle (GPS floating car, GPS fleet data, Bluetooth™, or other re-identification)</td>
</tr>
<tr>
<td>Travel Time Reliability</td>
<td>Cycle length, split, offset</td>
<td>• Travel time methods over multiple time periods (requires percentile travel times)</td>
</tr>
<tr>
<td>Speed</td>
<td>Cycle length, split, offset</td>
<td>• Point speed via dual point detection (tubes, loops, radar, video)&lt;br&gt;• Segment speed via probe vehicle methods</td>
</tr>
<tr>
<td>Quality of Progression (Percent Arrival on Green)</td>
<td>Offset</td>
<td>• Accurate detection and controller logging</td>
</tr>
<tr>
<td>Split Failures</td>
<td>Cycle length, split</td>
<td>• Queue detection plus signal indication data (manual observation or automated technology)&lt;br&gt;• Approximate with phase termination logging (max outs/force-offs versus gap outs)</td>
</tr>
<tr>
<td>Queuing</td>
<td>Cycle length, split, offset</td>
<td>• Manual observation or automated technology (video, radar)&lt;br&gt;• Approximate with occupancy</td>
</tr>
<tr>
<td>Capacity</td>
<td>Cycle length, split, offset</td>
<td>• Saturated traffic volumes and headway measurements</td>
</tr>
<tr>
<td>Safety-Related</td>
<td>Detection location and settings; clearance intervals</td>
<td>• Rate of deceleration from vehicles&lt;br&gt;• Red-light running (cameras, controller logging)&lt;br&gt;• Number of conflicts</td>
</tr>
</tbody>
</table>
You Get What You Measure

<table>
<thead>
<tr>
<th>Record Number</th>
<th>1344</th>
<th>Sample Period</th>
<th>60</th>
</tr>
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<tbody>
<tr>
<td>Date</td>
<td>02, 2012</td>
<td>16:30</td>
<td></td>
</tr>
<tr>
<td>Phase Service</td>
<td>8</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Red Service</td>
<td>0</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Average Green</td>
<td>7</td>
<td>82</td>
<td>0</td>
</tr>
<tr>
<td>Max Outs</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Force Offs</td>
<td>4</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Gap Outs</td>
<td>4</td>
<td>23</td>
<td>0</td>
</tr>
</tbody>
</table>

Phase Termination Graph from MDE log

815% of terminations are Force-Offs and Max-Outs.
16-59% of terminations are Force-Offs and Max-Outs.
In Coord - is gray if Force Offs are present.
More Design Elements …Load Switches …and Generic Detection
Important Concepts (Chapter 3): Putting the Pieces Together
Delving into Overlaps

**Typical Recommended Practice:**
Operate right-turn indication as an overlap, not hard wired to left-turn load switch. This provides more flexibility for signal timing and control.
Example of Advance Overlap Application

Hallandale Blvd, Ft. Lauderdale, Florida

- Used 3-phase Naztec Diamond Operation with SB frontage road overlap
- Use minus green yellow overlap for eastbound coordination of upstream signal operated as slave
It’s a System
(Chapter 4: Design Elements Matter)
Movements, Phases, and ....

- Signal Cabinet (Model 332)
- Signal Controller
- Detector Amplifier Cards
- Flasher
- Power Supply
- Breakers & AC Power
- Load Switches
- Conflict Monitor
- Relay
More Design

Yellow Trap

1. Opposing through signal
   - All red

2. Opposing left-turn display red lights
   - Protected left turn

3. Clearance interval (end protected left-turn)

4. Permissive phase

5. Change interval (Yellow trap)

6. Opposing through phase indication still green

Detection

- 6' x 6' advanced detection zone (presence), high speed
- 6' x 80' stop bar detection zone (presence), low speed
Chapter 5: Developing Timing Plans: Moving Beyond Simple Computer Models

Step 6:

- Using the Outcome Process
- Linking Outcome to Strategies
Step 6: Matching Operational Objective with Timing Strategies

<table>
<thead>
<tr>
<th>Operational Objective</th>
<th>Signal Timing Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prioritize pedestrians</td>
<td>• Longer walk times</td>
</tr>
<tr>
<td></td>
<td>• Shorter cycle lengths</td>
</tr>
<tr>
<td></td>
<td>• Pedestrian progression</td>
</tr>
<tr>
<td></td>
<td>• Lead or lag pedestrian intervals to reduce conflicts</td>
</tr>
<tr>
<td>Prioritize bicyclists</td>
<td>• Bicycle progression</td>
</tr>
<tr>
<td></td>
<td>• Bicycle-exclusive phases</td>
</tr>
<tr>
<td></td>
<td>• Lead or lag bicycle intervals to reduce conflicts</td>
</tr>
<tr>
<td>Prioritize vehicular through movements</td>
<td>• Maximize arrivals on green</td>
</tr>
<tr>
<td></td>
<td>• Minimize the number of stops for through vehicles</td>
</tr>
<tr>
<td></td>
<td>• Longer cycle lengths</td>
</tr>
<tr>
<td></td>
<td>• Coordinate arterial phases for through movements</td>
</tr>
<tr>
<td>Prioritize trucks</td>
<td>• Truck detection</td>
</tr>
<tr>
<td></td>
<td>• Truck extension</td>
</tr>
<tr>
<td></td>
<td>• Longer gap times</td>
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</table>
Simple Analysis: Linking Phasing to Critical Movement Analysis
More Simple Analysis: Simple Cycle Length Calculation

Linking Cycle Length to Critical Movement

<table>
<thead>
<tr>
<th>Cycle Length (Seconds)</th>
<th>Number of Cycles Per Hour</th>
<th>Lost Time Per Cycle (Seconds)</th>
<th>Effective Green Time Per Cycle (Seconds)</th>
<th>Number of Vehicles Per Cycle</th>
<th>Max Number of Vehicles Per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>60</td>
<td>20</td>
<td>40</td>
<td>16</td>
<td>933</td>
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<tr>
<td>70</td>
<td>51</td>
<td>20</td>
<td>50</td>
<td>19</td>
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<td>80</td>
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<td>90</td>
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<td>100</td>
<td>36</td>
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<td>80</td>
<td>31</td>
<td>1120</td>
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<td>110</td>
<td>33</td>
<td>20</td>
<td>90</td>
<td>35</td>
<td>1145</td>
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<td>120</td>
<td>30</td>
<td>20</td>
<td>100</td>
<td>39</td>
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## Analysis Software: Inputs and Outputs

<table>
<thead>
<tr>
<th>Signal Timing Parameter</th>
<th>Chapter 6 Reference</th>
<th>Chapter 7 Reference</th>
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<tbody>
<tr>
<td><strong>Inputs</strong></td>
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</tr>
<tr>
<td>Phasing (Phase Order)</td>
<td>6.1.1 Phase Numbering</td>
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<tr>
<td></td>
<td>6.1.4 Right-Turn Overlap Settings</td>
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<tr>
<td>Minimum Green</td>
<td>6.2.2 Minimum Green</td>
<td></td>
</tr>
<tr>
<td>Maximum Green</td>
<td>6.2.3 Maximum Green</td>
<td>7.5.5 Splits Guidance</td>
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<tr>
<td></td>
<td></td>
<td>7.5.6 Force-Offs Guidance</td>
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<tr>
<td>Yellow Change Interval</td>
<td>6.2.1 Yellow Change and Red</td>
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<tr>
<td></td>
<td>Clearance Intervals</td>
<td></td>
</tr>
<tr>
<td>Red Clearance Interval</td>
<td>6.2.1 Yellow Change and Red</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clearance Intervals</td>
<td></td>
</tr>
<tr>
<td>Leading/Lagging Left Turns</td>
<td>6.1.2 Protected/Permissive Left-Turn</td>
<td>7.4.2 Left-Turn Phasing</td>
</tr>
<tr>
<td></td>
<td>Phasing and Back-Up Protection</td>
<td>7.9.2 Phase Sequence</td>
</tr>
<tr>
<td>Passage Time (Vehicle Extension)</td>
<td>6.2.4 Passage Time (Unit Extension/Gap Time)</td>
<td></td>
</tr>
<tr>
<td>Minimum Gap</td>
<td>6.2.4 Passage Time (Unit Extension/Gap Time)</td>
<td></td>
</tr>
<tr>
<td>Time Before Reduction/Time to Reduce</td>
<td>6.2.4 Passage Time (Unit Extension/Gap Time)</td>
<td></td>
</tr>
<tr>
<td>Recall Mode</td>
<td>6.2.7 Recalls/Memory Settings</td>
<td></td>
</tr>
<tr>
<td>Pedestrian Phasing</td>
<td>6.1.1 Phase Numbering</td>
<td></td>
</tr>
<tr>
<td>Walk Interval</td>
<td>6.2.6 Pedestrian Intervals</td>
<td></td>
</tr>
<tr>
<td>Flashing Don’t Walk Interval</td>
<td>6.2.6 Pedestrian Intervals</td>
<td></td>
</tr>
<tr>
<td>Dual Entry</td>
<td>6.2.5 Dual Entry</td>
<td></td>
</tr>
<tr>
<td>Inhibit Max</td>
<td>7.5.5 Splits Guidance</td>
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<tr>
<td></td>
<td>7.5.6 Force-Offs Guidance</td>
<td></td>
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<tr>
<td>Coordinated Phases</td>
<td>7.3.1 Coordinated Phases</td>
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</tr>
<tr>
<td>Detector Locations and Settings</td>
<td>6.1.5 Detector Assignment</td>
<td>7.5.5 Splits Guidance</td>
</tr>
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<td></td>
<td>6.3 Detector Configurations</td>
<td></td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycle Length</td>
<td>7.3.2 Cycle Length</td>
<td>7.5.2 Cycle Length Guidance</td>
</tr>
<tr>
<td>Offsets</td>
<td>7.3.3 Offsets</td>
<td>7.5.3 Offsets Guidance</td>
</tr>
<tr>
<td>Splits</td>
<td>7.3.5 Splits</td>
<td>7.5.5 Splits Guidance</td>
</tr>
</tbody>
</table>
## Intersection (Uncoordinated) Timing

<table>
<thead>
<tr>
<th>Timing Parameter</th>
<th>Consequence for Too Much Time</th>
<th>Consequence for Too Little Time</th>
<th>Dependent On Variables Including:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow Change</td>
<td>• May encourage disrespect by familiar drivers • May cause a higher frequency of red-light running</td>
<td>• May create a dilemma zone</td>
<td>• Driver perception-reaction time • Vehicle deceleration rate • Vehicle approach speed • Approach grade</td>
</tr>
<tr>
<td>Red Clearance</td>
<td>• Wasted time at the intersection</td>
<td>• Intersection may not be clear when next phase begins</td>
<td>• Intersection width • Vehicle length • Vehicle approach speed</td>
</tr>
<tr>
<td>Minimum Green</td>
<td>• Wasted time at the intersection</td>
<td>• May violate driver expectations (leading to a possible increase in rear-end crashes) • May not accommodate pedestrian needs</td>
<td>• Driver expectancy • Detector locations • Number of queued vehicles • Pedestrian intervals • Bicycle speed and acceleration</td>
</tr>
<tr>
<td>Maximum Green</td>
<td>• Wasted time at the intersection (particularly if there is broken detection)</td>
<td>• Some vehicles may not be served because the phase capacity is inadequate for demand</td>
<td>• Vehicle demand • Intersection capacity</td>
</tr>
<tr>
<td>Passage</td>
<td>• Delays to other movements caused by extension of the phase</td>
<td>• Green may end prematurely before all vehicles have been served</td>
<td>• Detector design • Detection mode • Vehicle approach speed</td>
</tr>
<tr>
<td>Walk</td>
<td>• Wasted time at the intersection</td>
<td>• May not accommodate high volumes of pedestrians</td>
<td>• Pedestrian volumes • Location of pushbutton • Pedestrian crossing distance • Pedestrian walking speed</td>
</tr>
<tr>
<td>FDW</td>
<td>• Wasted time at the intersection</td>
<td>• May not accommodate the time needed for pedestrians to cross the street</td>
<td>• Pedestrian crossing distance • Pedestrian walking speed</td>
</tr>
</tbody>
</table>
Systems (Coordination)

- Traditional
- Lost Art
- Advanced
Coordination Issues

Walk Modes

Actuating the Coordinated Phase(s)
Another Coordination Issue (Clock Reference)

- “Time-Based”
  - Reference a function of cycle length
  - Clock drift

- “System” Based
  - System maintains the reference
  - No transition
  - Advantage of most “adaptive” systems
Understanding Force Offs

- Fixed
- Floating
- Fixed with Max timer
Chapter 9: Understanding Oversaturation and Other Things

- Long Cycle Lengths don’t always increase capacity
- Phase sequence affects intersection performance

Queue Starvation  Queue Spillback  Signal Phasing Solution to Queue Spillback/Starvation
Chapter 10: Preferential Treatment (Priority and Preemption)

Scheduling Based

- Transit (Bus & LRT)
- Trucks
- Emergency Vehicles
- Heavy Rail

[Diagram showing scheduling events and control phases for transit, trucks, emergency vehicles, and heavy rail.]
Multimodal Priority

Transit

Bikes

Pedestrians

- Multimodal Priority
- Three-Lens Signal
- Two-Lens Signal
- SINGLE LRT ROUTE
- STOP
- PREPARE TO STOP
- Flashing
- GO
- STOP
- GO

Major Street Phases

Ring 1

\(\Phi_1\) \(\Phi_2\) Coordinated Phase

\(\Phi_2\) \(\Phi_3\) \(\Phi_4\) \(\Phi_5\) \(\Phi_6\) Coordinated Phase

Ring 2

\(\Phi_5\) \(\Phi_6\) \(\Phi_7\) \(\Phi_8\)

\(\Phi\) = Phase Number

# or #P = Movement Number

LS# = Load Switch Number

= Protected Movement

= Permitted Movement

Kittelton & Associates, Inc.

Texas Transportation Institute

Purdue University

Kimley-Horn and Associates, Inc.
Example TSP Applications

- District of Columbia
  - McCain
- Tampa, FL
  - Econolite
  - Naztec
- Jacksonville, FL
  - Naztec
- Anchorage, AK
  - Traconex
- Portland, OR
  - Wapiti
  - Voyage
### Requirement Category Description

<table>
<thead>
<tr>
<th>Requirement Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional requirements</td>
<td>What the system is to do</td>
</tr>
<tr>
<td>Performance requirements</td>
<td>How well it is to perform</td>
</tr>
<tr>
<td>Non-functional requirements</td>
<td>Under what conditions it will perform</td>
</tr>
<tr>
<td>Enabling requirements</td>
<td>What other actions must be taken in order for the system to become fully operational</td>
</tr>
<tr>
<td>Constraints</td>
<td>Limitations imposed on the design my agency's policies and practices, such as type of software, type of equipment and external standards</td>
</tr>
<tr>
<td>Interface Requirements</td>
<td>Definitions of the interfaces between sub-systems or with external systems</td>
</tr>
<tr>
<td>Data Requirements</td>
<td>Definitions of data flows between sub-systems or with external systems</td>
</tr>
</tbody>
</table>

- **System Engineering Process**
- **Advanced Coordination**
- **Traffic Responsive**
- **Adaptive**
  - SCATS
  - InSync
  - QuicTrac
  - SCOOT
  - SynchroGreen
Questions?

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- 512-670-8074